Scoping the Potential Use of Serious Games for Public Engagement with Tree and Plant Health.

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Doctor of Philosophy

September | 2020

“*Unless someone like you cares a whole awful lot,*

Nothing is going to get better.

It's not.”

Dr. Seuss [1]

Acknowledgements

Working towards a PhD can be an incredibly isolating experience where you can spend four, or more, years immersed in what can be a niche field. Isolation is compounded by imposter syndrome, the feeling that you're singularly unfit to be working on your own research. This has, perhaps, been accentuated with the lockdown imposed by COVID-19. The road to submitting the thesis is long, with many twists, turns, and pitfalls along the way.

In my case those twists and turns started before University. It is a story that I have told many times before and have no hesitation in sharing here. I had been set on an officer's commission in the Royal Navy, even getting so far into the process as to attend the final stage before the Royal Naval College Britannia. I was young, fresh out of High School where I had been the proverbial big fish in a small pond. At the end of the board process I was told that I had failed and shouldn't consider re-applying. Quite the failure to start post-school life with.

However, from that crushing failure, the seeds of opportunity did sprout. A little over 9 years, one undergraduate degree, and an ungodly number of extra-curricular projects later, this unimaginable achievement is within reach.

The brevity of time spent with each person in this section should not be taken as a reflection of the contribution made. I am afraid that I have neither the skill with the pen nor space, to adequately apportion to each the thanks and gratitude that they deserve. Suffice it to say I would not have the privilege of completing my research without each and every one of you.

From a plant professional perspective, I have been incredibly privileged to collaborate with some of the most passionate, dedicated, brilliant, people I have had the pleasure of meeting. Thank you, Charles Lane, Lucy Carson-Taylor, Paul Beales, Max Coleman, and the many others that have welcomed me into the tree and plant health world and given so freely of their time.

To every person that has uttered the words "that's really cool! Tell me more?" when hearing about my work, or said that this topic has made them think. Those few words have given more encouragement than you know.

Welcome distractions have been given by content creators over the years. Many a day in the office, or redraft session, were vastly improved by material from the likes of Many A True Nerd, CGP Grey and Dr Brady Haran of Hello Internet, the British History Podcast, and others.

Michael, Neil, Phoebe, Rob, and Alex – thank you for your friendship and for pulling me from the PhD cocoon. Fiona, thank you for totally rebuilding my confidence at a time when it was lower than I perhaps wanted to admit even to myself. Robert, your American can-do attitude and encouragement has been a delight. Grace & Gemma, I don't know what I would have done over the years without you. Chris, thanks for putting up with my endless fretting and thesis chat. Kieran and Nicole, thank you for helping keep me sane in the home stretch. Dan, thank you for joining me on the latter half of this journey.

This entire wonderful project wouldn't be possible without Professor Nicola Spence and Glyn Jones and the serendipity of a shared train journey. Thank you for taking a chance on me. Thank you also to the Department for Environment, Food, and Rural Affairs and the University of Stirling for the funding that made that chance a reality.

Alasdair Rutherford, thank you for stepping into the second supervisor role when the project had already started, and your patience in working through my statistical questions.

Savi, it doesn't seem like eight years to the submission month that I walked into CSCU9A1 as a fresher. Thank you for your guidance and patience over the years. Especially when it would come to my wonderfully Dickensien turns of phrase and non-stop idea generation(!). I've learned a lot working with you and it has truly been a pleasure.

It is said that behind every great man stands a great woman. In my case I have had the humbling and unending support of a fantastic family. Whether it be my parents, brother, grandparents, aunts, uncles, and so on, the interest and engagement with my work has been the engine propelling me towards completion.

Thank you.

Abstract

After the devastating introduction of Chalara ash dieback into Great Britain in 2012, all devolved GB governments agreed on the need for increased public engagement in protecting tree and plant health. Serious games have been proposed as a tool for achieving this. This thesis explores two questions. Firstly, to what extent is there an appetite for using Serious Games among plant health professionals and the general public? Furthermore, when compared to traditional methods of presenting information in public engagement, can Serious Games improve participant engagement and retention of information?

To address the first question, we conducted two studies of attitudes to Serious Games. In the first study, we conducted face-to-face structured interviews of tree and plant health professionals. In this group, we found that there was interest in the potential use of Serious Games; however, a lack of game development skills emerged as a challenge. In the second study, we used an online survey aimed at the general public to ask about attitudes, preferences, and experiences with Serious Games. Again, we found that there was an interest in the use of games with some reservations.

In addressing the second question, two experiments were conducted comparing game and non-game methods of presenting identical information to participants. These experiments measured enjoyment and retention of information. In both experiments, the non-game treatment participants had higher quiz results, suggesting that the Serious Game treatment did not improve information retention. This may be because the learning content was not sufficiently related to the games. Additionally, despite Game players reporting a higher perceived level of learning in the second experiment this did not translate to longer term retention of information.

We conclude that Serious Games can be useful in arousing interest; however, careful design is needed if they are to promote, rather than distract from, learning.

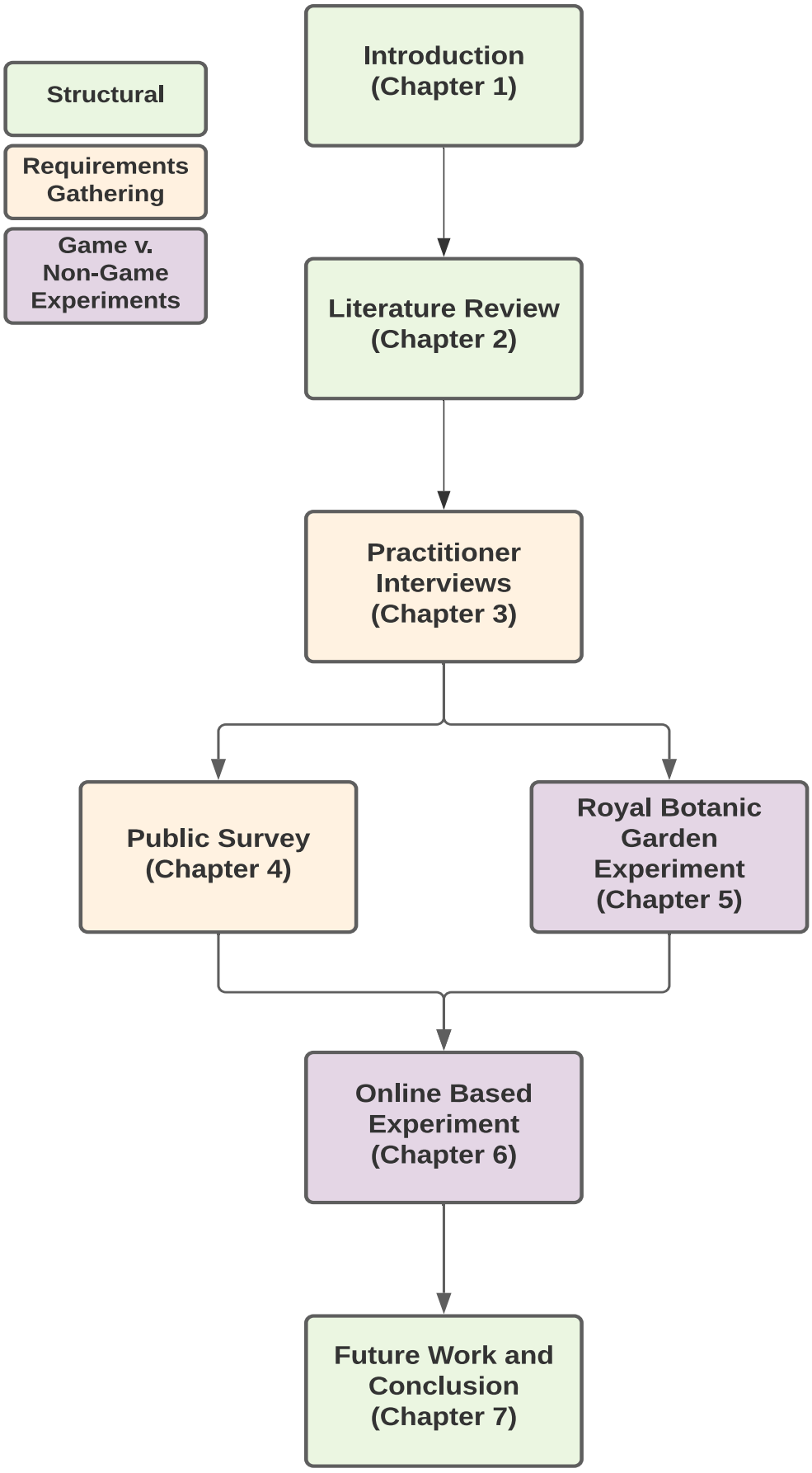

Figure 1: Thesis Structure

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Abbreviations

APHA	Animal and Plant Health Agency
DEFRA	Department for Environment, Food, and Rural Affairs
FC	Forestry Commission
FCS	Forestry Commission Scotland
HEI	Higher Education Institution
OPAL	Open Air Laboratory
PFB	Public Facing Body
RBGE	Royal Botanic Garden Edinburgh
RHS	Royal Horticultural Society
SASA	Science and Advice for Scottish Agriculture
SG	Serious Game
VO	Volunteering Organisation

Conferences and Presentations

Scottish Informatics and Computing Systems Alliance 2016	Demofest Poster Presentation; Demofest is an evening event that brings academia and industry together.
Three Minute Thesis (Stirling) 2017	Participated in the Stirling final of the Three Minute Thesis competition
Innovation in Plant Biosecurity 2017	Early Career Researcher Bursary; 2-day pre-conference workshop with four other early career researchers working on two grand challenges. This included a presentation on our research and a poster presentation of the grand challenge.
PhD Day 2016 - 2019	An annual internal event where PhD students showcase their work to the department via talks and a poster.
Annual Fera Science Symposium 2018	A talk was given and a poster presented [2]
DemoFest 2018	A poster was presented.
John McLeod Annual Lecture	The research was mentioned by the UK Chief Plant Health Officer in this annual lecture [3].
SICSA PhD Conference 2019	A poster was presented, and a short video outlining the work was entered into a short video competition [4].
GSGS'21 – International Conference on Gamification and Serious Game, July 2021	A paper and video presentation will be made based on Chapter 6 of this thesis. [5]

1 Introduction

"Ash dieback will kill around 80% of ash trees across the UK. At a cost of billions, the effects will be staggering. It will change the landscape forever and threaten many species which rely on ash." [6]. This is the stark assessment by the Woodland Trust of the eventual impact of the ash dieback fungus that first presented in the United Kingdom in 2012.

As of 2012*, "ash species were the second most commonly planted genus, and ash makes up nearly 15% of all broad-leaved woodland."* [7]. It is also predicted that ash dieback has a cost impact on British society in the region of £15 billion [8]**.** These costs stem *from "the practical expense of clearing up dead and dying trees, to the loss of its environmental services such as air purification."* [8].

The arrival of this fungus precipitated a change in attitude from the devolved administrations in the United Kingdom in how they conducted engagement on tree and plant health matters. This new strategy

> *"…sets out how we will ensure everyone with a role to play in plant health is aware of the risks and is acting on their responsibilities to minimise those risks. This is because government alone cannot tackle threats to plant health. The strategy therefore has a focus on working with others, building upon and strengthening partnerships with a wide range of groups including: government, the international community, industry, Non-Government Organisations (NGOs) landowners and the public so we can all contribute to protecting the health of our plants.*" [9].

Trees and plants have an important role to play in the United Kingdom. Ash dieback is one of many threats the country faces. While the strategy cannot prevent what has already arrived arriving, it may help minimise the spread or eradicate any new arrival.

The Governments' strategy lays out an expectation that greater public awareness will be driven through means such as posters & publicity, interaction at horticultural events, and training events [9]. These are traditional ways of raising awareness and engaging with the public.

Serious Games (SGs) are an emerging area of academic research that has been applied in similar scenarios, e.g. better energy usage, and building assertiveness. SGs may have a role to play in helping raise awareness as part of the new governmental strategy.

1.1 The Importance of Trees and Plants to the United Kingdom

The oak tree has long played a role in the history and culture of the United Kingdom. While it is unclear why the tree has assumed the status it has, the importance is evident. Royal Oak is one of the most popular names for pubs in the United Kingdom [10]. The Royal Navy gained the moniker of 'Wooden Walls' from the strength and durability of their oak timbers [10]. Both royalty and famous outlaws have sought refuge in their boughs, Charles II and Robin Hood respectively. From the early religious practices of the native druids to the quintessential yule log, oak trees have permeated and been bound up in British cultural life [10].

Beyond the oak, there is an economic benefit to the United Kingdom from forestry and ornamental horticulture & landscaping. Forestry, in a 2007 Westminster briefing note, was estimated to contribute up to £1billion to social and environmental benefits [11]**.** The Office for National Statistics stated that forestry and timber businesses were worth £6.4bn to the UK economy in 2008, and supported 155,000 jobs [12]. A 2015 sector report in Scotland estimated that just under £1bn was contributed to the Scottish economy alongside supporting over 25,000 full-time equivalent jobs [13].

The Horticultural Trades Association 2018 report on the economic impact of their sector in the UK reported that an estimated £24.2bn contribution was made in 2017. This sector also supported over half a million jobs in the same year [14].

It is said that money cannot buy happiness; however, trees can bring comfort. This is perhaps best exemplified in recent years when a project set up in Melbourne to monitor tree health, Urban Forest Visual [15], developed a rather charming side effect. A core concept of the citizen science monitoring project is the ability to email any tree in the city, ostensibly to report signs of potential sickness or damage. While some emails arrived to this end, a far greater number engaged with the trees in a social capacity.

Some admirers from half the world away wrote longingly about wanting to meet the tree of which they had grown fond. Others still wrote to the trees asking questions about their existence, what they might have seen, and seeking advice on their own lives. Several people also reminisce with English Elms in the city, lamenting their absence from the English countryside [16], [17].

In an incredibly touching message, replicated entirely below, an Australian that has emigrated to the United States reflects on the memories they have of the gum tree. It is intensely personal and speaks to the impact that trees can have on our lives:

> *“Dear Gum,*
>
> *Apologies if that's not the form of address you prefer. I wanted very much to tell you how much I miss your family. I've lived in Texas for two and a half years now, and I so fervently miss the heady scent of your cologne as the morning sun warms you.*
>
> *I miss your gentle swish swish as the wind tousles your leaves playfully. I miss your strong white trunk, rising majestically from the earth, striking up towards the clouds. I miss the dappled shade you so generously provide.*
>
> *The sound of magpies, harbouring in your foliage, does not grace my ears. The silver green of your long, lithe leaves does not appear in my current surrounds.*
>
> *I miss you, Gum. I miss all that you represent for me. Stand tall and strong, and know that my heart reaches out to you across the seas.*
>
> *With immense fondness, A”*[18]

The benefits and impact that green spaces can provide have been thrown into sharp relief in 2020. The worldwide spread of the COVID-19 virus and subsequent national lockdowns led to a new appreciation of trees and green spaces. During the height of lockdown, the UK Government permitted everyone a single hour of outdoor exercise near to home per day[19]. With many people taking to their local parks and green spaces to make the most of this time outside. Reports and

studies have highlighted the importance of parks, and other green spaces, on maintaining good mental health and fitness levels [20], [21].

Trees are also susceptible to pests and pathogens. A particularly devastating threat on the horizon is *Xylella fastidiosa*. This pathogen has been spreading through Europe for a number of years – causing extreme economic and environmental damage to Southern Italy, France, and parts of Spain. Damage has been dealt to olive trees, amongst other crops, causing *" the compulsory destruction of tens of thousands of commercial olive trees"* [22].

It should come as no surprise that olive trees are not a native species to the United Kingdom. However, it is believed that *Xyella* will attack broadleaf trees in the UK [22]. Most native trees in the UK are broadleaf [23], [24], and non-native species will also be at risk. This pathogen has the potential to cause economic, environmental, and ecological damage across the country [22].

1.2 An Introduction to Games – Regular and Serious

Academic interest in serious games and their applications is relatively new, emerging in the early 2000s, although Clark C. Abt published a book in 1987 exploring the concept. Abt has a background in the field, developing the first serious game that was used by the US military as a war-gaming tool [25].

However, games themselves have long held a social and cultural place in human society. Ranging from ancient times to the advent of modern digital games. There is evidence in the historical and archaeological records of games given as gifts in diplomatic exchanges [26]. Herodotus, in his writings, tells of the people of Lydia who played games every other day to distract themselves during a famine – a practice that reportedly lasted for 18 years [27].

Whilst digital games have become the norm, physical board and card games are still popular. Games today go beyond social and entertainment functions, although they are still very important in that regard. Games are used to comment on current issues, reflect on history, and have started to become more widely used in education [28].

Serious games are games for a purpose other than entertainment. These can be used for training, for education, awareness-raising, or other purposes. They offer

users a chance to experience and explore scenarios that would otherwise be too dangerous, costly, or impractical to create.

Some of these benefits are already being seen by those in the tree and plant health world. Caledon [29], Figure 2 below, is an example of a serious game from this domain. The game simulates and teaches estate management, with all of the difficult decisions that entails. While serious games can be developed in this area, there are academic questions to be asked about the efficacy of their ability to teach and how best to use them.

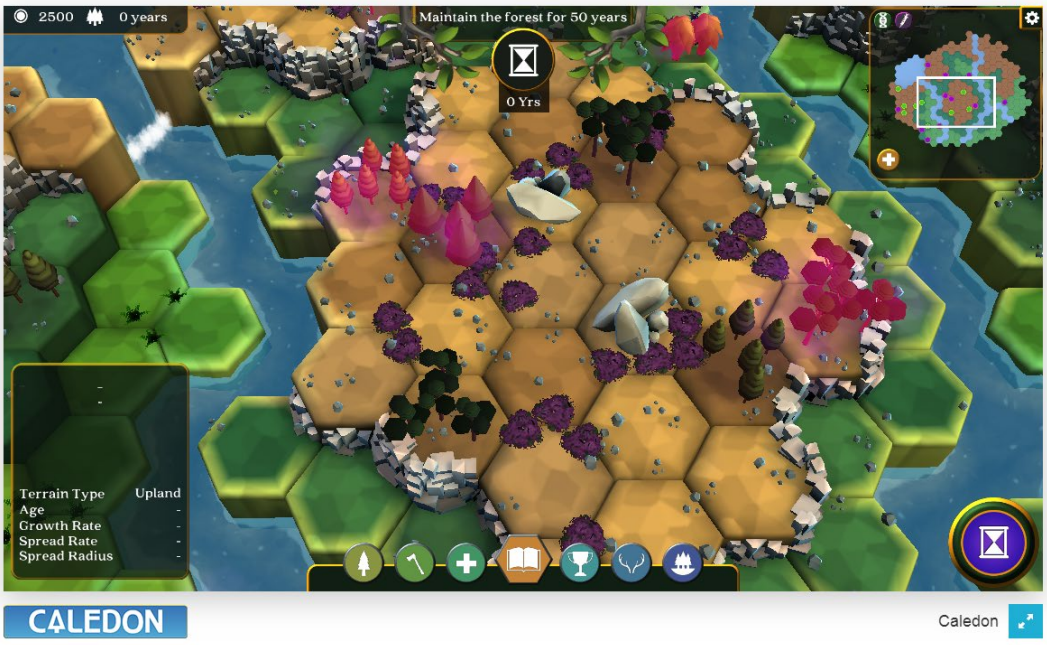


Figure 2: CALEDON

1.3 Research Questions

The use of Serious Games (SGs) for tree and plant health engagement is a novel application. During the literature review for this thesis, no papers were returned when searching for terms including Serious Games and Tree and Plant Health. However, this does not mean that there are no SGs from that domain. Games like Caledon exist and are being used. Additionally, reports such as that from the Forestry Commission reference workshops that both they and the Food and Environment Research Agency (FERA) have run, show that interest is growing in this area [30].

While there are no primary papers to draw from, there is a growing body of work of the use of SGs in other fields to draw upon. Additionally, given that public engagement work already takes place by tree and plant health professionals, their experiences are a rich seam of expertise from which to mine.

These experiences, and fundamental domain knowledge, will be a crucial component of this thesis as both tree and plant health and public engagement knowledge is something that this author does not possess. Gathering and understanding this information will form the first half of the thesis.

The framework used to structure this is drawn from the Software Engineering process, in which the first activity before any new software system can be developed is Requirements Gathering. This process focuses on understanding the problem landscape and identifying the needs of the end-users.

Requirements gathering is necessary to understand the needs of practitioners and the experiences and expectations of users if these systems are to a) be built in a way that is beneficial to those practitioners b) provide an experience that potential users want to engage with and learn from.

A common problem which arises in software development is that the requirements gathering, or requirements elicitation, phase does not lead to a product the customer is happy with [31]. In the introduction to their book on the subject, Sommerville and Sawyer identify four different reasons that may contribute to this issue.

Three of the four points can be summarised under the heading of communication: the needs of the customer not being reflected; incomplete or inconsistent requirements; misunderstandings between the customer, requirements gathering team, and development team. The final issue is commercial in nature; that is it may be too expensive to change requirements after time and effort have been invested into creating the system. Although the latter may be a function of the former. [31]

They also note that:

> *“The readers of a document are often practical engineers who can relate to implementation descriptions much better than they can understand very*

abstract problem statements. You have to write requirements which are understandable to the likely readers of the document." [31]

This is explained, in a comically tongue-in-cheek way in Figure 2. These kinds of graphics have been around since the 1960's and 1970's, with no-one really sure of their origin [32].

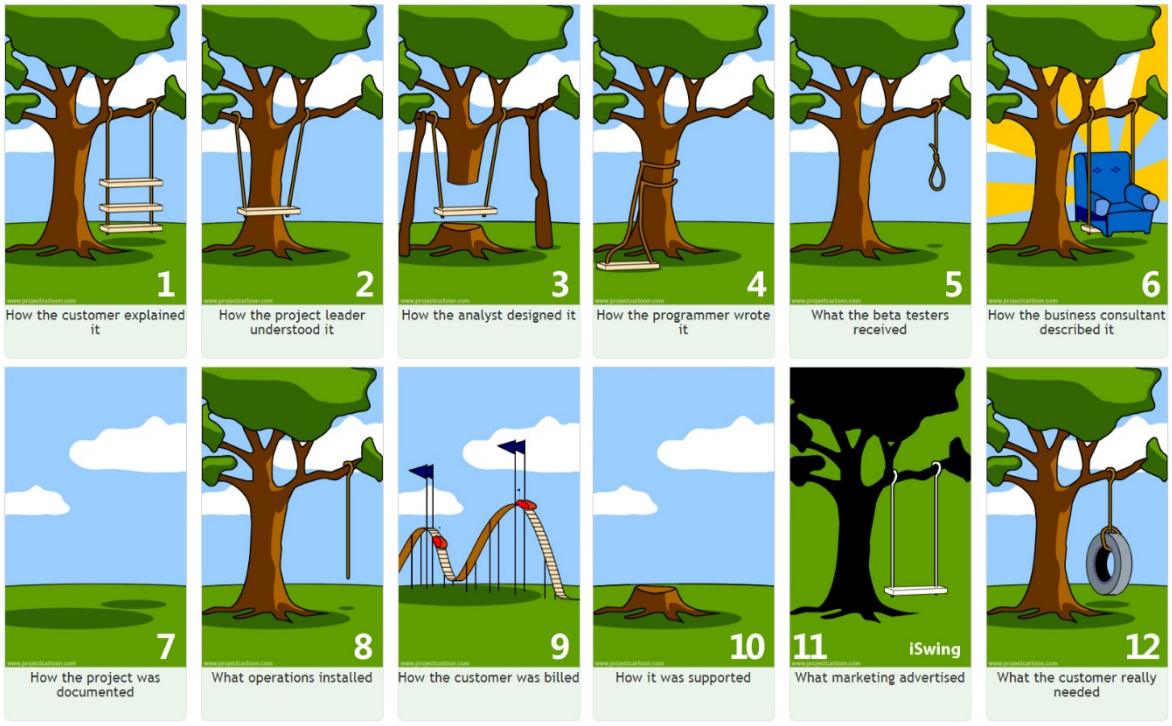


Figure 3: The Software Development Process applied to a tree swing [33]

Given the novelty of tree and plant health SG research, the second half of the thesis will focus on comparing game v non-game presentation of information. At present, it is not known whether introducing SGs to tree and plant health public engagement will have any impact. Therefore, the logical place to start is by focusing on that question. Future research may focus on specific genres or designs of games, but that goes beyond the scope of this thesis.

This approach, combined with the requirements gathering focus, leads to two questions that this thesis will tackle:

- To what extent is there an appetite for using Serious Games among plant health professionals and the general public?

- When compared to traditional methods of presenting information in public engagement, can Serious Games improve participant engagement and retention of information?

1.4 Chapter Plan

Chapter 1 has introduced the broad background to this thesis, giving an overview of the cultural, economic, and societal benefits provided by trees. It also explores the impact of novel threats should they become established in the United Kingdom. This chapter also explains the approach that the research has taken, describing the rationale behind the requirements gathering and experiment phases.

In **Chapter 2,** we explore the literature surrounding Serious Games. We start by introducing Serious Games and defining them. We then go on look at different categories of Serious Games and commonalities between them. Time is then spent looking at the design and evaluation of Serious Games. The chapter is finished by highlighting examples of tree and plant health Serious Games that have been used but are not the subject of published works, and a general discussion on Serious Games.

Chapters 3 and **4** cover the ***requirements gathering*** component of work. **Chapter 3** focuses on tree and plant health practitioners, looking at their current work and areas that they believe SGs can benefit them in. **Chapter 4** is concerned with the other side of that equation, namely the potential players of SGs and their needs and wants from a SG.

Chapters 5 and **6** cover the **public experiment** phases. These experiments use information that practitioners would present to members of the public. Participants were randomly assigned to either the non-game experience or the game experience to receive the same information. The control experience presents the information on its own. The experiment experience presents the same information but via a game. These experiments are therefore examining whether presenting the same information via a game has any impact on the ability of members of the public to learn it.

Chapter 5 covers an installation in the Royal Botanic Garden Edinburgh that was open to all members of the public to engage with. The experiment presented

some tree and plant health information, found in Appendix C. Users were then quizzed on what they had learned before being presented with demographic and enjoyment questions. Neither approach was found to be statistically significant, although lessons were learned about game design and the linking of information to the gameplay.

Chapter 6 discusses an online-based game that presents information found in Appendix D. This experiment drew on lessons learned from **Chapter 5**, namely that the information presented should be tightly woven into the structure of the game – not just presented as an additional component. This experiment, while also asking participants questions immediately after completion, extended the exploration of knowledge retention by asking a follow-up set of questions three weeks after participation. Again, no significant correlation was found between treatment and outcome in terms of correct answers, although an interesting perception of expected performance was discovered amongst those receiving the game treatment.

Chapter 7 summarises the thesis, and presents ideas for future work, while also reaching a conclusion to the two questions being asked:

- ***To what extent is there an appetite for using Serious Games among plant health professionals and the general public?***
- ***When compared to traditional methods of presenting information in public engagement, can Serious Games improve participant engagement and retention of information?***

2 Literature Review

Serious Games [25] written by Clark C. Abt in 1970 has been identified as the modern origin of the phrase *Serious Game* [34]–[40]. Serious games (SGs) can be broadly thought of games that are used *"for a variety of purposes that go beyond pure entertainment"* [35].

Abt's research focus was on the use of games as educational and training tools in the United States Military [36], specifically within the TEMPER project [41]. TEMPER was an early game designed to simulate real-world consequences with real-world constraints – used as a planning and wargaming tool [41]. A concluding report on TEMPER summarised the project as a successful proof of concept that future work would hopefully build on [42].

However, the concept of serious games is not a product of the Cold War. Wilkinson in his 2016 paper *A Brief History of Serious Games* discusses comments attributed to Plato [34] in which the philosopher discusses the nature of play and using play as a way to provide training for future careers [43].

Plato is reported to have expressed his belief that *"One should see games as a means of directing children's tastes and inclinations to the role they will fulfil[sic] as adults."* [43], such that *"if a boy is to be a good farmer or a good builder, he should play at building toy houses or at farming and be provided by his tutor with miniature tools modelled[sic] on real ones"* [43].

There is a temptation to think of modern SGs as a purely digital affair, as many of the published works explore the use, or potential, of digital games. However, there is a place for physical SGs either as prototypes to digital versions [44] or as full SGs in their own right [45], [46]. In this literature review, we drew from both digital and physical SGs.

This chapter will provide the definition that this thesis will use to understand the concept of a serious game and highlight the differences between serious games and *gamification,* a related concept that has become increasingly popular. We will then give a brief overview of different categories of SGs before delving into a more in-depth discussion on SG design and evaluation, before highlighting

examples of SGs that exist for tree and plant health use. We will also briefly explore the literature surrounding pedagogy, and that of Games themselves.

2.1 A Brief Exploration of Literature around Pedagogy, and Games

2.1.1 *Pedagogy*

While this thesis is not one focused on developing new theories or understandings around the interplay between pedagogy and Serious Games, a brief exploration of the underlying literature and concepts found in pedagogy will help give context to learning. We will start by defining pedagogy, and explore some structural theories around learning objectives and categories that can be used to understand how a teacher, or any pedagogue, can leverage theory and knowledge to teach.

Following from this, we will pivot to pedagogy with specific reference to e-learning, or digital learning. This pivot is important as this thesis is not looking at teaching in a classroom based environment, rather it will teach using digital Serious Games.

Pedagogy, as defined by Merriam-Webster, is “the art, science, or profession of teaching” [47]. Watkins and Mortimore offer the definition of “any conscious action by one person designed to enhance learning in another” [48]. With this definition expanded further by Mehanna in their 2004 work *e-Pedagogy: the pedagogies of e-learning*, to “pedagogy is any effective behaviour or activities designed to impart knowledge, it is used in the process of teaching and learning, and has an association with students’ learning and outcomes.” [49].

We will, therefore, view pedagogy through the lens of actions taken to enhance learning outcomes with respect to the student.

The Taxonomy of Educational Objectives developed by Bloom et Al. [50] has been cited as one of the most influential texts on educational thought and practice in the early-to-mid 20th century [51], with the text being written in 1956. The taxonomy is concerned with providing a framework that allows different levels of learning and activities to be mapped against learning outcomes. The taxonomy was updated in 2001 by a former student of Bloom, Lorin Anderson, to better reflect turn of the century teaching [52].

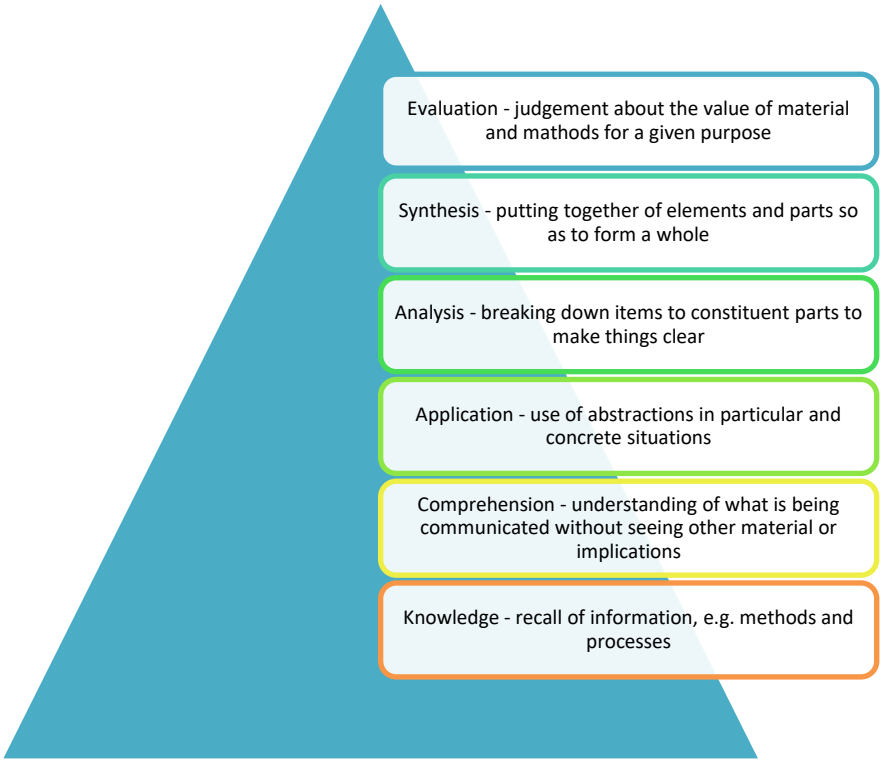


Figure 4: Bloom's Original Taxonomy [50]**, categories and definitions quoted from the same work**

The taxonomy is read from bottom to top, with underlying elements supporting progression to and activities within higher levels. The differences between the original, Figure 4, and revised models, Figure 5, are as follows:

- The use of verbs instead of nouns to name the categories; [53]
- Evaluation and Synthesis in the original are swapped, so that Synthesis, or Creation, is at the top of the taxonomy; [53]
- Move away from static “educational objectives”, to the more dynamic “teaching, learning, and assessment” categorisation. [53]

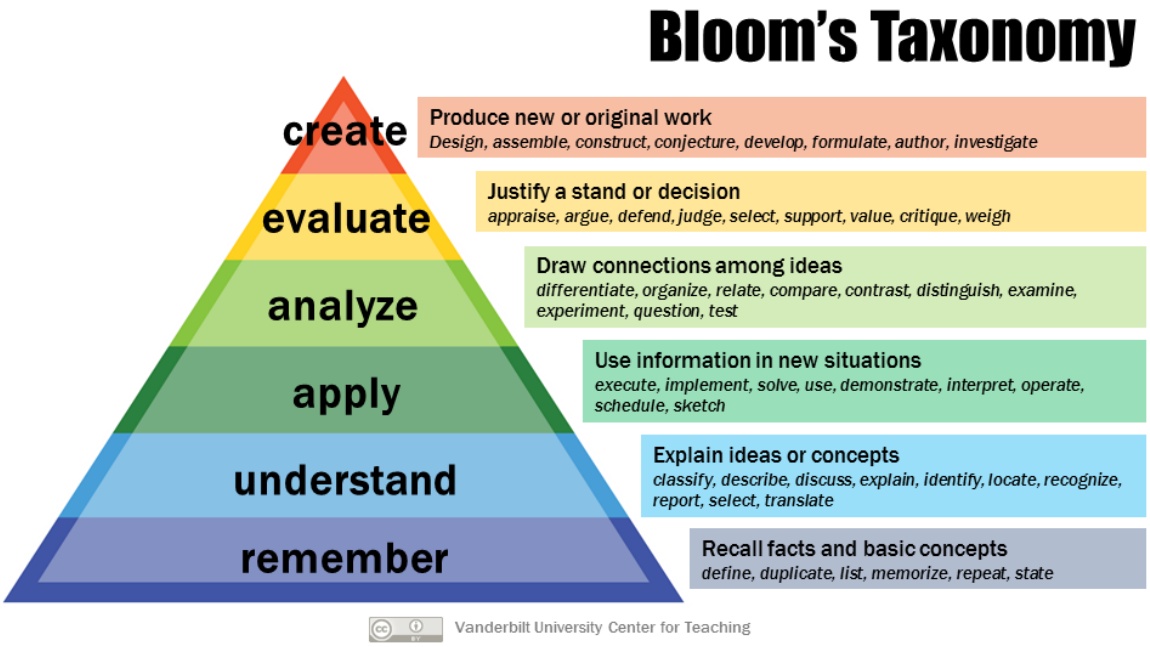


Figure 5: Bloom's Updated Taxonomy[52] **- replicated with attribution to the Vanderbilt University Center for Teaching** [53]

This move from more static schools of thought to a, hopefully, more dynamic system is not restricted to pedagogical frameworks. We see similar discussions play out regarding active v. passive teaching. Deslauriers et Al. explore this issue from both the educator and student perspectives in their 2019 paper *Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom* [54].

To summarise their paper, they report that active learning techniques can result in better results for students but that students prefer passive learning techniques, with educators themselves facing multiple barriers to providing active learning environments [54]. To define what is meant by passive and active learning:

- Passive learning techniques encompass traditional learning environments e.g. lectures, where the educator leads the teaching
- Active learning contrasts passive learning by putting the student in the driving seat, e.g. through student led problem solving.

An example given in the paper is students solving a physics problem. For the passive learning technique, the students are walked through the problem and solution by the lecturer, whereas the active group need to work through the problem with each other first before the lecturer gives the solution [54].

Alongside discussions around passive v. active learning environments, and the reframing of Bloom's taxonomy, education has been transformed through the introduction and development of e-learning opportunities and technologies.

E-learning, or digital learning, is directly related to the work explored in the rest of this thesis. The field is not, however, without its own challenges. Coomey and Stephenson found in their 2001 work that in the decade running 1991 – 2001 that there was no significant, if indeed any, evidence that e-learning methods proved more effective than more traditional methods [55].

This theme is further explored in Schrum et Al.'s, Schrum from here on, editorial in 2007 where they first recount Richard Clark's analogy from his 1983 work, *Reconsidering Research on Learning from Media*. Clark posits that technology alone is no more beneficial to education than having food delivered on a truck is to the inherent nutritional value [56], [57]. To put it another way, simple exposure to technology is, in itself, no more or less effective than putting a student in a room with books, pens, paper, and so on – it is *how* these instruments are utilised that realise their educational potential [56], [57].

Schrum puts forth a hypothetical explanation of this via planetarium software. They posit that one teacher may give students worksheets to follow such that the e-learning platform reinforces the lessons being taught while another may give the students free reign to come up with their own hypothesis and explorations of the concepts within the software [57]. They conclude that "Students' resulting comprehension of the content may differ based on the teachers' pedagogy, even though both groups used the same technology." [57]. Here we see echoes of the passive v. active [54], or static v. dynamic [50], [52], debates we have discussed previously in this section.

Interestingly, Schrum also highlights that as of the time their editorial was written a lot of studies "compared the effectiveness of one medium with another on a variety of dependent variables" [57], and that these kinds of studies are a "natural question for policy makers (and beginning researchers) to pose." [57]. This comparison between mediums underpins the research conducted in Chapters 5 and 6 of this thesis.

We can, therefore, conclude that if technology is to be used in an educational setting effectively then merely adding that technology alone is not enough. This is a theme picked up by Chris Fowler in his 2015 paper looking at Virtual Learning Environments (VLEs), where he concludes that there needs to be a linkage between the technological affordances of a VLE and pedagogical frameworks with the common focus on a learning outcome [58].

He goes on to suggest that one way VLEs can be leveraged to best support the identified learning outcome(s) is to derive the learning activities that will be used in the VLE [58]. He maps a framework previously developed with Mayes that considers the learning stages (Conceptualization, Construction, and Dialogue) [59], onto the revised Bloom's Taxonomy [52], and finally to a series of potential learning activities, e.g. recognising patterns and drawing conclusions, that is based on Conole et Al.'s 2004 work *Mapping pedagogy and tools for effective learning design* [60].

While it is a reasonable conclusion to draw that much is still to be explored around pedagogy and e-learning, some evidence of their effectiveness is discrete scenarios is beginning to appear in the literature. Zhao, Zhou, and Ding in their meta-study of digital games in the medical field over the 2010s conclude that the studies they consider show that digital interventions provide more effective learning experiences for students compared to the control measures [61].

Although this appears promising, the study was restricted to one specific subset of university education and general conclusions cannot be drawn. Instead, it is the position of Schrum that we return to, where they state:

"Until the pedagogical methods that uniquely take advantage of a technology's pedagogical affordances to achieve content-specific learning objectives are identified, it will not be possible to prepare teachers to make effective use of current and emerging technologies." [57]

This assessment will, we believe, hold true for our research into the potential uses of Serious Games with respect to public engagement using tree and plant health content. The lesson we draw is that we must understand not only what we need to teach, but how it is to be taught, and the abilities of the supporting technologies. Given that tree and plant health professionals hold knowledge on the material to

be delivered, and have experience with how it should be delivered to the intended audience, we are in a position to develop understanding of how the technologies – Serious Games in this instance – can function to support the professionals' aims.

2.1.2 *Games*

Before we can entertain the notion of a Serious Game, we must first understand what is conceptually meant by a game. An understanding that we will reach by starting with the concept of Play.

We will base this discussion on works by Johan Huizinga and Roger Caillois. These two influential authors have shaped the discourse on Play and Games over the 20th century. They appear frequently in the literature surrounding Serious Games as various authors look to discuss the structural theories underpinning games, e.g. [34], [35], [44], [62]–[65]. By understanding these works we can move towards understanding Games, and Serious Games by extension.

Homo Ludens by Johan Huizinga [66] is a seminal work that discusses the nature of play within culture and society. Huizinga opens his book by stating that "Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing" [66].

This seemingly cross-species, innate, need to play has a number of potential sources, as Huizinga highlights, ranging from burning off excess energy to developing social skills [66]. As he explores the concept of play he identifies 5 concepts that human play must have, or be:

- "A free activity" – that is play is not performed through a sense of obligation or as part of a societal ritual [66].
- "consciously outside "ordinary" life" – play takes place in a state of pretend, or suspension of the usual rules [66].
- "Play is distinct from "ordinary" life both as to locality and duration." – the play is carried out within its own time and place, e.g. a game of football on a special pitch for 90 minutes [66].
- "it creates order, is order" – play comes with rules and restrictions that may not be present in the normal world [66].

- “play is connected with no material interest, and no profit can be gained from it” – play is carried out for fun [66].

These core tenants of play are debated and expanded on by the French intellectual Roger Caillois in his 1961 book “Man, Play and Games” [67]. Instead of the five themes identified by Huizinga, Caillois posits that 6 core characteristics instead should be used to identify play, many of which are common to both definitions:

- It is free, or not obligatory
- It has its own time and space, separate from that of life’s routines
- There is a degree of uncertainty, that the results cannot be known beforehand
- There is no economic advantage or disadvantage to playing, that is it is unproductive from the perspective of wealth
- Play introduces its own special rules that are different to those of the normal world
- Play involves imagined realities, or a degree of fantasy, to separate it from the real world.

Beyond the challenging of the nature of play, Caillois also offers up four categorisations of game, and two categorisations of where they might be found. The categorisations are replicated below in Table 1 [67]. These categories of games can be combined together, e.g. a game may have elements of competition that also enhances the emotion felt by the player, a cross of Agon – Ilinx [67].

Game\Found	**Name**	**Description**
Game	Agon (Competition)	Skills are put to the test amongst players
Game	Alea (Chance)	Games of luck, opposite of Agon
Game	Mimicry (Role Playing)	Where the player inhabits a different role to that of their usual disposition, e.g. an online role-playing game
Game	Ilinx (Vertigo)	Temporary disruption of perception\enhancing of emotions

Found	Paidia (Uncontrolled Fantasty)	Spontaneous setup of rules and settings
Found	Ludus (Controlled environment)	Pre-defined rules and settings, e.g. Chess.

Table 1: Roger Callois' Game Categorisations

Through the exploration of play we arrive at the categorisation of games as a form of play. Rowe takes these categories in his 1992 work “The Definition of ‘Game’” and develops a working definition of a game as: “An abstract object (either a sequence or a goal) which is designed to have no instrumental value; the realization or pursuit of which is intended to be of absorbing interest to participants or spectators.’”[68]

Other definitions offered by others include:

- “A game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context”, Clark C. Abt [25]
- "A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome”, Katie Salen and Eric Zimmerman [69]
- “When you strip away the genre differences and the technological complexities, all games share four defining traits: a goal, rules, a feedback system, and voluntary participation”, Jane McGonigal [70].

Across these definitions, and the discussion on play, we can see common themes around freedom of participation, the imposition of rules that are different from those of the normal world, some form of goal to work towards, and either playing alone or with others.

Definitions of games, and the nature of play, do not exist in a vacuum. The way in which humans have experienced games over the centuries has been limited to the available technologies of the time. We know that board games have been used through history, e.g. the Roman era [26], as is the case with sports, e.g. ballgames across the Mesoamerican civilisations [71] and card games [72] also featuring in the historical record.

In the latter quarter of the 20th century, the development of digital video games transformed the relationship we have with games. Digital games gave us the ability to simulate complex military scenarios [42], and introduced different ways of engaging players. Much can be said about the development of different gaming platforms and genres, but that goes beyond the needs of this thesis. Suffice to say that as platforms and genres grew more mature and complex, so too do the experiences they provide.

In the modern world we have a range of gaming options available to us, from the individual gaming experiences, to augmented and virtual reality gaming[73], massively online role-playing worlds [74], and casual games that can be played in the brief snatches of free time in busy lives.

To conclude, elements of play, and games, have been present through human culture from antiquity to modern times. Recent technological developments have enabled new and more complex methods of engaging people with games. We can also see that there's some consistency in terms of what might constitute a game, including freedom to play without obligation, the introduction of special rules and locations to play, and the a degree of separation from the real world\the introduction of fantasy.

2.2 Definition and Differences Between Gamification and Serious Games

2.2.1 *Definition*

Having a working definition of what a serious game is can be challenging, as Djaouti et al. acknowledge in their 2011 paper on classifying serious games [35]. They state that *"the "Serious Game" industry brings together participants from a wide range of fields…who do not always agree what is and is not part of the Serious Games industry."* [35]. They land on a general definition for their work *"any piece of software that merges a non-entertaining purpose (serious) with a video game structure (game)."* [35]**.**

Several other definitions also capture the need to have a video game, or digital, component although we find this to be needlessly restrictive. While modern SG research tends towards digital experiences, there are some examples of non-

digital experiences that also exist, e.g. a SG on Urban Planning by Poplin [44] or teaching computational thinking via boardgames by Tsarava et al. [45].

The inclusion of explicit design, and therefore intended purpose, of the game, is essential. There are games that are set within, for example, historical periods, e.g. Assassin's Creed Odyssey that can provide educational experiences as a side effect of playing them [75]. Whereas SGs have, for example, education as their primary focus.

Therefore, in this thesis, we will define a Serious Games as any game that is designed and used for a purpose other than entertainment.

2.2.2 *Difference Between Serious Games and Gamification*

In recent years research has been conducted in the similar fields of Gamification and SGs. These two terms are used interchangeably in some cases (e.g. [76]). However there are distinctions between them that show why this should not be the case.

Gamification is the application of game design elements to pre-existing software (or physical situations) for a range of reasons, e.g. to make the situation more enjoyable; encourage new, or desired, behaviours; motivate users/participants [77].

Duolingo is an often-cited example of a gamified service [78], [79]. Duolingo uses gaming elements such as leaderboards, achievements, and levels to motivate and encourage users in their quest to learn a new language.

Gamification of a situation does not necessarily create a game – although the main reason for implementing it is to add an element of fun to an otherwise dull experience.

While SGs can be used for similar purposes to those outlined for gamification, there is one clear difference. SGs are created for a specific purpose, as an entirely new entity, compared to the bolting on of game design elements via gamification. It is, however, possible to have gamification components within SGs. For example, leaderboards are found within the SG FoldIt.

2.3 Categories of Serious Game and Common Elements

Serious games are used across multiple fields for a range of reasons. Even within a particular field, it is possible to see SGs used in different ways and with different expectations. Therefore, this literature review will not concern itself with attempting to catalogue the different domains that SGs can be found in; rather, it will categorise them based on what the SGs are being used to achieve. It should be noted that these categories are not exhaustive.

There are three categories that we will use to group SGs:

- Crowd Sourcing and Human Computation
- Educational
- Public Engagement

These categories comprise the potential components that are likely to be required to address the research questions. For each of these categories we will set out what is meant by the terms before looking at an example of each.

2.3.1 *Crowd Sourcing and Human Computation*

We are fortunate to live in an age where computers can be used to tackle, and solve, problems that would take humans an inordinately long time to do. However, as good as modern computers are, there are problems that they cannot solve alone or in a timely manner. Problems in this category require input from humans, which is a reversal of the traditional computer-human relationship [80].

These sorts of problems are often presented in a semi-disguised way, e.g. in performing one task an unseen task is also completed. An example of this is the reCAPTCHA system which has had humans help computers digitise words from old books that they cannot read [81].

Google now uses its v3 reCAPTCHA to help annotate images and build machine learning datasets [82]. This builds on the positive contribution that the original system made in digitising books.

Crowd sourcing, on the other hand, takes a slightly different approach to things. The first academic definition by Brabham in 2008 defined the concept as an "*online, distributed problem-solving and production model*" [83]. Jeff Howe, an

editor at Wired magazine, defined the concept two years earlier in a 2006 article as

"crowdsourcing represents the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call. This can take the form of peer-production (when the job is performed collaboratively), but is also often undertaken by sole individuals. The crucial prerequisite is the use of the open call format and the large network of potential laborers." [81]

The point here is that within crowdsourcing a problem is being tackled by a wide pool of participants. Sea Hero Quest is one such example of a crowdsourced game. Participants navigate a boat around a 3D world, completing tasks along the way, with their activities generating data to be used for research into alzhimers [84]–[86].

The main distinction we draw between crowdsourcing and human computation is that with the latter it is with the aim of solving a concrete problem, whereas the former can solve problems but can also be used to gather information or lay the groundwork for solving problems.

For this thesis, the distinction is important to know when one technique should be utilised over the other. As discussed, the two techniques have different expectations of inputs and outputs, and as such would guide how players would engage with games designed with either technique in mind.

2.3.2 *Educational*

For this particular category, and in contrast with Public Engagement or Science Communication, SGs must be meant for an educational setting. This can be across academic or workplace settings. The main point of the SG will be to deliver or support a fully realised piece of educational content or training.

For example, Tan et al.'s work on designing and evaluating a SG for the safe administration of blood transfusion, is specifically concerned with delivering training on how to perform that procedure safely [87]. This was done within the context of a university course prior to joining the workforce as a nurse.

2.3.2.1 Educational – PULSE – Case Study

Cook et al.'s 2011 paper describes a web-based SG that focused on life support training for nurses. The purpose of this SG is to reinforce learning from lectures, practical sessions, and hands-on learning with a view to sitting the ILS (Intermediate Life Support) qualification as part of their university course [88].

The game allows players to repeatedly test their skills in digital scenarios through levels ranging from identifying the objects on the medical cart to making decisions at pace in a simulation of a lifesaving process [88].

The authors highlighted research which showed that repeated practice of techniques could help improve performance in the practical examination. While, perhaps, a self-evident statement this is hampered by the limitations of the practical setting. The students both learn from and perform their examination on physical, computer-simulated manikins that need to be shared with other students.

The study found that students who engaged with the PULSE platform performed better in their ILS examination than those that did not. All students that participated in the study had access to the same lectures and training materials. The only difference between the two groups was the experiment group having access to the PULSE platform.

Having the ability to replicate potentially limited or expensive physical equipment – and to give as much access as the student wants – is an interesting contribution that SGs can make to educational scenarios [87]. Additionally, SGs have the ability to take learners into situations that may otherwise be very dangerous.

These situations may be a danger to themselves, e.g. earthquake evacuation practice [89], [90], or to those that they would be working with, e.g. blood transfusions [87] or life-saving techniques [88]. In these situations, mistakes can be made and lessons learned with the simulations run an unlimited number of times, bringing to life points that may otherwise have been worst-case scenarios in lectures or training materials.

2.3.3 *Public Engagement*

Public engagement also exists in an education space but does not occupy the same space that the Educational category does. SGs in this category are much

more casual in their educational setting. That is we may find them in museums, or science centres or they might be exhibits that are put together by academics to showcase their work to the wider world. Or any other setting in which a non-formal learning outcome is the goal.

In these cases, the participants are free to engage with and leave on their own free will. No qualifications or work-based requirements are relying on completion of games in this category.

Despite this seemingly more casual approach, information included in these types of SGs should not be underestimated. It is possible to get deep, meaningful, learning experiences from them.

2.3.3.1 Public Engagement – Data Pipe Dreams: Glimpses of a Near Future – Case Study

This exhibit from the Edinburgh College of Art, at the Edinburgh Fringe Festival, in 2018 hosts installations from Design Informatics researchers. The pavilion aims to *"investigate the possibilities of designing with data, and how this can enrich or challenge our personal, economic and social lives."*[91].

Not every exhibition in this pavilion would be termed a SG. However, there was one, in particular, that was a great example of public engagement communicating a research topic.

The Lens installation provides users with a series of choices around sharing data, e.g. their uber rating, or Fitbit metrics and the impacts that may have on their life. In the game, the player takes on a fictitious persona and picks a job that they would like to apply for. They then select which data they would like to share with the hiring organisation before being presented with a hiring decision and the reason(s) for\for not being hired.

In this way, users are taken into the world of data. Specifically, addressing the vast quantities of data that we generate on a daily basis and the potential uses that such data may be used for in the not too distant future.

2.3.4 *Common Themes across Categories*

Across the categories we have just discussed, we can find some common themes. We will briefly discuss these themes in this section. We may not find

these themes in every SG but they are sufficiently common to warrant commenting on.

2.3.4.1 Simulation

Simulation is commonly referenced([46], [87], [92]–[96]) when discussing SGs.

Being able to explore real-world choices and consequences in an environment that demonstrates outcomes without suffering the real-world implications is a unique, and leading, attraction of a SG.

For example, learning how to give blood transfusions correctly [87] or exploring the consequences of unprotected sex and the realities of HIV [97] are two areas explored by SGs. In both cases, there can be life-altering, or ending, consequences to the wrong decisions. So being able to make choices in a SG, see the outcomes of those choices, and thus be able to make the right choice in the real world is powerful.

The graphical quality of the SG simulation is linked to the purpose it is serving. Games that look at evacuation during an earthquake [89], [90] or are teaching people to identify serious faults in levees [98] must, by their nature, be of high graphical quality and identical to the real world. Failure to do so may leave participants unprepared for the situations for which they are being trained.

Conversely, games that are teaching a concept, e.g. the relationship between overfishing and population levels [99], or are looking at solutions to pest/pathogen outbreak [100] can forego a high level of graphics as long as the educational material is taught.

There are other, more immediate, benefits that simulation can bring. SGs can complement expensive physical labs, and help more students spend time with those topics that would typically only be covered there, e.g. [87]. They also give the opportunity for people to learn and make mistakes without damaging each other or the environment.

Finally, it is possible to recreate or simulate situations that would otherwise be incredibly dangerous, or rare, for humans to come up against, e.g. Earthquakes or terrorist attacks, in order to train the participants and/or learn about how people respond in these scenarios.

2.3.4.2 Abstraction from the Problem Domain

While we have established that a SG can provide highly realistic environments capable of simulating the real world, this is not always required. In SGs there will always be a degree of abstraction away from the real world.

Abstraction is *"the quality of dealing with ideas rather than events"* [101] or translated into SG parlance stepping away from capturing every part of the real world to focus on a contextually appropriate scenario.

Alderliesten et al. in their work on MainTrain use abstraction to explore rail user empathy for delays arising from required maintenance. While the authors could have created a semi-realistic recreation of railway, they instead opted to procedurally generate the railway tracks, routes, and stations [94].

In the case of this SG, the stations and routes used are not that important. Instead, it is the concept of trains travelling between stations over a track that then necessitates maintenance of both the track and rolling stock that is.

Similar levels of abstraction can be found in graphical detail in Cook et Al.'s work on fireblight, where the geographic region of Australia has been represented by a grid system [100]. Ameerbakhsh et Al.'s 2019 paper also demonstrates this graphical abstraction to help teach students about sustainable fishing practices [99].

It can be all too tempting to want to give the user an experience that has the least amount of abstraction from the topic as possible. However, the aim of the SG, e.g. policy planning, should dictate that individual components can be less realistic in favour of others.

Having a great deal of abstraction across the SG can allow for what is important to shine through. The player can then engage with the SG without being distracted by elements they should not be concerned with.

For example, returning to MainTrain, that trains and railways require maintenance and travel delays should not be viewed as an annoyance is the key point – educating players on the main railway stations of Europe is not.

2.4 Serious Game Design

While each SG is designed for a particular purpose, there are common areas of research interest, and learning that span the many domain areas in which SGs can be found.

This subsection will discuss two elements of SG design. Firstly, it will look at how SG design has been approached in published works. Secondly, it will discuss some of the ongoing research questions that are being asked.

2.4.1 *Current Design*

Researchers have designed games in various spheres including Education ([46], [95], [102], [103]), Awareness Raising([44], [94][104]), Behaviour Change([105], [106]), and Teaching Skills([41], [87]–[90], [92], [96], [98], [107]–[109]). While some researchers do work with external agencies to develop their games, many papers indicate that the researchers themselves have led the design and development of the games.

There have been several frameworks developed to help navigate the world of game design. These include, but are not limited to:

- Four Dimensional Framework (4DF) [110] ;
- Intervention Mapping Approach (IM) [111];
- Mechanics Dynamics Aesthetics Model (MDA) [112];
- Learning Mechanics – Game Mechanics Mapping (LM-GM) [113].

2.4.1.1 Four Dimensional Framework (4DF)

The Four Dimension Framework was created by Sara de Freitas and Steve Jarvis in an attempt to answer the following question that was part of a larger project: "*What are the characteristics of people that are relevant to the use of games for learning?"* [110].

The Framework covers four key areas that the authors believe to be the aspects of a SG [110]:

Context: The type of game that has been selected and where it will be used. With the location helping to influence the type of game that might be suitable.

Learner Specification: The demographic makeup of the group that the game is intended for, along with any preferences and skills they may have that could influence the game, e.g. how well versed they are with digital technologies.

Representation: How everything is represented in the game from realistic environments to immersion within the game. This will also include balancing expectations off against practicalities, e.g. higher graphical quality.

Pedagogical Model or Approach Used: The educational and learning model that is used to underpin the teaching in the game.

de Freitas and Jarvis developed the model as a response to the then growing trend of using a customized version of a Commercial Off The Shelf (COTS) game for serious purposes. The hope behind the model is that it will inform those making these decisions and have them think about whether the game and therefore investment is worthwhile and likely to meet their aims [110].

Additionally, this model also puts the learner – not the game – at the centre of the discussion. This is important as the authors highlight their own experience that where the learner is considered ahead of the technology, that is the specificity of the learner guides which technologies should be used, the learner has improved outcomes [110].

2.4.1.2 Intervention Mapping Approach (IM)

L. Kay Bartholomew et al. developed the Intervention Mapping protocol in 2016 [111]. The protocol sits within the health promotion and health education space, although the general framework could be applied to any particular problem. At a base level, the protocol itself is not necessarily concerned with SGs, but the approach it promotes could be a useful design companion.

There are six key steps, and associated sub-steps, that can be summarised as follows:

1) Understand the problem that is being solved, the people it is affecting, and the world they exist in. Also, gather people that hold the information required to solve the problem.

2) This step focuses on looking at who and what you want to change with the intervention. This will be done at all levels from the individual to the group\community.
3) In step three, theory to support the change that is to be attempted is looked for—a literature review in other words.
4) Step 4 concerns itself with the overall plan of the program, informed by the information gathered in previous steps. This step will also be used to develop methods of communication with external partners, e.g. designers. Pilot testing of strategies will also happen here.
5) Implementation of the intervention happens here. However, this is a living step that will adapt to changing circumstances and emerging information.
6) The evaluation plan is formalised here, along with the necessary instruments for evaluation. Evaluation metrics will be gathered throughout each step via outcome matrices.

As has already been mentioned, this protocol is very much designed with a view to health care interventions, many of which will not be games. However, the focus – especially in the first three steps – can provide a solid base for any piece of SG research to better understand the domain it is to be used in, gathering the necessary knowledge, and knowing what exactly is to be measured.

2.4.1.3 Mechanics Dynamics Aesthetics Model (MDA)

The Mechanics, Dynamics, and Aesthetics Model *"is a formal approach to understanding games – one which attempts to bridge the gap between game design and development, game criticism, and technical game research."* [112].It was developed and taught by Robin Hunicke, Marc LeBlanc, Robert Zubek *"as part of the Game Design and Tuning Workshop at the Game Developers Conference, San Jose 2001-2004"*.

The framework breaks down games into their core components, that is Rules -> System -> Fun, and maps them to Mechanics -> Dynamics -> Aesthetics. The translated components can be understood as follows:

Mechanics: These are the underlying systems in the game. That is how the player can interact with the game. This can also include things like levels and assets within the game.

Dynamics: The dynamics of the game are how the mechanics are utilized by the player during the game to influence how they play the game and how others, if appropriate, play with them.

Aesthetics: This is where the emotional response, in terms of what makes the game fun, is to be found. E.g. should the game be providing role playing adventure that the player can create their own extensive narrative in?

Each component of the model is described by the authors as a way to interrogate the game experience, each individual but casually linked. Interestingly, it is also a model that involves diametrically positioned experiences. Designers will view the model from an M – D – A perspective, looking to build the underlying mechanics that drive the dynamics which provide the aesthetic of the experience. However, players will experience this in reverse.

A strength of the model is the re-evaluation of a game through different lenses can provide for a finetuning of that game – or allow it to be explored for use in different situations. The example provided is for an AI system for a game of tag. By applying MDA to that concept, it is possible to interrogate the requirements for games that are suitable for 3-7 year old children, 7-12 year old children, and 14-35 year old men [112] .

2.4.1.4 Learning Mechanics – Game Mechanics Mapping (LM-GM)

The Learning Mechanics – Game Mechanics framework was developed by Sylvester Arnab, Theodore Lim, Maira B. Carvalho, Francesco Bellotti, Sara de Freitas, Sandy Louchart, Neil Suttie, Riccardo Berta and Alessandro De Gloria. The model is an attempt at *"…providing a concise means to relate pedagogy intentions and ludic elements within a player's actions and gameplay"* [114]. The lists of Learning Mechanics and Game Mechanics that are presented by the authors in the framework are a non-exhaustive list of possibilities.

Learning Mechanics (LM) that the authors include in their model are a result of literature reviews and discussions with experts on 21st-century pedagogy. The research was focused more on theories that were closer to game education. Similarly, the Game Mechanics (GM), were fleshed out by reviewing papers on game dynamics and mechanics.

The model itself consists of LM on the left and GM on the right, as shown in Figure 7. The authors state that nodes that are closest to the centre should are the root nodes of the LM\GM with variations and expansions on the concept to be found in the wider nodes.

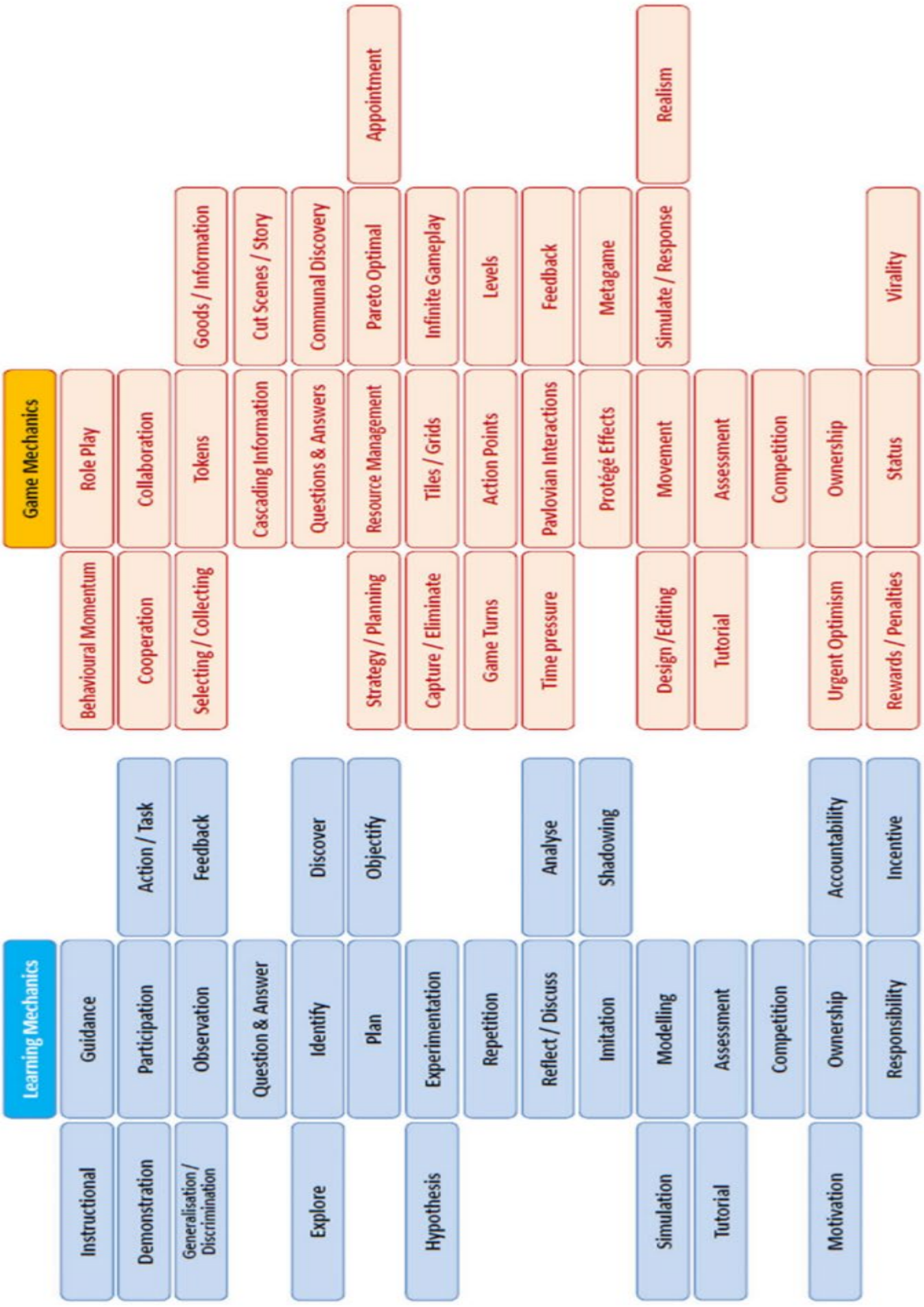


Figure 6: LM-GM Model, S. Arnab, T. Lim, M. Carvalho et al. [114]

Interestingly, this particular model exists in both static and dynamic contexts. It is static in that if we consider the pairing of Incentive and Rewards\Penalties, then it is clear that Rewards or Penalties are implementations of an Incentive model. Similar links exist between the other nodes in that row. So from a static reading, it is possible to understand how the elements come together.

The model becomes dynamic when applied to a real game scenario. The example presented by the authors is a third-person shooter game, Re-Mission, which was designed to help young people understand how their cancer treatment works.

When the game is broken down into the highest level steps a player will go through, e.g. level selection, it is possible to map the LM and GM against each step. Focusing level selection, the authors identified the LM node Instructional paired with the GM Goods\Information, Cut Scenes\Story, and Levels [114].

Therefore the model is, as the authors state, not prescriptive but rather descriptive. This allows for SG researchers and designers to interrogate exactly what would be required at each high level step in the SG e.g. level selection, and select appropriate component combinations from both the LM and GM wings.

2.4.1.5 Framework Discussion

Considering the four frameworks that have been discussed in this section there is one clear theme emerging that goes beyond the specificities of each framework. That is encouraging whomever uses them to think about, and interrogate, the problem they are trying to solve. The frameworks will then provide a potential blueprint that can be applied to the deconstructed problem.

However, frameworks while offering a guide to the less experienced team – deciding on the right framework to select can be a difficult task [115]. Frameworks are designed to solve a particular type of problem, e.g. the Intervention Mapping approach for healthcare issues, and navigating the many potential choices can be a daunting task.

SG design is not, however, only influenced by the theoretical works from the field, but they draw inspiration from the fields in which they are operating. That is to say

those SGs may include pedagogical frameworks and learning models from within the fields they are serving.

An example of a SG being built around a pedagogical model can be seen in O. Petit dit Dariel, T. Raby, F. Ravaut et al.'s 2013 paper on developing the SG potential in nursing education, specifically around Clinical Reasoning [37]. Clinical Reasoning is the ability of nurses to think and act in the best interests of the patient whilst navigating the complexities of clinical realities and stakeholders.

The authors describe the Clinical Reasoning model put forward by Levett-Jones et al., which is broken into discreet segments. These segments can then be used to guide the development of a SG based on learning and applying each key concept. In this case, the authors are looking to fill a gap in the education offered to nurses – specifically around community and home-care situations.

Y. Politis, N. Robb, A. Yakkundi et al. present an interesting twist on the inclusion of models as a basis for SG design in their 2017 paper *People with Disabilities Leading the Design of Serious Games and Virtual Worlds* [54]. While the model used by Petit dit Dariel et al. provides a model to be used to design the SG, Politis et al. instead focus on bringing end-users into the design process and having them actively participate in developing an experience that they would want to use.

This puts representatives of the target audience in a position to influence the design of the experience and may present the researchers with views and lived experiences that they otherwise might miss. The exciting part here is that it provides a more in-depth focus on understanding the problem that is being tackled and then designing the SG around that knowledge.

Theory is a good place to start, and indeed offers an informed opinion that can enhance the potential effectiveness of any SG that is developed. However, theory must come up against the limitations of real-world research. Teams of researchers can also supplement themselves with experts in the pedagogical bases, technical skills required to develop SGs, or even the underlying theory for SG development (e.g. [44], [46], [88], [97], [116]).

While frameworks and theory offer excellent starting points, they cannot give an exhaustive guide on every possible permutation of SG that researchers will want to develop. Indeed, they should not be looked to as fixed points to be followed

dogmatically, instead as guidelines that should be expanded on and modified as required.

2.4.2 *Discussion Around Design*

While many areas can be focused on when thinking about SG design and research in the field, one particular challenge has been highlighted by Kafai where education and SGs come together.

The problem revolves around two approaches to using games in a formal education setting, e.g. inside a classroom, although we believe it can also fit less formal education settings. These approaches are Instructionist and Constructionist.

The instructionist approach is defined as "*hav[ing] a desire for games to teach a particular subject e.g. Maths"* [117]. That is to have a complete game to use as a teaching aid, whether that is supplementing points made in a lesson or teaching entire concepts.

The constructionist approach, on the other hand "*has a desire for the same games but would have the students make the games to teach the topics"* [117]. Considering a game that might be used in a maths lesson, the educator would have a game that was incomplete for the students to complete as part of learning the material. The intention is to reinforce the material that is being taught by having the students apply it first to complete the game and then in the playing of it.

As discussed in 2.3.1, there is currently a wide disparity in the makeup of teams designing SGs, often without the intended recipients being included in those discussions. Politis et Al. in their work *People with Disabilities Leading the Design of Serious Games and Virtual Worlds* [118] explore three instances of including the intended audience, disabled users, and the benefits that can bring.

They report that having the intended recipients involved in the design of games has a positive effect on the impact of those games. What is gained is an understanding of what the target audience wants; how they will engage with the tools being built; and a potential appreciation by eventual end-users that someone like them was involved in creating the experience they will have.

This approach had success in Hieftje et Al.'s 2016 paper [97]. The researchers here had contact with their intended audience, minority young people, through the development process, taking their input on board to understand them as fully as possible.

Questionnaires and interviews covering everything from hopes and dreams to the realities of life were used. Adults involved in their lives were spoken to as well. Those young people were also asked to take disposable cameras and document their lives. This rich data afforded the research team the ability to build a game that not only looked right graphically but spoke a language that the audience lived. In short, it was not just a game that was being developed it was *"their game"*[97].

Here there is almost a blending of the instructionist and constructionist approaches. By including the end-users in the design and development phases, elements of constructionism are brought into the SG creation process. However, the end result is a complete SG that can be used by the target audience – the hallmark of instructionism.

While the study does not explicitly explore this concept, when viewed through this lens, there is potential to bring advantages from both of these approaches to bear on SG research projects. Although, this will not be possible in every situation where there is potential pursuing it will be of interest.

2.5 Serious Game Evaluation

While the design and purpose of a SG are essential – equally, so is its evaluation. While not all SGs are developed as part of an academic experiment, experiments can play a role in evaluating SGs.

Where evaluation in other fields can be relatively simple, e.g. does the model provide the expected results over N runs, or does the element react in an expected way, SG evaluation has a great degree of difficulty.

The primary source of this difficulty comes from the human component of this research. While experimenting with humans is exciting, being able to empirically state that any SG intervention has the expected outcomes, especially in a long-term frame, can be very difficult

So what is meant by evaluation? Is evaluation the culmination of analysis of data gathered during the experiment phase? Alternatively, is it something more, something that should be considered through the entire design and development process.

Evaluation of a SG is not always to do with how the game performs in a completed state. It may be prudent to perform an evaluation at any point in the SG development cycle, whether that is to build evidence for a SG concept in a specific domain area or give early feedback and validation on the design of a SG.

A. Poplin evaluates the concept of an urban planning SG via a physical model of what would be a digital game. This proof of concept evaluation allowed Poplin to test the various systems that would be present in the final product at a fraction of the cost and time that would otherwise have been expended for a digital game. [12]

However, a proof of concept evaluation does not have to be a physical game rather than a digital one. Returning to the MainTrain example that was introduced at the start of this chapter, Alderliesten et al., much like Poplin, take the initial concept for the SG's systems, basic design, and gameplay and test that experience with players. This enabled them to tease out some changes and modifications that would strengthen the next iteration of the SG. [19]

S.T. Yong, I. Harrison, and P. Gates approached domain area applicability evaluation for mathematics SGs from two directions. That is they had separate studies for the parents\educators\students at secondary school level and foundation university-level students [102], [119]. These studies did not explicitly include any game developed by the researchers. Instead, it allowed the researchers to gain an understanding of what their target audience thought about SGs. This is akin to market research before the development of a new product.

Finally, it can be difficult to understand the impact SG interventions can have both in terms of long-term effectiveness and isolating the impact of the SG from other sources.

Conducting experiments looking at behaviour change over time can be costly and difficult to manage, and we cannot ensure that the SG alone is the sole contributing factor to the presence, or lack thereof, of any change.

There are also challenges around introducing SGs for education. When considering new pieces of technology in such a vital field, it is crucial to both prove the value to the educational establishment and not disadvantage students. However, this may be overcome with more robust evaluation and design frameworks.

2.5.1 *Data Collection Methods and Frameworks*

While there is a great deal of uniqueness in SGs, as has been evidenced so far, there is a far more limited set of data collection methods, frameworks, and tools that researchers can draw on for evaluation purposes.

2.5.1.1 Evaluation Frameworks

Tsita and Satratzemi discuss a range of frameworks in their 2018 paper *Conceptual Factors for the Design of Serious Games.* This discussion covers many aspects of SG frameworks but is clear in noting that assessment of the learning outcomes, e.g. evaluation, is lacking in 7 of the 8 frameworks presented [115].

A similar lack of *"well defined model[s] or method[s] to conduct evaluation"* [120], is noted by Petri and Gresse von Wangenheim in their exploration of evaluation for computing games. Specifically, that 94 (>81%) of the games included in their study met this criterion.

However, they did identify 3 frameworks that had been used: Model for the Evaluation of Educational Games (MEEGA); EGameFlow; Connolly et al.'s Game Based Learning framework.

MEEGA – This model exists to evaluate educational games. It draws upon a Goal\Question\Metric approach to drive the analysis. That is users are presented with a questionnaire after the game has been played to evaluate their motivation for taking part\learning; their experience during the SG; and what it is they have learned [120].

EGameFlow – This is another evaluation metric administered via a questionnaire after a participant has engaged with a SG. The tool is used to evaluate 8 different factors: immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement [120].

Game Based Learning framework – This framework proposes criteria that should be considered when evaluating learning via games. Specifically how the learner performed, learner/academic motivation, learner/academic perceptions, learner/academic preferences, the game environment itself, and collaboration between players (if applicable). While it gives guidance on these topics, it does not offer any particular data collection instrument [120].

MEEGA and EGame Flow have been used as the basis for at least two published works, therefore having some degree of validation in the literature, [121] (in Portuguese) & [122] respectively.

Other tools like the System Usability Scale, Game Experience Questionnaire and the Mathematics and Technology Acceptance Scale are also employed [120]. These tools give guidance on how to structure questionnaires and assess different components of SGs and attitudes around them.

NASA's Task Load Index (NASA-TLX), could be an interesting addition to the evaluation toolbelt when considering SGs that are more focused on training. The NASA-TLX tool allows users to rate how they perceived their workload across six scales: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration [123]. Therefore, this tool may be useful when considering SGs that have a potential impact on real life, e.g. [89], [107]

Beyond the frameworks and tools already validated in the literature, researchers are starting to develop their own frameworks that include evaluation as either a core focus or a key component. These include works by Heiftje et al. that has been discussed earlier in this Chapter.

2.5.1.2 Data Collection Methods

Table 2 highlights several avenues open to researchers to capture data for analysis. These components can operate independently but can, and often are, used together to create a more complex picture. For example, the usage of pre and post SG quizzes can help track knowledge gained from playing a SG and give a baseline for comparison.

Method	Description	Examples
Pre-SG quiz	A quiz given before the start of a SG	[104], [124]
During SG quiz	A quiz given during the SG	[124], [125]
Post-SG quiz	A quiz given after the completion of the SG	[104], [124], [125]
Questionnaires	Lists of questions that can be asked at any point e.g. during the game.	[94], [102], [120], [124], [126]–[130]
Game data	Data gathered from within the game e.g. moves the player has made	[109], [124], [128], [129], [131]
Interviews	An interview with participant(s)	[97], [119], [132]
Real world data	Data gathered from sensors in the real world e.g. energy usage	[105], [106], [124], [127]
Focus group(s)	Conducted to elicit feedback from a range of participants	[97], [109], [129]
Workshops	Used to reach consensus on a topic, e.g. design decision, or conduct training	[133]
Google Play Store / Apple App Store	Comments and ratings left by users on the Google Play Store/Apple App Store	[134]
Playtest	Having users/game professionals play the game to test gameplay	[97], [125]

Table 2: Evaluation data collection methods

The selection, or combination, of these methods will be guided by the question that is trying to be answered. Similarly, the level of access the researchers have to the game will play a part. For example, Toftedahl et al. engaged with developers that had created a game for commercial use, and as such were limited to using the Google Play Store data for analysis [134].

The researchers can design these data collection methods; additionally, experts can be brought in to assist. With Tan et Al.'s work, experts were involved in the validation of questionnaires for evaluation [25]. Bringing in additional resource to the research team in this way can help build confidence that the data being collected will help answer the questions being asked.

2.5.2 *Successful and Unsuccessful Examples of Evaluation*

When discussing successful and unsuccessful examples of evaluation, we want to make it clear that we are not looking at it through the lens of studies that proved their hypothesis or did not prove their hypothesis. Instead, the position we are taking here is to explore four papers that we feel warrant discussion with regards to how they have approached evaluation as a component of their design and execution.

These are examples that we have found interesting during the literature review that clearly set out their approach to evaluation and the successes and difficulties those approaches threw up.

2.5.2.1 Successful

Development of an HIV Prevention Videogame Intervention: Lessons Learned

This study outlines lessons learned while developing their SG, and as such, there is not an evaluation of the SG in the intended domain space. Instead, it serves as an excellent example of the concept of continual evaluation, that evaluation should not be limited to the gathering and analysing of data in the experiment phase.

Heiftje et al. invested a lot of time and effort early in their SG design to capture the realities of the world their health intervention was being designed for. This meant that focus groups and interviews with end-users were conducted, along with building theoretical framework, logic model, and communication tools to ensure

that both the researchers and the game designers were able to communicate clearly and effectively about their own areas of expertise.

This effort took place over a period of two years and generated several learnings for the authors. To list all of the lessons learned here would only serve to duplicate the paper that Heiftje et al. have written. We will, instead, give an outline of the lessons we have learned from their paper.

Firstly, that continual evaluation is a concept that projects can benefit a lot from. Not waiting until the SG is with end-users to evaluate aspects of the design and data collection, and so on, seems like a simple concept but it is one that has been missing from many papers that we have read. Additionally, deciding on the in-game assessment and data to be collected early in the process allows evaluation to be built around those concepts.

Secondly, work with the SG audience to drive the development and integration of the learning concepts at the appropriate level and tone. Their work continually went back to the audience, getting an understanding not only of their understanding of the topic but what their lives were like –to reflect that within the game accurately. This can help reduce dissonance when playing the game; as the players will see a world that they recognize.

Finally, an acceptance that we researchers are not experts on everything and when to get outside help. The authors created a multi-disciplinary group that covered the behavioural, medical, and SG design knowledge bases required. However, they also recognized that they needed external development capability to build the game and spent a considerable amount of time identifying companies, sending requests for information, and tender documents.

The outcome of this is to realise that the research team is not an expert in all things games, and the game designers are not experts in all things behaviour change – or even the topic that is being designed around. This understanding led to the creation of design documentation, playbooks, that both the research team and the developers could use as a common language to explain and convey important information without it being lost in translation.

Ultimately, the lessons learned in this design experience are a good baseline for continued evaluation during the design and execution of a SG intervention. While this is based on healthcare interventions, we feel it could be extended to any field.

Lessons Learned from Two Usability Studies of Digital Skiing Game with Elderly People in Finland and Japan

This SG is designed to help elderly people remain active via a digital game. The SG has players interact with a virtual skiing environment via motion-sensing technology. However, it is not in the content of the game that excellence in evaluation is seen, but rather the approach to the whole experiment.

In their literature review, the researchers noted there was a gap in evaluation on usability of digital games for elderly people [126] and used this as the basis for their work. Additionally, it was discovered there was very little in the way of cross-country and Western-Eastern comparisons in the literature. In addressing this gap, the researchers set themselves three questions, shown in full below [126]:

1. What are the Finnish and Japanese elderly people'[s] feedback towards the usability of the Skiing game and their user experiences in the gameplay?
2. What are the differences in user experiences between the Finnish and Japanese elderly people?
3. Are digital game-based exercises useful for both the Finnish and Japanese elderly people as an alternative way of exercising?

The study conducted to answer these questions has evaluation at its core. Data is gathered in pre and post gameplay interviews with the participants. Further data is gathered during gameplay from questions asked of the participant and notes taken on their comments. All sessions were video recorded.

The questionnaires used in these interviews have been designed based on the Game Experience Questions, System Usability Scales, and Senior Technology Acceptance and Adoption Model, and inclusion criteria for the elderly participants were advised on by a physiotherapist and clearly set out.

Both the Finnish and Japanese phases of the study were conducted in the native language of the respective countries. The same interview tools were also used in both countries.

This is where we believe we see an excellent example of evaluation preparation. The research questions being asked were defined against the gap in the literature. Using existing, peer-reviewed, frameworks as a basis for creating interview questions to answer the research questions allows the researchers to craft appropriate interview questions.

2.5.2.2 Unsuccessful

Missing: Understanding the Reception of a Serious Game by Analyzing App Store Data

The way Toftedahl et al. selected their game has led to the categorisation of undesirable evaluation. They state that they first saw the game at the Nasscom Game Developers Conference in Hyderabad, India in November 2016, and approached the development team after their presentation to collaborate on evaluating their SG [134]. The game was selected due to the researchers specifically wanting to explore the evaluation of mobile games.

The authors acknowledge "*The quality or success of a serious game can be measured based on how the purpose of the game has been fulfilled* [62]*"*[134]. While the SG selected meets the requirements of the research question, the way in which the game has been developed serves as a hindrance.

Given that the game was already developed by the time the researchers established the project, they were unable to embed any specific evaluation tools into the SG. This limitation was recognized by the researchers *"Due to this, there are limited means of measuring the impact of the game by using traditional evaluation tools"*[134].

As a result, primary evaluation of the SG was reliant on the "*automatic evaluation tools provided in the Google Play Console"* and *"manually analysing the datasets available in the Google Play Console"*. These datasets are gathered by Google as part of their application development ecosystem.

Before discussing what this means for the evaluation itself, there are some worrying implications for this particular approach. Firstly, relying on access to the Google Play Console via the developers is a risky approach. While there is no reason to think that information would be withheld, should the relationship sour for any reason, this could stop the flow of evaluation data.

The authors encountered difficulties with the automated generation of data that the Google Play Console (GPC) provides. Whilst it can give a "*quick overview of trends and general attitudes"* it is also "*problematic for a more thorough analysis of questions related to the app"* [134]. They go on to further describe that the developer has *"little or no control over how the data is processed and presented"* and that it is "*less reliable"* when compared to manual analysis, but also faster.

What do these difficulties mean in practice? An example raised by the researchers is focused on how it approaches design. Specifically, the example cited shows a reviewer has stated that the game had a "*beautiful storyline"*, and the "*graphics were also good*". In this case, both beautiful and graphics were highlighted as triggers used for inclusion in design by the GPC.

Additionally, the authors describe a review that was filtered under engagement. This review is negative, with the reviewer espousing negative views about the SG's focus on women, women in general, and the disturbance of the "*games addicted people*" they identify with. It is the word addiction that the GPC has decided to use for inclusion in the engagement metrics.

Clearly, automated tools do not always understand what a reviewer is trying to say, meaning that – as has been done here – additional work is required by the researchers to understand the data that has been gathered.

Additionally, when relying on user reviews the researchers noticed that a lot of the mid to low ratings were less focused on the themes and messages of the game, and were instead focused on the technical issues users faced.

While there were some previous attempts to analyse data from mobile app stores identified by the authors, they were unable to apply these frameworks to this work as those frameworks had not been made public [134].

To summarise, while the researchers had the best of intentions with regards to answering their research question, they have come up against challenging situations while attempting a novel evaluation method. These challenges stem from a lack of researcher involvement in the design and implementation phase of the SG and how the GPC automatically aggregates and presents data.

Green My Place: Evaluation of a Serious Social Online Game Designed to Promote Energy Efficient Behaviour Change

Green My Place is a SG that was utilized as a part of a larger European Union project on energy-efficient public buildings, SAVE ENERGY [124]. The SG was designed by the researchers to affect behaviour change via teams made from the buildings selected; scoring from energy sensors in those buildings; mini-games; quizzes; and web pages of information. The researchers also hoped to include social elements, e.g. using a social network, as part of the project.

The study comprised of two phases, (1) an open field study over the course of a year (2) a controlled trial of 3 months duration [124]. 5 European cities participated (Helsinki, Leiden, Lisbon, Luelå, Manchester) with government buildings participating in each city (School (2), City Hall, Municipality Office, House of Culture, City Hall, respectively).

While It is important to outline the aims of both phases, we will begin with phase 1 as lessons learned there highlight the requirement for phase 2.

There were 4 objectives for phase 1 [135]:

- Each one-week period, complete one or two learning tasks or mini-games, and maintain energy-saving gains;
- Within the mini-games during the one week period learning objectives should be learned through play;
- With the one month timeframe, the one-week achievements should be built on to grow a community in the pilot buildings
- Over the year the objective was for each pilot location to compete against the others to become the leading case study for energy savings

Several evaluation pitfalls were addressed by the authors. Firstly, due to the SG intervention being part of a larger project, there was no guarantee that participants had not been exposed to other measures and interventions from the project. The research team did not have the resource to build a sufficiently meaningful social network component, which was one of the assessment aims, and this was compounded by restrictions implemented by stakeholders, namely that they deemed it *“inappropriate…to obtain direct measurement of social activity from players…due to concerns about privacy and/or interruption of work.”.*

Additionally, given the nature of the pilot locations, it was noted that those in work are not allowed to play games during work time and that children in school are not able to play games all the time. Finally, another factor outside their control was the differences in the measuring of energy consumption, including the objects being used as part of the test and devices being used to measure consumption.

The authors acknowledge that a solution should have been *"more vigorously sought" to* the lack of a social network but as this came out during the development of the SG the *"resources of the GMP team were over-stretched"*. Additionally, the variations in energy monitoring were to *"facilitate the most efficient technical solution in each location*" [124].

Phase 2 was developed to address the lack of temporal isolation from other interventions within the broader European project, explicitly exploring a *"between-groups comparison of GMP's psychological effects"*[124]. However, even here, there are restrictions and barriers faced by the researchers. Namely, their participants cannot be people who used or worked in the pilot buildings, there was no energy data that could be applied to the control phase, and participants were incentivised to participate in such a way that their motivation for playing is not an applicable evaluation metric [124]. Additionally, all of the recorded improvement was self-reported, e.g. based on questionnaires of activity pre and post-intervention.

We feel it is important to note that the hypothesis the researchers were tackling is well thought out and clear. The tools they used to evaluate – especially in phase 2 – are also based on peer-reviewed work and care has been taken to design them. In this case, it appears that the words of Scotland's national poet, Robert Burns, are appropriate *"The best-laid schemes o' mice an' men, gang aft agley"* [136], or put another way, despite careful planning other influences have caused the disruption.

2.5.3 *Challenges*

Evaluation is a challenging concept for SG research. This subsection shall explore several of those challenges. While the SGs used in experiments in this thesis will be evaluated, there is no focus on providing solutions to the wider evaluation challenges as this goes beyond the scope of this review and thesis.

While SGs can create fantastically realistic and complex worlds for users to engage with and can, as has been discussed, handle evaluation in the form of quizzes and questionnaires with ease, more subjective – or sensitive – forms of evaluation may need to take place outside of the SG itself.

Petit dit Dariel highlights this issue in their 2013 paper, specifically that evaluating the effectiveness of the SG to develop Clinical Reasoning skills will be done outside of the SG as the nuances of assessing that skill are too complicated for an algorithm to handle [37].

This complexity is also explored within Toftedahl et al.'s work on *Missing*. However, in this case, it is the ability of an algorithm to divine meaning from comments left by reviewers. Despite these issues, we believe that this particular space is worth exploring.

Educational evaluation is often in terms of performance against particular skill or knowledge metrics [92]. As we have seen with Heiftje et al.'s work, where a framework for continual evaluation is emerging, there is a gap in evaluating each stage of the development of a SG.

While it is true that a lot of SG research trials the game as a proof of concept, evaluating at this stage and not during the entire process can lead to issues appearing that there is neither time nor resource to rectify. The counterpoint to this argument is that taking that additional time to do the continual evaluation can take more time or expertise than a project has allocated to it.

Sample sizes are another challenging area that SG evaluation must contend with. Many of the papers read use small sample sizes to test their SGs, whether those are drawn from University populations or the target audience.

Depending on the question being asked, small sample sizes can be perfectly fine to answer questions around playtesting or get professional game developers to look at the SG. However, more definitive conclusions on the outcomes of SGs will require more extensive studies, whether that is in terms of time or participants.

Many of these challenges are symptoms of two larger challenges, one of which is ultimately solvable. That is the maturity of the field. While SGs have existed in a

modern sense since the 1960s, it is only in recent years that academic interest has turned to digital SG research.

The second challenge is the diversity of the research space. Given that SGs can be applied to virtually any field, a subsample of which are reflected in this chapter, more bespoke or domain-specific solutions will be required rather than field-specific ones.

2.6 Serious Games in Tree and Plant Health

While no published works could be found in the literature base that explores the use of SGs in a tree and plant health context, SGs have been developed and are in use. Two of these will be explored in this section; Caledon and Fraxinus. Referring to the categories used at the start of this chapter, Caldeon can be considered a mix of Public Engagement and Education game, while Fraxinus falls into the Crowd Sourcing and Human Computation category.

2.6.1 *Caledon*

Caledon is a SG developed under the PROTREE Project [137] with the aim of teaching about: the many threats that our trees face and forests face; the complexity of creating a sustainable forest landscape; the value of genetic diversity [138]. It is also hoped that it will lead to a behaviour change regarding the diversity of our forests and the benefits that brings [138].

The game itself is a turn-based hexagonal tilemap game that presents different natural estates to the user for them to manage. This management takes the form of:

- The types of trees to plant and their usage, e.g. cash crop (1);
- When to cut trees down for sale;
- Healthcare options for the trees (2);
- Wildlife management options (3)

Figure 7: CALEDON Game Opening

In Figure 8: CALEDON Game Opening, we see the hexagonal game world – complete with a range of healthy and unhealthy trees, different types of terrain, and empty tiles for planting. Green trees are deemed healthy, while red ones are unhealthy.

Players can advance the time in the game by pressing the hourglass button, moving the world forward by five years at a time. Players can also develop genetic enhancements and improvements for their forests.

Alongside the main game functions, the game also provides an encyclopaedia that gives background and further material for learning – as shown in Figure 9.

Figure 8: CALEDON Encyclopaedia Screenshot [138]

The game is aimed at teenagers, either to be used on their own or within a classroom setting. During its development, the game was aligned with specific outcomes and experiences as part of the Scottish Curriculum For Excellence [29].

At the time of writing, there have been no published evaluations of the project.

2.6.2 *Fraxinus – Social Media based Game*

Fraxinus emerged from the panic surrounding the introduction of Chalara in 2012. The SG was developed for use "*by non-scientists on Facebook to contribute to genomics studies of the pathogen that causes the disease and the ash trees that are devastated by it"* [139].

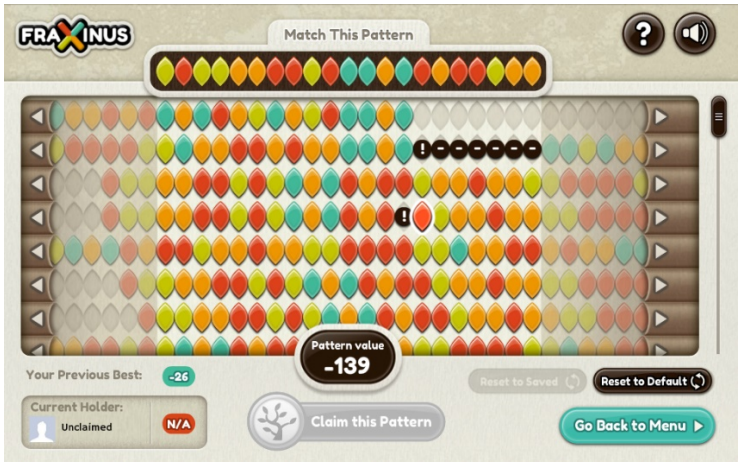


Figure 9: Fraxinus Facebook Game (https://www.facebook.com/fraxinusgame/)

As shown in Figure 10, and as described by Dan McLean in an interview with the Independent [140], the game has an abacus like approach whereby you have to match the lines to the pattern presented. Lines that do not match are rows that have lines of genetic variation in the ash trees. The four coloured lozenges match to the four types of nucleotides that make up DNA.

The game was developed as it has been identified that human players can crunch through this type of genetic data far faster than a computer can [140]. Thus it is an example of the Human Computation style SG we previously discussed.

A 2014 paper by Rallapalli et *al.* concludes that the project has allowed for non-specialists to participate in citizen science and that the majority of the work has been done by a small number of returning players [139]. Having a small number of participants actively contributing, or continuing to contribute over time, is not unique to Fraxinus. Similar results are shown in a 5 year review of EyeWire which aims to map out all neurons in the brain [141].

2.7 Conclusion

This chapter provided the definition that this thesis will use to understand the concept of a serious game and highlighted the differences between serious games and gamification; it then gave a brief overview of different categories of SGs before delving into a more in-depth discussion on SG design and evaluation, before highlighting examples of SGs that exist for tree and plant health use.

It is understood that a SG is any game that is designed and used for a purpose other than entertainment. While elements of gamification may be found inside a SG, leaderboards for example, the clear distinction between the two is that gamification elements in and of themselves do not a complete game make.

While there are many ways that SGs can be categorised, we have identified three in particular that are relevant to the research question being asked. These categories, Crowd Sourcing and Human Computation, Educational, and Public Engagement offer different lenses through which to view potential SGs that can be used for tree and plant health education.

Despite differences existing between the categories, simulation and abstraction from the problem domain, emerged as consistent themes. Simulation enables the

player to be placed in a representation of a real-world situation that may otherwise be too dangers, rare, or expensive to replicate. Players can also be provided with the unique opportunity to replay scenarios that may otherwise have required the use of limited physical equipment. Abstraction allows the SG to focus on what is important, delivering depth where required and glossing over elements that are not.

When considering the design of SGs we established that there are several frameworks already in use, all of which encourage those using them to more deeply consider the people and issue(s) for which they are developing a SG. We also discussed the complexity faced by newcomers to the SG field in selecting a framework that would be suitable for their needs. Finally, we finished with a discussion on instructionist compared to constructionist approach to SG design, concluding that there may be benefits in taking a hybrid approach where possible.

Evaluation is an area of SG research that requires significant work. Evaluation can take many forms and be conducted at any point in the SG process. Examples of different evaluation needs, data collection methods, and frameworks were discussed. Time was also spent working through examples of successful and unsuccessful evaluation.

Successful examples had their research questions predicated against gaps in the literature, and that knew how they intended to conduct their evaluation from the very start. Unsuccessful examples, however, were so due to the difficulty of third party tools, the researchers stepping into an already established project that was not designed with experiment evaluation as a concern, or being restricted by a wider research project that they could not control.

The discussion around evaluation was finished with a review of some challenges that emerged during the review of the literature. One such challenge is that some forms of evaluation cannot take place, yet, within the confines of a SG. This could be due to the complexity of the real-world topic being evaluated, such as Clinical Reasoning, or the interplay between time and intervention, e.g. behaviour change.

Other challenges that emerged were around working with external game developers and ensuring that clear communication was established. Additionally, the recent explosion in interest in an immature field means that work will be

required to explore the nuances in evaluation that a field as wide-ranging as SG requires.

Finally, we showcased two examples of SG that have been developed for use in the tree and plant health world. Caldeon, an educational forest management game, and Fraxinus, a pattern-matching game that helped with the analysis of a pathogen's genome.

This establishes that there are SGs developed, and developed professionally, for the tree and plant health field. While Fraxinus contributed to the literature from a crowdsourced citizen science perspective, it is important to note that neither of these SGs generated published works on tree and plant health education. Thus meaning, to the best of our knowledge, this area remains to be explored from a scientific perspective.

DEFRA, with its Great Britain Plant Health Strategy and the vision for what plant health should look like in 2020 [9], and Fuller et al.[142] & Klapwijk et al.[143] agree that greater inclusion of the general public in tree and plant health protection is an essential step to take if the environment is to be given the greatest possible protection from invasive pests and pathogens.

When considering the first question this thesis is addressing, to what extent is there an appetite for using Serious Games among plant health professionals and the general public, two separate investigations emerge. Firstly, looking at public engagement and training professionals. Secondly, the general public.
Before looking at what the general public would want, we must first understand what is currently done by plant health professionals.

Interviewing the professionals first may reveal other games that are already being used or previous attempts that have been made. Understanding that history could influence the design of the questionnaire that the public will be presented with. The Intervention Mapping framework [111] has influenced this choice as an early critical step in that framework is understanding the community.

When considering the tree and plant health domain and developing SGs for public engagement, working with professionals is essential. These professionals: hold the knowledge that needs to be communicated to the public; have experience in engaging the public; face challenges and barriers that need to be overcome; and have experimented with, and have thoughts on, the use of technology to help them achieve their aims. In order to extract this information, these professionals were interviewed, and their answers analysed.

This Chapter will discuss how our interview participants were selected, their backgrounds and organisations, before going on to analyse the results of transcribed interviews, finishing with a discussion on what we have learned from the participants.

3.1 Methods

This section will discuss the recruitment of our participants and describe the participants who accepted the invitation to join the study and the study itself.

3.1.1 *Participant Recruitment*

In order to understand what is currently done in public outreach and engagement, and to understand the wider tree and plant health field, we first identified three categories of organisation that we would like to interview.

- *Public Facing Body (PFB) – An organisation that works with the outside world.*
- *Volunteering Organisation (VO) – An organisation that works with volunteers, e.g. citizen scientists*
- *Higher Education Institution (HEI)*

These different organisations each bring a piece of the complete picture of outreach and engagement. The *PFB*s work with the outside world, engaging everyone from schoolkids to visitors to botanic gardens and gardening shows. *VO*s deal with members of the public that give their time to engage with citizen science initiatives. Both *PFB*s and *VO*s can also give training to those they work with whether that is in the form of training for professional activities or skills and techniques required to complete the citizen science activities. Universities are responsible for delivering education to the next generation of tree and plant health professionals. It is also possible that some *PFB*s may provide training to *VO*s. Although professional training can be provided by organisations, some *HEIs* may provide specific training related to fields such as Forest Management.

After identifying the different categories of organisation, we then identified organisations operating within those groups. This was done through a combination of google searches, e.g. HEIs that had forestry degrees, personal contacts, organisations and groups seen at tree and plant health conferences. We approached a total of twelve organisations and groups for inclusion in this study. Table 3 details these twelve and indicates the seven that agreed to participate.

Organisation	Classification	Accepted Invite
The Yorkshire Arboretum	*PFB*	Yes – Could not arrange interview
Fera Science Ltd.	*PFB*	Yes
Forestry Commission Scotland (FCS)	*PFB*	Yes – Could not arrange interview
Royal Botanic Gardens Edinburgh (RBGE)	*PFB*	Yes
Royal Horticultural Society (RHS)	*PFB*	Yes
Observatree	*VO*	Yes
Open Air Laboratory (OPAL)	*VO*	No
Treezilla (Open University)	*VO*	No
University of Aberdeen	*HEI*	No
Bangor University	*HEI*	No
University of Stirling	*HEI*	Yes

Table 3: Chapter 3 - Organisations approached for inclusion in the study.

3.1.1.1 Reasons for Inclusion

3.1.1.1.1 Public Facing Bodies

The Yorkshire Arboretum (originally the Castle Howard Arboretum) is a young arboretum founded in 1959. The Castle Howard Arboretum Trust currently running the arboretum was founded in 1994 and opened the arboretum to the public in 1999 [144]. The Arboretum has a focus on biodiversity alongside pests and pathogens – being involved with a simulated outbreak of Asian Longhorn Beetle in 2016 to train plant health inspectors and other citizen science groups [145]. Looking to the future, the Arboretum has secured funding for a Tree Health Centre that is expected to be completed and open to the public in 2020. This centre has

the remit of offering training courses delivered by specialists that will cater to all levels of expertise.

Fera Science Ltd. (formerly the Food and Environment Research Agency within DEFRA), provides a range of analytical, research, and scientific services to the agri-food sector [146]. They also offer training and outreach and engagement services to professionals and schools/colleges.

The Forestry Commission Scotland (FCS) was a body that ceased to exist in April 2019 [147], with the functions it used to have split between Scottish Forestry[148] and Scottish Forestry and Land [149]. When we approached them for participation in the study, they were responsible for all forestry functions across Scotland.

The Royal Botanic Gardens Scotland are a collection of four separate gardens: Edinburgh; Benmore; Dawyck; Logan. These gardens are living collections that serve a dual purpose of educating visitors on tree and plant health issues [150]. In the financial year ending March 31st 2017 it was revealed that the gardens had a combined total number of visitors of 962,473 [151].

The Royal Horticultural Society (RHS), founded 1804, is one of the oldest horticultural societies in the world. They have a series of gardens across the United Kingdom, and run events both in those gardens and in local communities e.g. Britain in Bloom. The RHS have also recently passed the half a million member mark, making them the largest horticultural society in the United Kingdom [152]. The RHS were approached for inclusion in the study as they work with a wide range of the public, fielding questions from their members and the general public, as well as working with schools.

All of the *PFB*s approached agreed in principle to participate in the study. However, due to scheduling issues it was not possible for the Yorkshire Arboretum and the then Forestry Commission Scotland to actually participate.

3.1.1.1.2 Volunteering Organisations

Observatree works with volunteers that complete pest surveys across the United Kingdom, with specialised training being given on a yearly basis to help them complete the surveys [153]. Observatree have a list of 22 pests and pathogens that they are interested in looking for – these threats may not be present in the

United Kingdom but are surveyed for to ensure they have not entered the country. They also provide identification guides and reporting abilities for members of the public that are concerned they have found one the target threats.

The Open Air Laboratory (OPAL) [154] is a survey based citizen science initiative that covers everything from air quality to the presence of tree and plant pests and pathogens. They want to make more than a million people aware of the world around them, showing them how they can contribute to the protection of the natural environment. Alongside this, they aim to make people more confident in debating environmental issues, create a new generation of environmentalists, deliver a greater understanding of the state of the natural environment, and build stronger partnerships between the community, voluntary and statutory sectors. The project has had more than 1 million participants across the UK, received over 72,000 surveys, and generated over 20 scientific publications [154].

Treezilla is part of Forest Research, that is – in their own words – "…a free, online multi-purpose platform designed to support tree-related science projects as part of the Open Science Laboratory in the Science Faculty of the Open University. The objective is to create an online map of all the trees in the UK that can be used for 5 types of activity: Education, Outreach, Research, Inventory and Biological Surveillance."[155].

Unfortunately, both OPAL and Treezilla were unable to contribute to the study; however Observatree was able to commit to participating.

3.1.1.1.3 Higher Education Institutions

Aberdeen and Bangor both deliver courses related to forest management, Environmental and Forest Management MSc [156] and a Forestry BSc [157] respectively, and were approached for the study for those reasons. Unfortunately, it was not possible for academics at those institutions to participate.

The University of Stirling was not initially included – but as the other universities were unable to participate, a colleague with related research and teaching interests in the department of Biological and Environmental Sciences agreed to take part.

3.1.2 *Participants*

Participants held a range of roles from Entomologist to Plant Health Consultant. These roles were assigned to one of three categories:

- *Public Engagement – Roles that primarily focused on engaging the public*
- *Recruitment of Citizen Scientists – Roles that focused on recruiting, and managing, members of the public for citizen science efforts*
- *Education – Roles that focused on education.*

The participants, their roles, and organisations are outlined in Table 4.

Participant Number	Role Classification	Organisation	Organisation Classification
1	Public Engagement	Fera Science Ltd	Public Facing Body
2	Recruitment of Citizen Scientists	Observatree	Volunteering Organisation
3	Public Engagement	RHS	Public Facing Body
4	Public Engagement	RBGE	Public Facing Body
5	Public Engagement	RBGE	Public Facing Body
6	Public Engagement	RBGE	Public Facing Body
7	Public Engagement	Animal and Plant Health Agency	Public Facing Body
8	Education	University of Stirling	University

Table 4: Participant Information

3.1.3 *Study*

Participants were interviewed either at their workplace or by telephone. Interviews lasted between thirty to sixty minutes. The interviews were conducted from the 17th March 2017 to the 31st July 2017 with each interview being recorded and later transcribed.

Questions for participants were selected to develop knowledge of practitioners' current activities, their plans for future activities and engagement priorities, and gauge interest for participants to use Serious Games or Gamification in their future work. We include Gamification here as it was initially considered as part of the thesis; this was subsequently revised.

Full descriptions of the questions and definitions used during the interviews can be found in Appendix A.

These pre-defined questions structured the analysis that was conducted using NVIVO, a qualitative data analysis and organisation tool [158]**.** Three main themes were identified, with information grouped into several sub-themes within each main theme. The themes and sub-themes are identified below.

Theme	Sub-Themes
The Participants	- Motivation for Public Engagement - Participant's Background - Participant's Role in Organisation
Current and Future Work	- Evaluating Success - Messages for the Audience - Methods and Activities - Problems and Barriers - Target Audience
Games	- Attitudes - Current Uses - Future Possibilities

Table 5: Practitioner Interview Themes and Sub-Themes

3.2 Analysis & Results

Each transcript was individually transcribed before qualitative analysis of the interview transcripts was conducted, using NVIVO. NVIVO is a popular Computer Assisted Qualitative Data Analysis Software (CAQDAS) package that is used to analyse non-numerical, unstructured files, e.g. text, audio, video [159].

NVIVO is used across different industries, from academia, e.g. [49], to non-profit organisations [159], and offers great flexibility through not forcing the user to conform to a pre-determined methodology [160].

NVIVO facilitated the textual analysis required with the ability to place segments of the texts into *codes*. These *codes* are analogous to themes and sub-themes, with the same pieces of text being able to be placed into different codes. These codes can be used across multiple documents within the same NVIVO project.

NVIVO allows users to export the codes for further use, e.g. in developing the results within this section. The software can also offer other advanced functionality for textual analysis, such as creating word clouds for the selected text.

3.2.1 *The Participants*

The participants offered information on their roles within their organisations and their (or their organisation's) motivation for the engagement work that they do.

Role in the Organisation

The participants cover a range of positions in the organisations represented, coming at the issue of tree and plant health engagement, education, and outreach with different agendas. The participants have research, education, managerial, and communication responsibilities across their organisations – with several participants combining several of those responsibilities.

The participants also have different requirements when it comes to engagement and the potential application of SGs to their work. For example, Participant 2 manages a group of volunteers that collect citizen science data. This is contrasted by, for example, Participant 7 who has a broad-ranging remit of the general public, charities, private companies, and government departments.

Several of the participants discussed the different engagement work that they carry out with professional bodies, through paid training and events, contrasted with the events and projects used to engage members of the public. This distinction is mirrored in the analysis with separate analyses of professional and public engagement groups.

Motivation for Engagement

Five participants discussed the motivations of their organisations for carrying out the public engagement work that they do; these can be summarised in three categories: *Helping to build a citizen science network, Inspiring the next generation of plant health professionals, Making the best use of resources and engagement opportunities.* Engagement for professionals comprises training, promoting good biosecurity practices, and raising awareness – this is carried out either through paid sessions or in professional environments like conferences or workshops.

3.2.1.1 Helping to build a citizen science network

Creating a network of citizen science volunteers to act as an early warning network, aiding government bodies such as DEFRA, has been identified as a key motivation by Participant 2. The scale of the problem facing the United Kingdom, and the complexity of the many pathways and points of potential incursion, means that government acting alone will not be sufficient to protect the country [9].

3.2.1.2 Inspiring the next generation of plant health professionals

DEFRA have identified a need to encourage a new generation of plant health professionals, drawing not only from the traditional biological backgrounds but taking a holistic approach to capture as many disciplines as possible to enhance capabilities in areas from detection and diagnosis to the development of new tools and training [9]. This ongoing need forms the basis for the work that Participant 1 undertakes, wherein they developed the concept of *inspiring the next generation of plant health scientists* and the inclusion of plant diseases in the GCSE Biology specification.

The other side of inspiration comes from inspiring the public to play their part in protecting the biosecurity of the country. Work in this manner, highlighted by

Participant 7, is not as much about building capacity or bringing scientists into the industry (although this may be a potential side effect). Instead, the motivation of the work is to convey messages related to biosecurity at garden/agriculture shows, creating show gardens, through innovative exhibits and events, highlighting the simple and achievable ways that attendees can help.

3.2.1.3 Making the best use of resources and engagement opportunities

Some organisations, like botanic gardens, are naturally well placed either through their facilities or the nature of the work they carry out to engage the public. This may take the form of communicating the science work they carry out, explaining biosecurity issues and simple steps that can be taken to protect the country, or they may host education programmes on a range of topics. Participants 5 & 6 identified this motivation as central to the outreach and engagement work that their organisation carries out, describing their facility as having an “incredible” opportunity to engage with hundreds of thousands of members of the public over a year.

3.2.2 *Current and Future Work*

The work the participants carry out, the messages they communicate, their audience, how success is evaluated and measured (along with any barriers or problems with any of these) were spoken about at length, both in terms of current work and what is hoped for in the future. Where appropriate, participants’ thoughts on work they would want to carry out in the future are presented alongside current work.

3.2.2.1 Messages delivered by participants

The messages that the participants currently promote and engage with can be linked to two distinct forms of raising awareness. In the first instance, participants focus on raising awareness of current and potential threats, good commercial biosecurity practices, and ways in which members of the public can help maintain the biosecurity of the UK. The second strand of awareness raising concerns itself with inspiring the next generation of plant health scientists and professionals. This takes the form of showing the different careers possible and what could be expected of such a career.

Looking towards the future, participants continued discussing raising awareness in much the same terms as had been explored within their current work. This is a

function of the themes being explored and the long term nature of their implementation.

However, a new theme was suggested by the Participants. Specifically, that wider public understanding and pressure on the issue of plant provenance could lead to government departments and private companies taking a similar interest. This is important as plants imported into the United Kingdom carry the risk of bringing an invasive pest or pathogen with them.

3.2.2.2 Breakdown of Target Audiences

The audiences targeted by the participants can be, as discussed earlier, broken down into two distinct categories – professionals and the public. This is a categorisation that we have made to simplify the disparate groups introduced by the Participants.

Professionals are those that are either paid for their work or have some statutory responsibilities for tree and plant health, whereas the public group comprises anyone else. There is no change between current and future target audience composition save some refocusing on students in the People category.

Professionals

The professionals identified in this study are a diverse group. The Participants (e.g. 1 & 7) either work directly with organisations (or representatives of) such as the Department for Environment, Food, and Rural Affairs, Supermarkets, or contractors for government services, or they will try to engage professional industries and organisations, e.g. the Arboricultural Association.

Participants expressed mixed views on using games with this group. Participant 1 discussed the paid training that they provide to professionals, touching on their desire to make the training more fun and engaging - which they believe games may help with – but that the expectation of the trainees for a serious experience has dissuaded them from using games in that setting. Conversely, Participants 1 & 2 discussed the success they had using a serious tabletop roleplaying game with members of this group – although this was in a workshop and conference setting.

Participants report that they are cautious when engaging with the professional group. Where money is involved, e.g. paid training, a more cautious approach is taken, however, if it is done within a larger event, e.g. conference or as a workshop, participants seem more open to using games.

Public

The public, as identified in this section of the study, comprise any person that the practitioners would engage with that are not paid for their work or are acting in a capacity where they have a statutory responsibility to the environment, e.g. a DEFEA inspector may visit a botanic garden off duty and would be categorised under the public rather than professional category.

When engaging with this audience, participants want to deliver a pleasant experience, whether that is a family visit to a garden or a school visit to a facility. From their own experience, Participant 4 reflected on how making events, facilities, and messages open to the broadest possible range of visitors underscores how the general public is considered when planning engagement pieces.

Participants are aware of the range of backgrounds their audience will present with. Participant 7 discusses this through the lens of people not having confident science backgrounds and modifying their message to assuage the members of the public. Participant 7 also uses more alternate methods to communicate with this group, e.g. flashing lights to show the spread of disease or a fairytale-style book to show different pests and pathogens in Wales.

Practitioners are clear that they understand the range of approaches required when dealing with the public and carefully design their experiences to cater to the widest possible audience.

3.2.2.3 Methods and Activities used in Engagement

Participants 1, 3, & 4 try to make use of their organisations' facilities where possible, hosting tours of laboratories, using elements of botanic gardens to show

pest and pathogen spread or show edible plants, or putting on seasonal events with hands on activities for the whole family

One participant from a *Public Facing Body* explained that when going to external events, for example, Chelsea Flower Show or similar gardening events, stalls – or in some cases show gardens – are used to engage the public. These stalls can contain everything from leaflets/pop-up posters to models of pests like the Asian Longhorn Beetle. The show gardens usually contain a specific message, e.g. the spread of pests and pathogens across borders, with staff members on hand to talk through the garden and its exhibits.

Wider public engagement can take the form of writing articles for newspapers and organisations, or by visiting arboricultural associations to give talks and presentations on biosecurity issues. Participants also reach out to schools to engage with pupils directly. Examples of this are via a competition run by the Royal Horticultural Society for schools to create a raised garden bed around a particular theme, e.g. Rocket Science/Space. Another example is schools being recruited to participate in experiments; a specific example described was an experiment testing different defences against gastropods, SlugIt.

The final type of activity is training. Participants work with volunteers, members of government and professionals to deliver training on everything from data collection methods through to the necessity of plant passports when businesses import products.

3.2.2.4 Evaluating Success

Evaluating success is a challenge in some form for most non-university participants, with Participants 2 & 3 being the exception to this rule due to the nature of their organisations. Observatree has reporting obligations to EU funders and the RHS is an active science organisation. As a result, evaluation is built into everything for the former and where science is conducted with the public (e.g. SlugIt) the same applies to the latter. However, with Participant 3's organisation, there are elements that are not science-focused that are more difficult to evaluate and can only be done so by, for example, the number of visits to a webpage.

For the remainder of the participants, rigorous evaluation is an issue. In some cases, this is a product of the area of engagement, experience has taught

Participant 7 that the public is unwilling to answer many questions or hand over personal details at stalls during garden shows. Participant 1 also reflects on how difficult it is to evaluate the effectiveness of behaviour change both in students and the wider public. When creating and using interventions in education, where there may be a 10-year gap between the material being presented in a class to the student entering the workforce, it is difficult to know how much impact a specific intervention has had.

Time emerged as a factor that hampers evaluation. It was stated that there is no time to carry out a rigorous evaluation by Participant 4, instead they have to rely on headcounts for visitors, and reflecting on conversations with guests throughout the event. Finally, Participant 4 highlighted the lack of skills to do proper evaluation – when discussing their Caledon game they stated there were around 1000 unique views/downloads across the website & app store. However, they were unsure if this number over 6 months was a sign of success.

Looking to the future, the difficulty of long-term behaviour change was a continuing theme raised by participants, whether that is directly influencing behaviour or moving people into plant health careers. Several ideas were, however, floated for success that projects could be evaluated against. Participants 1 and 5 discussed changes in behaviour; the public having a keen interest in where their plants come from, similar to the current interest in where food comes from, for the former – and, for the latter, government bodies, when considering tenders for landscaping and public works, not just going for the lowest possible cost but valuing the biosecurity implications of the bid.

3.2.2.5 Problems and Barriers in Engagement

The problems and barriers that the participants face when engaging with the public can be divided into the following categories:

- Lack of Resources
- Uses of Technology
- Messaging & Activity
- Audience Engagement Issues
- Lack of Skills

Lack of Resources

Resources cover a range of items from funding to signage to the physical locations of gardens and staffing. Funding is always an ongoing barrier to success – the nature of organisational, or governmental funding, means that projects may not survive beyond the initial funding phase or that funding may not become available for future developments, e.g. the Caledon project discussed by Participant 4.

Participants 2 & 3 discussed physical locations, such as botanic gardens or the arboretum in Yorkshire, which are – by their very nature – beneficial only to those in the immediate area. This raises issues when, for example, the Arboretum developed a training facility for Asian Longhorn Beetle infestations. This is something Participant 2 would find very useful for training their volunteers; however, it would be challenging to get all of their volunteers to that one location.

Similarly, it was pointed out that RHS gardens do try and engage the local community, but with no gardens located outside of England engagement with the rest of the UK can suffer. Although it should be noted that efforts are made through various teams to try and engage schools from across the country in experiments that the RHS run.

Signage is another issue that was raised, specifically the lack of expanded signage or the age of it. Participant 5, however, did acknowledge that this particular barrier is something that they are working on – with the main issue being how best to expand or replace the signage rather than lacking willingness to do so.

An additional barrier with resource was identified by Participant 6 in that at present, to their understanding, the most effective pathway to target to reduce the likelihood of incursion into the UK is not known. The Participant went on to explain that as the most effective pathway is not yet known, they are unsure where best to target resource to stop the incursion of pests and pathogens into the United Kingdom. This contrasts with comments from other Participants, who paint a picture of a lack of resource in general, not that they are unsure of where to target any resource that is made available.

A lack of staffing is another issue. Participant 1 pointed out that their tabletop game requires a facilitator so that additional staffing requirement limits the number

of times, and where, it can be played. Similarly, Participant 1 noted that their facility is exceptionally specialised and they can only host so many visits from interested colleges and schools in any given year. Additionally, they mostly rely on those groups reaching out to Participant 1's organisation to arrange those visits.

Participant 2 told a positive story of their volunteer network expanding in the next few years, which would increase the number of citizen scientists out looking for threats to the country, yet that very expansion then means that their normal face-to-face training methods would become very difficult to run. So even where there is a positive story to tell, there is always that pressing need to have the resource to support it.

Uses of Technology in Engagement

Technology can be anything from the use of tablets and interactive screens, to any form of exhibit that has moving/mechanical parts.

In some cases, using tablets or interactive screens can limit the number of people engaging with an exhibit at once, which is something Participant 4 noted at a science fair they had an exhibition at. The technology identified by Participant 3 was described as being 10 years old and out of date. Therefore, another barrier with technology is keeping it relevant and updated.

Understanding how technology will be perceived and used by the intended audience (and practitioners) is another barrier that is hard to get past. For example, it could be – as discussed by Participant 2 regarding Tree Alert[161] – that introducing a tool as an app will encourage people to help, but the nature of the reports that come in are of low quality. Although Participant 2 did go on to say that redeveloping the tool as a web-based product has helped solve that issue.

From a practitioner perspective as well, it is important to know how the technology will work and what compromises might need to be made to bring a product to the public. Participant 4 spoke about the conversations the team designing the content for Caledon had and how it was difficult to decide what to include in the game, how to communicate that to the developers, and what would make a good experience for the player.

Messaging & Activity

There were clear concerns raised by participants around the nature of messages and messaging with regards to biosecurity threats and information to the public. It was felt by Participants 6 and 7 that too much information is being put to the public too quickly. With Participant 2, feeling that the information was not being honestly reported in terms of risk and timescale by the media. Participant 7 felt that this could cause recipients of that information to switch off and disregard warnings which could have negative consequences for biosecurity in the future.

There can sometimes be tension between messages that the practitioners would like to focus on but are unable to due to their organisations, for example Participant 7 described the need of focusing on government messages compared to the work they would like to do.

Ensuring activities and messages are tailored correctly for the audience is a potential barrier that was identified by Participants 4 and 7. Participant 4 found that focusing on mainly presentation based activities did not serve to work as well as short presentations and mixed activity events. However, designing the activities and messages primarily for an audience of children was found to work best by allowing participants of all ages to take part.

Participant 2 highlighted that when volunteers engage with citizen science projects, they are usually on the frontline of data collection, providing the information that helps inform policy and paints a picture of, in this case, pest and pathogen presence in the UK. However, it is hard for volunteers to see – at times – how the hours of painstaking data collection they carry out feeds into the larger picture. Having messaging that enables these volunteers to understand the impact they are making, that highlights how the data they are collecting is being analysed and used in decision-making processes, was a key barrier identified by Participant 2. Overcoming this barrier can provide additional benefit to the volunteers that give up a significant amount of time to contribute to the biosecurity of the country.

Audience Engagement Issues

People are at the heart of what the Participants do; however, the participants identified issues around the expectations, age ranges, and attitudes people that make achieving their aims challenging.

Participants engage with people at all stages of life, from young children through to elderly members of society. Catering for that age range, whether that is via the staff that might be giving presentations or signage and exhibits can be challenging (Participant 4). On the one hand, the message has to be simple enough to get through but needs to contain enough substance to be interesting. Participant 4 has suggested that in their experience designing experiences for children tends to provide an interesting experience for everyone. However, Participant 5 counters that suggesting when viewing that engagement through a technology lens - teenagers, in their opinion, will have higher expectations of technology than younger children might.

In the same way, the people that carry out public engagement need to be equally able to deal with a wide range of ages (Participant 4). Therefore, the potential barrier is two-way, comprising the audience and the staff.

Attitudes are a significant barrier to success in engagement. Participant 7 discussed an event where they were engaging people in London – this audience was comprised of general working professionals – where the prevailing attitudes to trees was they were a nuisance that created a mess in the garden and had to be kept due to protection orders.

Interestingly, attitudes in the tree and plant health world also cause issues. Participant 5 discussed an infestation of a new type of scale discovered in London and was not, as they understood it, eradicated due to the scale being thought unable to establish itself in the UK – which it then did.

Some issues with attitudes are more easily overcome. Participant 7 discussed the negative experiences that people have had in the past with science and as a result, feel uncomfortable when approached in that capacity about tree and plant health issues. This is something they take into account when designing their engagement experiences.

Longer-term expectation and attitude issues have been raised by Participant 1 who feels that using games in paid training would be a risky proposition due to the investment of time and money people make for these events combined with a lack of understanding of how games would be perceived by the audience.

Participants 1 & 8 also discussed potential future problems and barriers with regards to people. Participant 1 highlighted the potential impact of Brexit and how that could make it difficult to adjust people's attitudes for purchasing plants through to how the supply chain would be impacted. This was specifically viewed through the lens of cost and availability – if cheaper foreign products become available post-Brexit then it would be difficult to explain to people that have a smaller budget for garden improvement why they should spend more on British products. Similarly, moving forward, there is tension to manage between what companies want to do to maximise profit and economic viability contrasted with what government needs done to maintain a biosecure country.

Participant 8 spoke about designing, for example, a skill tree based around a university course that would link modules studied to career options. The engagement issue here would be ensuring it was designed in such a way that people aren't bored or demoralised with it - making sure that their expectations are met, whilst fostering a positive attitude about the process.

Lack of Skills

Our participants in this survey are tree and plant health specialists, as outlined in their backgrounds. However, beyond the lack of evaluation skills – in some cases, as discussed in the Evaluating Success section – there is a clear lack of technical skills to design, develop, and implement technology (Participant 7). Participants want to use technology moving forward, but a key worry in this regard is cost. Participant 7 highlighted this as a key consideration for any projects carried out in this field, whilst Participant 4 spoke about how lucky they were to have had their game – Caledon – developed at a reasonable price. Although they did go on to say that the lack of future funding, and skills, meant that no further development would be possible unless funding was obtained.

3.2.3 *Games*

Attitudes to the use of Games

Participants are broadly supportive of the use of games both for current work and future projects. Value is seen in the ability to engage wide audience, deliver information in a more enjoyable manner, and provide activities that can engage the whole family. Participants highlighted children as a great audience to use

games with, with all but tabletop scenario exploration games designed for participation by (or exclusively for) children.

However, there were some reservations expressed. Participants raised concerns regarding graphical quality and expectations of players, and about using games in particular settings. For the former, some participants were concerned that teenagers would expect a particular level of quality from any game and games that don't meet those expectations would not be as appealing or effective. In terms of the latter, when conducting training with fee paying individuals, there was a feeling that using games may be poorly received – so the practitioner would likely not use games in that setting.

Current uses of Games

Participants highlighted some current uses of games in their work ranging from digital to physical. The digital game, Caledon, was built to teach forestry management techniques. It can be used as a standalone experience, using the inbuilt encyclopaedia to learn the concepts, or could be used in a classroom setting as part of a lesson.

There are more physical games and game experiences used by Participants 1, 2, & 7 in their work. These range from tabletop exercises that allow players to assume different roles and play out a scenario, e.g. an infestation of Citrus Longhorn Beetle in the UK through to object hunts and top-trump style card games. Quizzes have also been used by Participant 1 in training events to ease attendees into the event and to establish a knowledge baseline to help the facilitator lead the session.

Future Possibilities

Participants suggested multiple games for future projects, with these games are all being digital in nature. Games suggested include an augmented reality pest hut for use in botanic gardens or parks for training or awareness-raising, multiplayer games to teach students population growth rates, choose-your-own-adventure training games, and digital versions of existing tabletop games.

3.3 Discussion

The current state of tree and plant health engagement is one of diverse audiences, varied engagement techniques, and motivations. Participants, except for Participant 8 due to their University focus, are passionate about their engagement work and don't view it as merely a part of their daily job.

Participants are focused on raising awareness as a core part of their engagement process both presently and for the future. They are interested in ensuring that professionals are kept up to date with current best practices and threat information, whilst also showing the public how small actions on their part can contribute to the wider bio-security picture, surveying the presence of threats, and showing pathways to, and the nature of, careers in tree and plant health.

However, there are concerns that there is either too narrow a focus on the most dangerous pests and pathogens without sufficiently exploring less well known threats or the potential evolutions of existing ones. Marzano et al, in their analysis of stakeholder awareness and knowledge of invasive pests and pathogens, found that there is a worrying lack of specific threat knowledge from the study participants despite there being generally good awareness of threats [162].

Conversely, constantly introducing new pests and pathogens, can also dilute the public's interest and potentially remove focus on important existing threats. There is the risk of desensitizing people to the dangers and risks associated with the introduction of pests and pathogens if this "constant conveyor belt" of new information isn't introduced in a way that is innovative, realistic with regards to how long the pest might take to cause damage and the scale of said damage.

This feeling, expressed by participants, is supported by Fuller et al. in their 2016 study of a representative sample of the general public of the United Kingdom. Despite ash dieback being widely reported in the media in 2012, 69.9% of respondents had either never heard of or had heard of but had no knowledge of the threat in 2014 [142].

Whilst games are not currently widely used by participants – there are exceptions in the form of physical games and quizzes – there is an appetite for introducing them into future work. However, participants do not have the skills to build the games that they would like to have, combined with a lack of guaranteed funding

for future development of games (or even having external companies build games in the first place) leads to a barrier in achieving the goals the participants have.

Participants have expressed concerns about using games as the main component of paid professional training sessions, yet are more open to using them for general public engagement. These reservations come the participants not knowing how those attending paid training sessions would respond to games being used rather than the usefulness of games themselves. This suggests that the way forward with research in this area is to focus on public engagement.

Evaluation of projects is currently an area of difficulty for our participants, although there is some success and an easier time with projects that have evaluation built into them from the start as a reporting metric or require that evaluation as a necessary component. It should be noted, however, that the participants that are struggling with evaluation do want to evaluate their work and they are keen to see that they are engaging the public with the most effective methods and activities.

From these interviews and the subsequent analysis several things have become clear. Firstly, that there is a greater appetite for using SGs in the public engagement work practitioners are involved in compared to paid engagements in a professional setting.

Secondly, having an understanding of the audience and their needs is a key part of the engagement strategies used by the Participants. Emulating this understanding will be required in any experience that is designed for public engagement.

Finally, the openness around engaging with members of the public and the suggestions of SGs for that audience, make the public group the clear choice to focus on in this thesis.

4 Game Players Requirements Gathering

In Chapter 3, we looked at the backgrounds, work, and needs of practitioners of public engagement in tree and plant health. We discovered that practitioners are interested in using SGs to assist their public engagement strategies. The people engaged with by the practitioners were broken into two groups, the general public and professionals. We needed to narrow this to one group; otherwise, the scope would be too broad.

During the interviews practitioners that engaged with professionals consistently expressed hesitation and reservation in using SGs with that audience. Professionals engaged by those participants would be done so via paid training courses. Within this setting, the participants felt that introducing games would be seen unfavourably by the participants. Although, this is an assumption on their part rather than a quantifiable fact.

Conversely, the interview participants were much more open and enthusiastic about using SGs with the general public. The general feeling that this group would be more open to engaging positively with games was a factor taken in consideration with the hesitation expressed around professional groups when deciding on which group should be selected.

Other limiting factors were the bounds of expertise and resource available during this doctoral project. With regards to experience, the lack of public engagement and tree and plant health knowledge held by the author would mean that the inputs from external partners would be essential. Therefore, working with the group they felt most comfortable with exposing to SGs was a sensible decision.

Time limits were also an issue. Sites like botanic gardens receive visitors all year round, and there is an established schedule of gardening shows. Both of these locations are popular with the general public. These factors lead to one clear benefit compared to professional training, which is organised on an ad-hoc basis.

Taking the preference of the practitioners with the limitations of experience and resource led to the general public being selected for future studies in this body of work.

Beyond helping define the group that would be included in experiments, the practitioners also provided helpful insights into the games and approaches that they already use in their work. Additionally, they gave first-hand experience of what we could expect when engaging with the general public in tree and plant health settings, e.g. botanic gardens and gardening shows.

However, these practitioners only form half of the knowledge that is required to create and conduct informed experiments in this novel field. We must also take the expectations and experiences of the general public must into consideration if we are to design an experience they will find attractive.

Therefore, the aim of Chapter 4 is to begin to understand the experiences and expectations of the general public when it comes to SGs that have been used for public engagement. The study is also designed to gather information on the gaming habits of respondents, and their visitation habits of public spaces (botanic gardens/museums) and specialist events (garden and agricultural shows). This information will inform the design of any subsequent SGs and the location(s) that they may be deployed in.

As discussed in Chapter 1, the underlying framework that guides both Chapter 3 and 4 is the requirements gathering phase of the software engineering process. This process allows us to understand more about the needs of the client. In this case, it will allow us to learn more about the needs and experiences of the practitioners and the general public. Engaging in this process, and learning about these needs, should help avoid SGs that are not suitable, e.g. being too complicated for the audience\experiment location.

There is a particular risk of this happening when creating public engagement games because computer programmers are often enthusiastic gamers who are used to playing relatively sophisticated games. This can cause them to overestimate the level of complexity and length of gameplay that would be acceptable to a more casual player while underappreciating the importance of clear communication of the scientific content.

In the case of this thesis, the information gained through this Chapter will help temper our own gaming experiences and expectations, and those of future developers in a similar situation.

It may be that potential users have had experiences in the past that may attract them to a particular installation or could equally repel them. Pyae et al. in their 2017 exercise SG paper touched on this theme when discussing reactions expressed by elderly participants playing their game. Specifically, that "*negative feedback from the game can discourage them*" [126]*,* and *"negative reactions in the game can lessen their level of confidence to continue playing"* [126]**.** Conversely, the participants also expressed interest in the real world activity-based setting of the game, with some going on to say that there were other activities they would try if presented the same way [126]**.**

As we will go on to discuss in Section 4.2, some participants in our study explain that having the games devolve into shooting games or being too childish can turn them off, while some participants feel that the use of games and technology can bring the material and subject area to life in a way that printed media cannot.

Having an insight into these experiences and expectations will help in designing appropriate projects that stand a better chance of effectively communicating the content of the game to its players. As discussed during the literature review, engagement with users during the design phase is a pathway to designing a SG that better meets the expectations and needs of the target audience e.g. Hieftje et al.[97].

In Chapter 2, we established that there appears to be a lack of published papers exploring the role of serious games for tree and plant health public engagement. This study looks to begin addressing that apparent gap by starting to understand the experiences and expectations of potential users of games for public engagement. The end result of which will be experiments using tree and plant health based SGs.

4.1 Methodology

4.1.1 *Study and Aims*

As stated in the introduction to this chapter, the aim of the work is to begin understanding what potential users of games in a public engagement and education setting want from those games, or even if games are something they would like.

The study was conducted via an online survey that was distributed via several channels. The survey tool and participant recruitment, along with the conceptual framework, will be discussed in greater detail later in this Chapter.

We were interested in answering questions on; the experiences of the general public with regards to Serious Games and standard video games; botanic garden\gardening show visiting behaviour; respondents' attitudes to a hypothetical learning scenario using SGs compared to traditional methods.

These questions are essential in understanding the type of Serious Game that we should design for public experiments, including how complex that game should be. Learning more about the levels of engagement that respondents have with tree and plant health-based activities, e.g. botanic gardens is important as these locations were discussed with external partners are good locations to conduct these public engagement experiments. Additionally, these locations are highlighted in the Protecting Plant Health Report as an area of interest for enhanced public engagement by DEFRA [9]. We also extended the scope to include references to museums as many SGs are used within that setting also.

Knowing more about the public's attitudes towards SGs addresses the willingness that the practitioners expressed in Chapter 3 to use SGs with that group. While the practitioners did not express reservations with this group, having input from the general public allow them to express any reservations or advantages they may have.

The following four outcomes were identified as expectations from this study:

1) Examples of good and bad experiences that the general public have had with engagement and educational games in a public setting
2) Understanding of their gaming experiences
3) Understanding of how often educational and agricultural\horticultural events were attended
4) An insight into respondents' attitudes towards learning from a game compared to other methods

4.1.2 *Conceptual Framework and Study Tool*

Taking the outcomes, we broke them down into four categories that would guide the questions we asked the user: Demographics, Activities, Game Experiences, Engagement. Activities is used broadly to capture both Gaming and Tree and Plant Leisure activities.

Demographics – Limited demographic questions were selected to get an understanding of the spread of people that completed our survey. Additionally, the country of residence question was asked to filter out geographically invalid responses.

Gaming Activities – These questions were included to begin to understand how often respondents engaged with video games in their day to day lives.

Educational Leisure Activities – These questions are essential in understanding how visiting educational attractions, e.g. museums or botanic gardens form part of the respondents' leisure activities. Especially given the focus placed by DEFRA on botanic gardens [9].

Horticulture\Agriculture Leisure Activities – This questions is used to understand how often respondents visit Agricultural\Horticultural shows.

Game Experiences – Questions in this category were selected to understand: what types of games the participants had played with; what their experiences of those games were; and if they were to pick a type of game to play in a similar situation, then what would it be.

Engagement – These questions were inspired by the responses from Chapter 3. Specifically, that the interviewees in Chapter 3 already use printed media in their work, and have an interest in using more interactive methods of engagement. Asking participants if they think a game would help their learning was used as a way to gauge the perceived effectiveness of SGs in public engagement and education.

These areas form the conceptual framework used to devise and frame the questions being asked in the survey tool. The questions, how the respondent can answer, and the categories they fall under are shown in Table 6 below.

Question Number	Question	Answer Type	Category
1	What is your age?	Single choice age band: - Under 18 - 18 to 27 - 28 to 37 - 38 to 47 - 48 to 57 - 57 to 68 - Over 68	Demographics
2	What is your gender?	Single choice: - Female - Male - Rather Not say - Other	Demographics
3	Highest level of education completed?	Single choice: - Primary School - Secondary School - College - Undergraduate - Postgraduate	Demographics
4	What country are you residing in?	Free text answer	Demographics
5	How often do you play video games per week?	Single choice: - 0 hours - 1-2 hours - 2-5 hours - 5-10 hours - 10+ hours	Activities
6	How often do you attend museums, botanic gardens, etc?	Single choice: - Several times a year - Once or twice a year - Never	Activities
7	How often do you attend gardening or agricultural shows?	Single choice: - Several times a year - Once or twice a year - Never	Activities
8	Have you ever played an educational game at a museum, botanical garden, or gardening/agricultural show?	Single choice: - Yes - No. If the respondent answered yes then they would directed to questions 8a – 8d	Game Experiences
8a.	How long did the game last?	Single choice: - Less than 5 minutes - 5 – 10 minutes - More than 10 minutes - Cannot remember	Game Experiences

8b.	Describe it briefly	Free text answer	Game Experiences
8c.	How effectively did it communicate its educational content?	Single choice: - I understood it well - I understood it a little - It was confusing - I don't remember	Game Experiences
8d.	Did you enjoy it?	Single choice: - Yes - No	Game Experiences
9	What kind of educational game would you like to play when visiting a museum etc?	Multiple choice from the following game categories: - Action - Action-Adventure - Adventure - Board\Card - Puzzle - Role-Playing - Simulation - Strategy - Sports - Trivia	Game Experiences
10	When visiting museums etc how likely are you to engage with information presented on a printed poster?	4 point Likert scale: - 1 – Very Likely - 4 – Very Unlikely	Engagement
11	When visiting museums etc how likely are you to engage with information presented via an interactive touch screen	4 point Likert scale: - 1 – Very Likely - 4 – Very Unlikely	Engagement
12	Do you think that playing a game would impact you learning the content that the museum etc would want you to learn?	Single choice: - Yes - No. If the respondent answered yes then they would directed to question 12a.	Engagement
12a	Why?	Free text	Engagement

Table 6: Game Players Requirements Gathering Questions and Categories

Respondents had, in the vast majority of questions, restrictions placed on their answers e.g. selecting a single choice from a pre-populated list. This was done in order to simplify data ordering and analysis at later stages. With respects to the Likert scales in questions 10 and 11, this restriction was done to force respondents into expressing some opinion by removing the neutral option.

We have used question 4 as a filter. Given the doctoral work focuses on the United Kingdom, responses from outside of the United Kingdom are not to be included. Any responses that originated from people residing outside of the United Kingdom would, therefore, be discarded.

Question 9 was not asked with specific reference to tree and plant health focused games. This was due to two factors. Firstly, there are a lack of tree and plant health games that have been released to the public. Secondly, this study was interested in any examples of SGs in the public engagement setting.

There are some changes that would be made to the survey design should it be conducted again. Firstly, respondents would be asked to clarify whether they were reflecting on the most recent game they had played or all of their experiences. Secondly, respondents would be asked where they had encountered the study out of the channels that had been used for recruitment.

The first change would give a more precise understanding of whether the respondent is making general comments about a range of experiences or if it was a particularly memorable experience that had come to mind. The second would allow us to ascertain which channel proved most useful for participant recruitment, allowing for that channel to utilised in future online participant recruitment.

A further change that should be made to the survey design would be focused on the definition of terms. At no point in the study are terms like “video game” or “strategy game” defined for the participant. It is possible that there was no shared understanding across participants around what would constitute a video game, e.g. possibly excluding games played on smartphones, or even what types of games could fall under each category of video game.

By including a definition of terms used we would be sure that every participant was answering the question with the same level of understanding. It is possible that participants may have answered that they do not play video games regularly, thinking of game console or computer based games, but play smartphone\tablet based games.

The survey was constructed and hosted on Online Surveys, an academic survey website, using a verified University of Stirling account. The survey was open for respondents to complete between the 10th September 2018 and the 7th October 2018

Before answering questions, we presented respondents with an overview of why the survey was being conducted; how we would handle their data; an explanation of consent; and contact details for the author and their supervisor to both ask further questions and\or revoke consent. These contact details and the ability to revoke consent were repeated with a thank you message upon completion. This is in line with the approval received from the University of Stirling's Ethics board.

4.1.3 *Participant Recruitment*

In an ideal scenario, this particular study would have been contracted out to an external company that specialises in surveys to collect responses that were representative of the United Kingdom (in line with the 2011 Census) while excluding those who work as tree and plant health professionals – following the model of Fuller et al. in their 2016 study [142]. Thus allowing us to draw conclusions that were more representative of the public as a whole.

As we were looking for members of the general public to participate in this study, a range of recruitment channels were considered. Participants were looked for within audiences that the author both had ready access to, and that would hopefully provide a range of backgrounds and experiences.

Within the University itself, an advertisement was placed on the intranet portal asking for participants – many studies are advertised in this way. It is, therefore, a familiar way for potential participants to find studies in which to participate.

The author sent invitations to contacts in the tree and plant health sector, asking them to both participate and to share the survey with their networks. Those working in the tree and plant health sector can also be members of the general public.

The social media sites Reddit and Twitter were also used to circulate the survey. The sub-reddit r/SampleSize is a dedicate subreddit for research studies (at all levels from High School to academia) to be circulated and completed. Twitter was used as a convenient way to reach the general public. While the reach of the author's twitter account is limited, partners and colleagues re-tweeting the appeal for participants would spread the invitation to a far larger audience.

With both Reddit and Twitter there was a far greater chance of receiving participants from around the world. However, on the subreddit, part of the

submission process involved stipulating where you would like to receive participants from. This would somewhat restrict those that might elect to participate from what channel.

Of the initial tweet made by Docherty to advertise the survey, there were 11 retweets, including the Royal Botanic Gardens Edinburgh's education account and the Chief Plant Health Officer of the United Kingdom.

Using Twitter Analytics for the tweet sent by Docherty, we can say that the tweet was seen a total of 4011 times with 51 engagements and eight clicks on the recruitment link, as shown in Figure 11. Twitter analytics work on the basis of engagements and impressions. Engagements involve actions on the tweet, e.g. other users clicking on the tweet, retweeting, liking, clicking on any included links [163]. Impressions are a representation of the number of people that have actually seen the tweet, with the potential reach being a function of all followers of the author of the tweet and each account that has also retweeted the tweet [163].

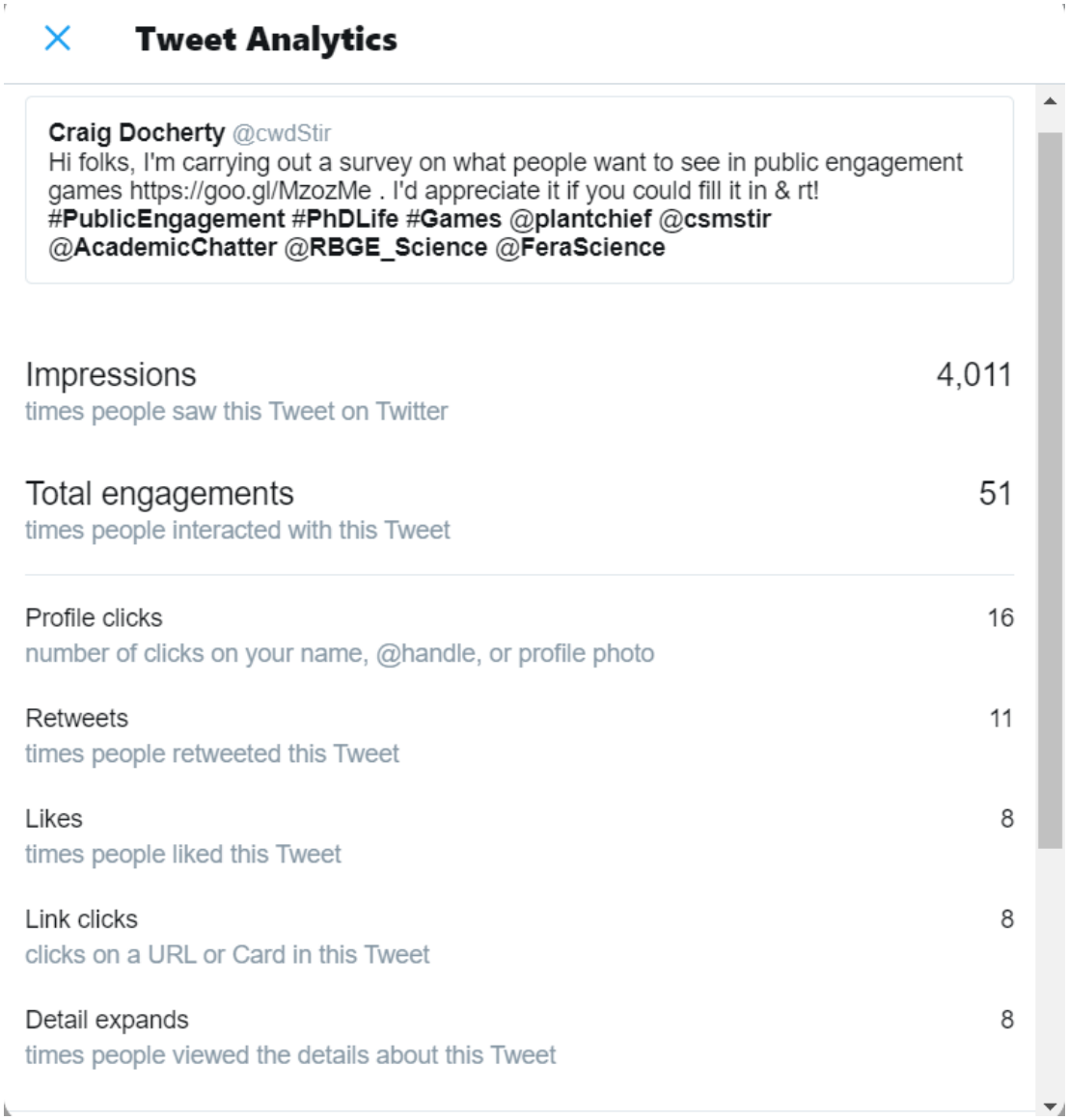


Figure 10: Twitter Analytics of Docherty's recruitment tweet

4.2 Results

There were 138 respondents to the survey over the four week period. Of these, 119 were from the United Kingdom – the remaining 19 were removed from the results set due to being outside the geographic area our study was concerned with.

We cannot state that results gained through this study are representative of the general public, instead they can be more accurately described as being more likely to be motivated to assist with studies (Reddit and the University Intranet), or being interested in tree and plant health related research and issues (twitter).

It is therefore reasonable to conclude that there is likely a population bias introduced to the study. As previously discussed, this is partly influenced by not

having a population spread commensurate with that of the 2011 UK Census (the last Census prior to this thesis being written.

For example, in the 2011 Census, ~25% of respondents indicated that they had a level of education at undergraduate degree level or higher [164] , whereas in this study we see 71% of our respondents report being educated to the same level.

Therefore, lessons learned from examination of these results should be viewed in that context. That any SG developed from these insights is more likely to appeal to those two groups of people rather than the general public.

This subsection will discuss the quantitative results first (All questions excluding 4, 8b, and 12a), followed by the qualitative results (Questions 8b, and 12a). Question 4, country of residence, is excluded from this analysis due to it being a filter question as previously described.

4.2.1 *Quantitative Results*

4.2.1.1 Demographics

86.56% of all respondents were aged between 18 to 57, with the remaining 13.44% split between Under 18 (1.68%) and 68+ (11.76%) (Figure 12). Respondents were roughly split between male (53.78%) and female (45.38%) – with one respondent stating they would rather not say (Figure 13). 86.56% of respondents had above high school levels of education, with 41.18% being educated to postgraduate level, and 30.25% at undergraduate (Figure 14).

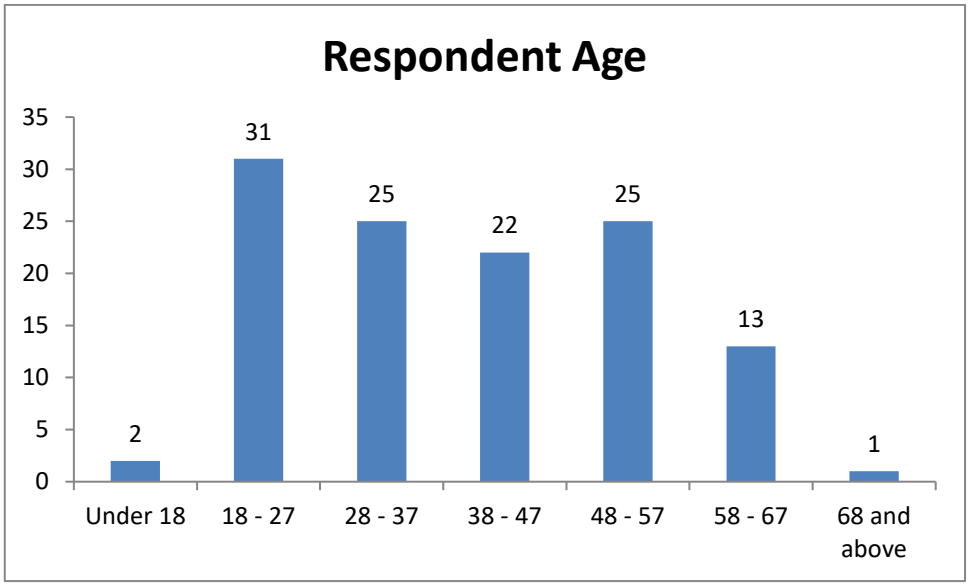


Figure 11: User Survey - Age Distribution

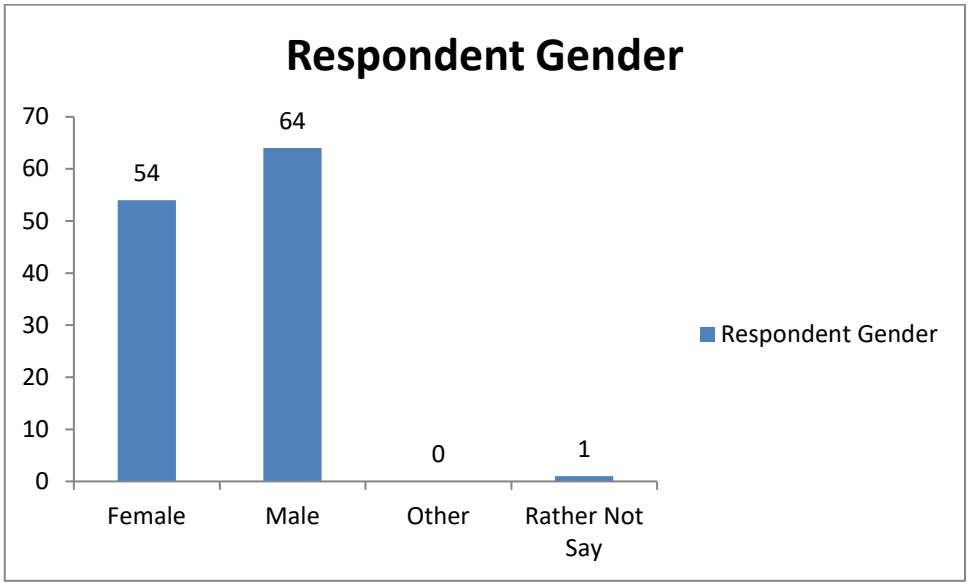


Figure 12: User Survey - Gender Distribution

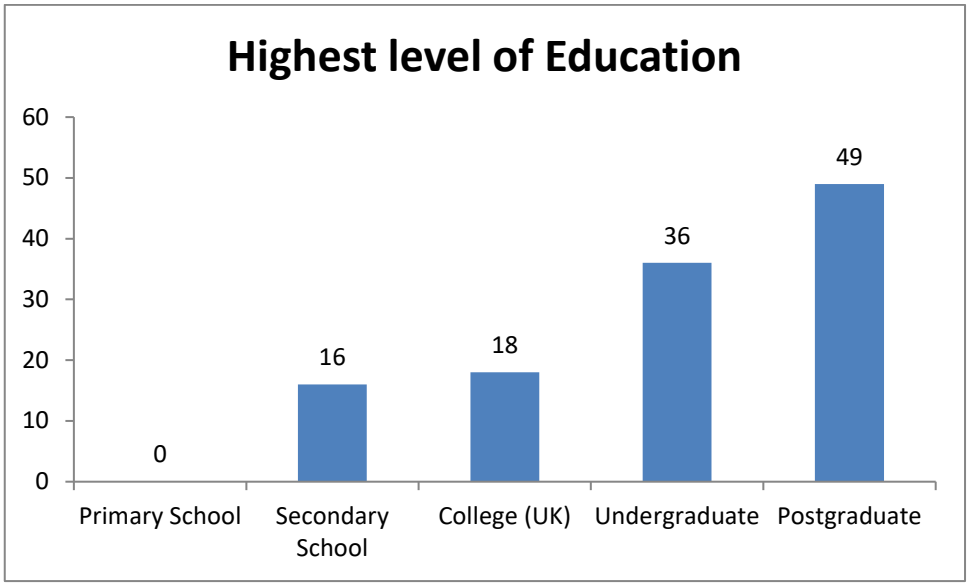


Figure 13: User Survey - Levels of Education

4.2.1.2 Game Experiences

The UK average, as defined by the State of Gaming – 2018, for hours of games played per week is 7.15 [165], with the global average sitting at 5.96 hours. 78.15% (93) respondents play video games for 5 hours a week or fewer, indicating that the majority of our respondents play video games less than both the Global and UK averages (Figure 15). 42.02% (50) of the respondents have played an education game at a botanic garden, museum, or gardening/agricultural show. These respondents shall be known as Experienced Gamers (EG). The Non-Experienced Gamers group will be known as nEG.

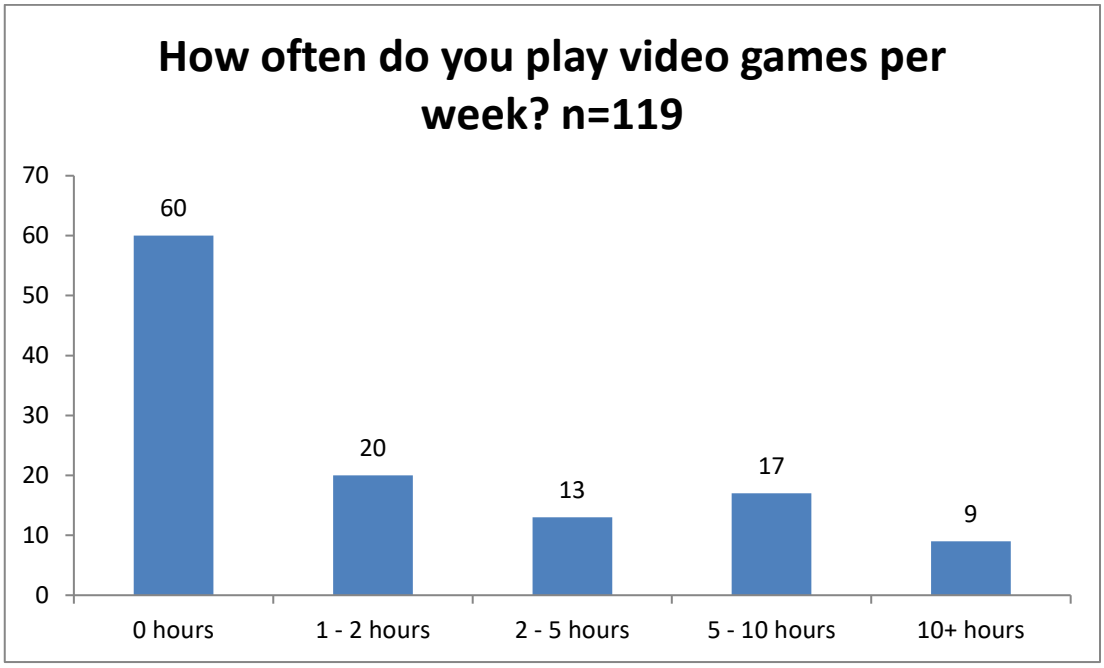


Figure 14: User Survey - Hours of Games Played Per Week

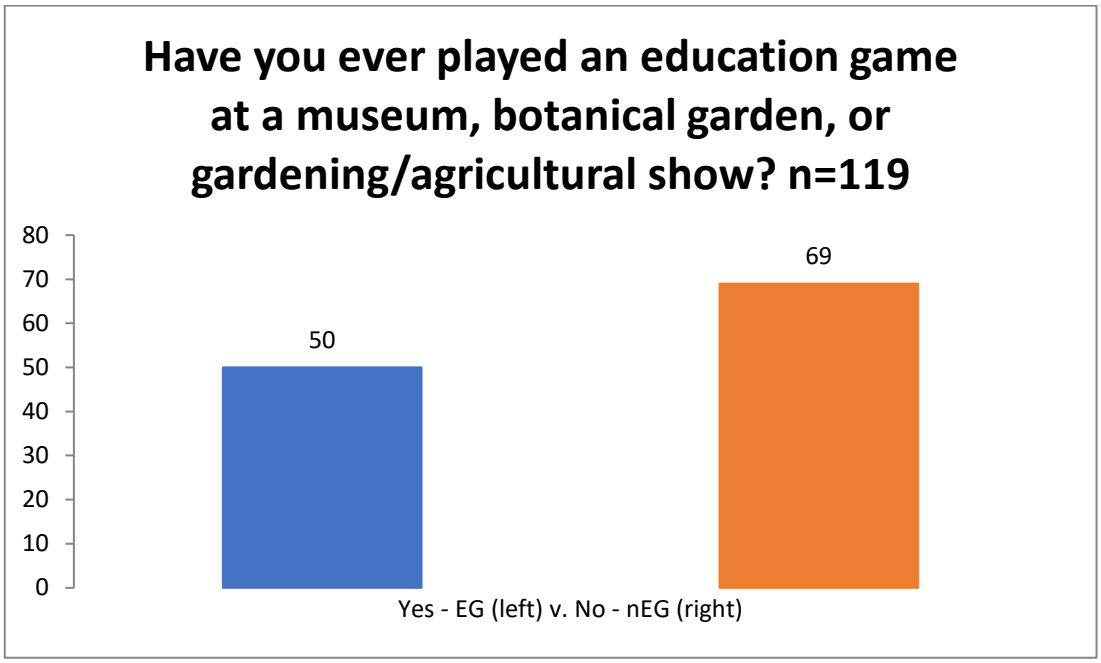


Figure 15: User Survey - Engagement with Games by Participants

Slightly over half of the games experienced by EG were short, lasting less than five minutes 26 (52%). Most of the EG believed that the game they played was effective in communicating the education content (72%), with the remaining responses ranging from a little understanding to not being able to remember.

All respondents were asked what sort of game they would like to play with respondents able to select multiple options from the following categories: Action,

Action-Adventure, Adventure, Board/Card Games, Puzzle, Role Playing, Simulation, Strategy, Sports, and Trivia.

In total, 403 votes were cast. Of these categories, the top three were Simulation (79 votes), Puzzle (65 votes) and Trivia (60 votes). The least popular category was Sports (2.48%).

When restricting the votes to those in the EG group, only a slightly different picture emerges. There were 111 votes cast in this group compared to the 403 of all participants. The top three categories become Trivia (40 votes), Simulation (20 votes), and Strategy (18 votes).

Additionally, looking at those in the nEG group with a total of 292 votes being cast a different rank ordering to the top three emerges: Puzzle (61 votes), Simulation (59 votes), and Strategy (33 votes).

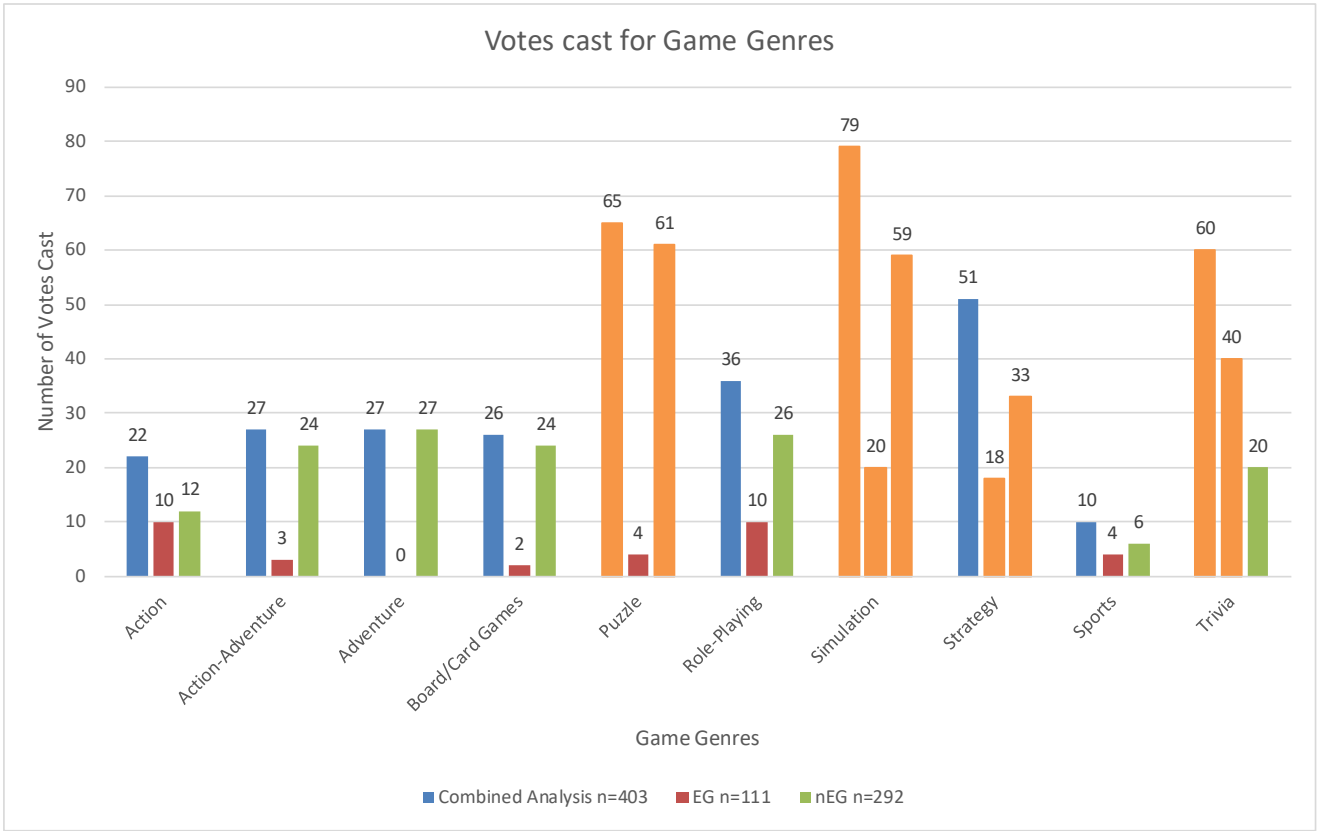


Figure 16: Votes cast for preferred genres of game to play. Orange bars are the highest scoring 3 genres in each analysis.

4.2.1.3 Activities

Figure 18 below shows the breakdown of how respondents visited the two groups of activities. 45 respondents (37.82%) reported that they visited either group once per year. However, there was a significant difference between both groups in terms of several visits and never visiting. Several visits in the year to the museum and botanic garden group was the most popular response with 69 (57.98%) responses. 55 (46.22%) respondents had never visited an agricultural or horticultural show. This suggests that a museum or botanic garden setting is the most frequented by our respondents.

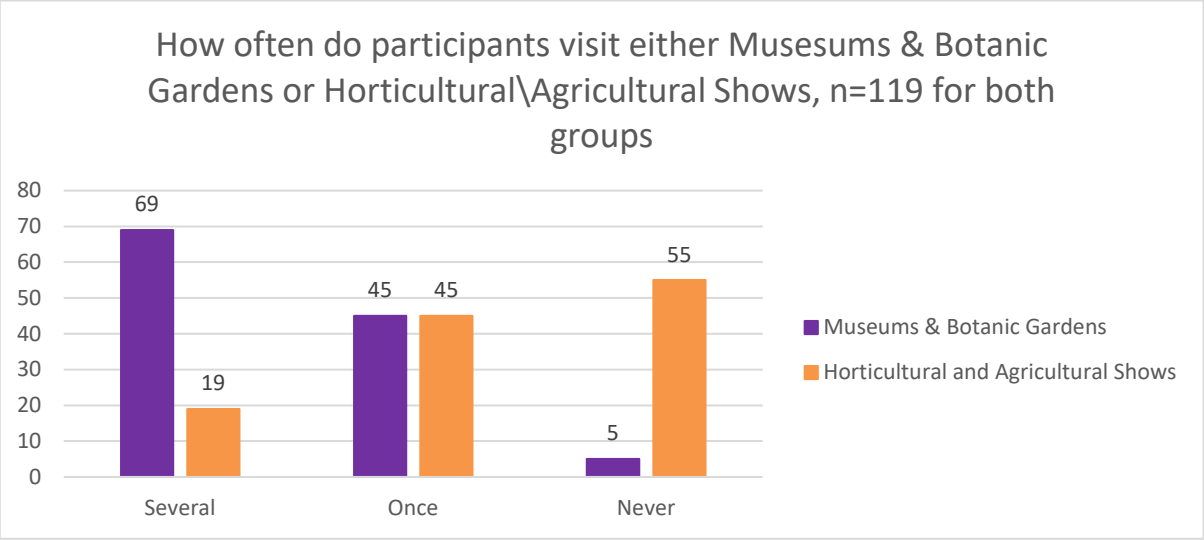


Figure 17: Breakdown of visits to Museums and Botanic Gardens & Agricultural and Horticultural Shows

4.2.1.4 Engagement

65.55% of respondents were likely/very likely to engage with information on a printed poster while 73.95% of respondents were likely/very likely to engage with information via an interactive screen, Figure 19. Therefore, our respondents are likely to engage with information in any form.

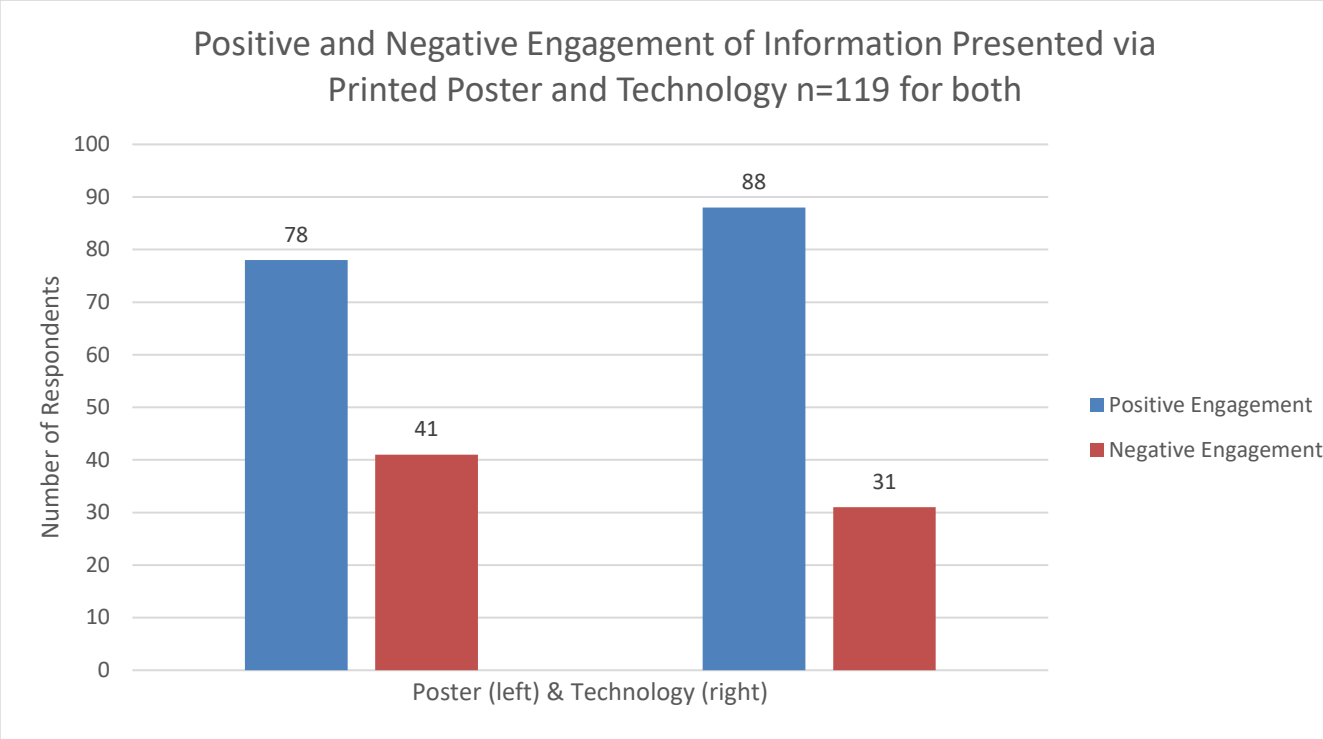


Figure 18: Positive v. Negative interaction with Printed and Technology presented information.

Participants were also asked whether they thought that the use of a game in a museum, botanic garden setting would impact their learning of the material presented. 76.47% of respondents answered Yes to this question.

4.2.2 *Qualitative Results*

All participants had at least one opportunity to give a free-form text answer as part of the questionnaire, specifically when asked whether they believed a game would impact learning. The members identified as part of the EG had a second opportunity when we asked them to describe the game(s) they had played.

4.2.2.1 Game Experiences

Respondents in the EG group described the games that they had played. These games included simulations of applying brakes to trains to stop at the station correctly and driving a fishing boat. Quizzes were also featured, including an online game matching pictures to the names of species quiz, and a physical search to find objects from a given sheet in a castle and museum.

Strategy games were a common experience, with respondents from EG reporting experiences that covered: local government wolf control policy; managing a country's renewable power station; and managing a Machair, a fertile low lying

grassy plain [166], by bringing in biodiversity, accommodating tourists, restoring peat, and other activities.

4.2.2.2 Engagement

All respondents were given the opportunity to explain why they believed games may or may not impact their learning. This question was a yes\no question with space to further explain their answer. While negative and positive opinions were expressed in these explanations, they have been grouped under the original yes\no question we asked.

Of the respondents that answered yes, they felt that there could be positive impacts from using a game. Some respondents felt that it could “bring the topic alive” or allow the information to “stick” more than just “read[ing] one of many text displays”. Broadly, there are positive expressions from the respondents that using a game, specifically a digital game, would be beneficial for learning and engagement.

However, some respondents also highlighted that any impact might depend on their mood or the type of game. There was also some concern about the type of game used. Specifically, that the game should not “turn into a shoot out game where all your attention is focused on killing things”.

Conversely, those respondents that answered no expressed a desire to read information over engaging with a game to learn. Others also felt that many games used in public engagement settings are “aimed at children and are therefore very simple”. Other responses highlighted that games can be “very simple” and are “not always as accurate as they could be”.

4.3 Discussion

From the results, we have met the outcomes stated in the Study and Aims section of this chapter. For this study we accept that it is not an accurate reflection of the general public, as laid out in the 2011 UK Census, and as such any lessons learned are particular to the demographic makeup of our respondents. A further study conducted with population weighting commensurate to that of the 2011 Census, or the most recent Census at the time, may return different results.

4.3.1 *Outcomes 1 and 4 – Examples of Good and Bad Experiences with SGs & Insight into Attitudes of Learning with Games*

In expressing their experiences with SGs respondents revealed some interesting insights into what they enjoyed and disliked with their experiences. While these insights can be contradictory at times.

Making sure the game is fun and has an adequate amount of challenge is important for having an impact, with a respondent feeling that failure to provide those characteristics would impact their desire to play the game or retain information. However, other respondents felt there might be too much focus on enjoying gameplay rather than learning information.

Other respondents highlighted that keeping the games simple and to the point would be a benefit for learning – yet at the same time that very simplicity is seen by others as a negative that would abstract away from complex information for the sake of gameplay.

Despite the contradictory experiences and preferences, there was a feeling that SGs do have the potential to bring the material to life in a way that printed materials cannot.

4.3.2 *Outcome 2 – Understanding of Gaming Experiences*

When considering the types of games that respondents would enjoy an interesting picture emerged. Simulation is the only category that appears in all three analyses of the data as a preferred category, although it is the 2nd preference category in the individual EG and nEG group analyses. Strategy is not one of the top three categories in the combined analysis but does feature in the individual analyses. So, even though the overall analysis does not immediately reveal it as a possible category, a strategy game may be enjoyed or appealing to both groups.

Additionally, the below-average amount of time spent on playing video games would indicate that the general public are more casual gamers – if indeed they are gamers at all. With that in mind, SGs should be designed around that fact. When combined with the relatively short time that games experiences last for, 0-5 minutes, this suggests that less time-intensive and complex SGs should be designed.

However, these conclusions come with the caveat that terms were not defined in the study tool. A repeat of this study with the terms clearly defined,e.g. what constitutes a video game, may return different results.

4.3.3 *Outcome 3 – Understanding of Event Attendance*

While there were equal levels of only attending either the museum\botanic garden or agricultural\horticultural once per year, there was a clear favouring of attending the former over the latter multiple times per year.

However, we would remove the references to museums in the questions should this survey be conducted again. Having it alongside botanic gardens and set against the agricultural and horticultural shows makes little to no sense in retrospect and muddies the analysis as there was no way to differentiate visits to museums from botanic gardens.

This study has a few ways it could be improved should it be rerun. As discussed earlier in this Chapter, an ideal scenario would have had this survey conducted by a professional company that could guarantee a representative sample of the general public. A representative survey would be one that matched the latest UK census, based on the approach taken by Fuller et Al. in their 2016 study [142]. Our study was not representative due to the self-selecting nature of participants.

Additionally, there were shortcomings in the design of the questions asked. Respondents were not asked to report where they had seen the invitation to participate. Having this information would have been useful for promoting the online invitation to participate in the experiment discussed in Chapter 6. Respondents also were not asked to indicate how many games they were thinking of when answering questions around experiences with games in a public setting.

It is interesting to note that the lack of hesitation expressed by the practitioners in Chapter 3 around using SGs with the general public is not at odds with the feeling that games could have a positive impact expressed by respondents.

Those feelings, however, that the SGs will not impact their ability to learn information from a SG will form an interesting question to be asked in Chapter 5 and Chapter 6. Specifically, whether SGs have any impact on the ability of the general public to learn information compared to non-game methods.

5 *Comparing Game v. Non-Game approaches in a public installation*

Chapters 3 and 4 laid out and discussed the requirements gathering that plays a crucial role in the software development process. From engaging with the practitioners in Chapter 3, we saw how they currently work with their target audiences; the methods employed; and their hopes and aspirations for the potential of SGs. While Chapter 4 brought the SG experiences and views of members of the public to light.

In this Chapter, we will discuss the first of two experiments comparing game v. non-game approaches in presenting public engagement information. These comparisons are conducted by presenting the same information via a game or on its own. Comparing these methods is of interest as it begins to address whether SGs are a beneficial tool in delivering engagement information.

This experiment discussed in this Chapter ran concurrently with the survey in Chapter 4. Therefore, the results of that study were not included in the design of the SG discussed in this Chapter. Instead, the SG was designed with the input of external partners from the Animal and Plant Health Agency (APHA).

These partners had the most experience with public engagement in locations such as horticultural events and botanic gardens. These locations are identified in the UK Governments' Protecting Plant Health report as a place they want to increase public engagement on tree and plant health issues [9].

Members of the APHA were involved in shaping the experiment by suggesting which locations could be utilised for field testing and the experiment proper, including facilitating access to those locations. The partners also helped steer the development of the SG by giving insight into how attendees at horticultural events behave when visiting APHA stalls.

We needed to select a location to conduct a pre-launch, or field, test of the experiment software. Gardening Scotland was selected under direction from partners at APHA. Following this field test, the experiment would be conducted at the Royal Botanic Garden Edinburgh (RBGE).

Gardening Scotland is a yearly event that is well attended by members of the public, horticultural companies, and agencies such as SASA (formerly the Scottish Agricultural Science Agency). As the Gardening Scotland show only runs for three days, and the experiment was designed to run for several weeks, a different location was selected for the experiment.

The RBGE would host the experiment, which would operate without direct researcher supervision. The RGBE is open all year round, meaning that data collection can last longer, resulting in a greater potential participant base.

This Chapter will discuss constituent components of the experiment in Methods, before going on to examine the results, and concluding with a discussion.

5.1 Methods

5.1.1 *Phases and Timeline*

There were two distinct phases involved in this study:

1) Field test of games and data collection methods – June 1st, 2018
2) Experiment at the RBGE – July 20th, 2018 to August 24th, 2018

While we conducted testing during development with University colleagues, who generously gave their time to assist, when planning the experiment, we recognised that this testing would be insufficient. Ideally, we would want to test the software in the intended location or use, e.g. being asked to test instead of being curious to engage.

Therefore, the concept of performing a playtest, or prototype experiment phase, was included to tease out details and errors that otherwise would not be possible inside the University. Playtesting is a concept that emerged in literature review as good practice for engaging with the intended audience to discover shortcomings in the software that may not have been evident before that point.

The two study phases had different outcomes. We expected the playtest to test the games, discover any potential shortcomings, and the remote data collection method. The experimental phase would collect data to go towards answering the research question.

It is important to note that the installation at the RBGE coincided with the Scottish school summer holidays and the Edinburgh Fringe Festival. Therefore, it is likely that there would be more visitors attending the RBGE than at other points of the year.

5.1.2 *Experiment Structure*

The experiment follows a straightforward structure, as shown in Figure 20, with the only point of difference being the treatment the player is assigned. We explain these stages below.

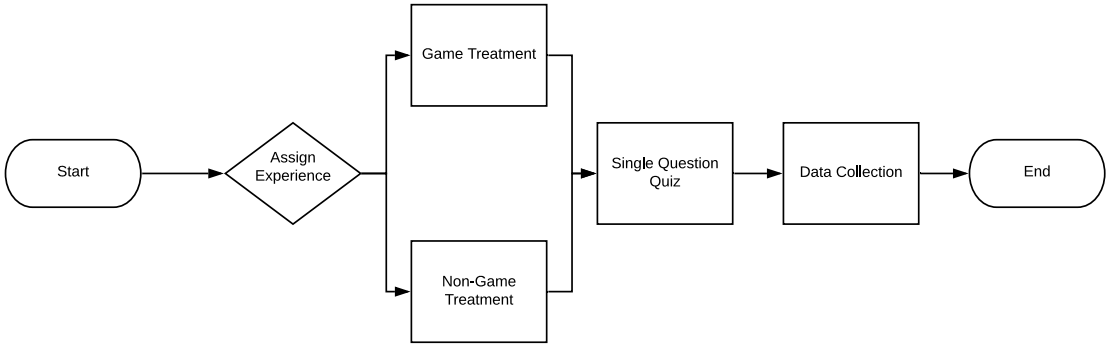


Figure 19: Public Game v. Non-Game Experiment Structure

Start

Players choose to engage with the experiment at this point with consent for data gathering and participation given here.

Assign Experience

The experiment software follows a pre-determined path of assigning experiences to participants. Alternate participants experience a game and non-game treatment. The content is also presented in an alternating pattern. The content focuses on three invasive pets: Emerald Ash Borer, Asian Longhorn Beetle, and Oak Processionary Moth. The progression of treatment and content is as follows:

Game	-	Emerald Ash Borer
Non-Game	-	Asian Longhorn Beetle
Game	-	Oak Processionary Moth
Non-Game	-	Emerald Ash Borer
Game	-	Asian Longhorn Beetle
Non-Game	-	Oak Processionary Moth

We selected this progression to counteract a problem identified by Heath et al. in their investigation of computer-based exhibits. Specifically, that potential users observing a current user and learning information that may interfere with their own experience [167], should a pair, or trio, of participants, wish to use the experience sequentially they will all receive different content. Although, the binary nature of game v. non-game means that only a pair of players that arrive together will receive entirely different experiences.

Non-Game

The non-game path presented the user with three facts across sequential screens comprising some text and an associated image. These image and text pairs are fact-files that participants view in the same order for each presentation of a threat. Participants move onto the following fact at their pace, viewing each fact-file once.

Game Treatment

The game treatment contains the same fact-files as the non-game treatment. However, while the content is the same, the order of presentation is different. While the non-game fact-files are presented in a pre-determined order, in the game treatment they are revealed by the participant's actions in the game.

Although we discuss the game development process thoroughly in section 5.1.3, at this point, a brief explanation of how participant actions drive the revealing of fact-files is appropriate. The participant must match an associated pair of cards comprised of the text and image from the fact-file. When the participant flips over the associated fact-file is revealed.

Therefore, while the non-game treatment will present the fact-files in a 1 – 2 – 3 order, the game treatment will have one of the following six orders:

- 1 – 2 – 3
- 1 – 3 – 2
- 2 – 1 – 3
- 2 – 3 – 1
- 3 – 1 – 2
- 3 – 2 – 1

Single Question Quiz

Guidance from partners at APHA led to the user answering a single question based on the information that they read. APHA experiences of stalls at horticultural events revealed that members of the public were reluctant to answer too many questions at once. Participants answer the same question for each information set regardless of the treatment.

Data Collection

Within the experiment, there are two types of data collected: visibly asked for data e.g. the quiz question; and data gathered in the background, e.g. the time spent reading each fact-file. The data collection step is for explicit data collection only. A full list of data and its categorisation is presented in 5.2.6.

If there is no interaction with the software after the start phase for a period longer than one minute, the software wipes all data collected for that specific participant and returns to the start menu. We designed this to handle two scenarios: participants that wish to withdraw consent and participants that lose interest.

We store the collected data in two places. We firstly send a copy to a cloud storage location. A copy is also stored on the device running the experiment software as a redundancy backup.

End

This step concludes the participant's experience. We present them with a message thanking them for taking part and wishing them a pleasant day. The participant also has a finish button on the screen, pushing this button completes the data storage process.

5.1.3 *Games*

The initial development of the experiment software saw the creation of three distinct games with each game only containing information on one pest or pathogen. These games were developed using Unity3D, Table 7 below lists the games, their content, and the aim of the game.

Game	Content	Aim of the Game
Card Matching	Oak Processionary Moth	Match pairs of symbols
Pipe Rotation	*Phytophthora ramorum*	Create a safe path for the oak tree's roots to reach water, avoiding the pathogen
Picture Slider	Asian Longhorn Beetle	Rearrange a mixed up image of the beetle

Table 7: Initial games, their content, and aim

We selected these games after discussions with our partners in APHA. They informed us that visitors to public stalls and installations tend to spend very little time engaging, cover a range of ages, and will require a simple experience. These constraints placed limitations on the complexity of any games developed and the data we could directly request.

Each of the games selected for development shared a common theme, they were themselves common games. Card Matching as a concept is seen in games like Snap [reference here]. Picture Slider puzzles are fairly common as well, being represented both in digital mini-games and physical puzzles [reference needed]. Pipe Rotation is a newer, digital, game but as a concept is still a fairly common mini game [reference needed].

The aim here was to present games that the player may have encountered before so that prior gaming experience barriers were reduced as much as possible. Given that we could not guarantee any form of experience with gaming, or expertise with technology in general, having a less complex experience was a necessary design decision.

We decided that information would be revealed to the participant as they played through the games. This could be based on the number of moves the participant made, e.g. x number of pipe rotations would reveal an information snippet, or if the participant matched a pair of cards. This decision was made as we wanted to reveal information about the threat the game was dedicated to during gameplay in contrast to the control group receiving the information on its own without any gameplay.

We also made specific decisions regarding the length of each game. We attempted to restrict the number of moves\matches a player would have to make to complete the game. As previously discussed, we had been informed that participants would likely not have a lot of time to spend on the study so keeping

the number of moves\matches required was intended to respect that low-time requirement.

From a broader technological perspective we decided that the games would be given to participants via a tablet that we controlled. This meant that we could ensure consistency across the entire experience, but specifically in how the games would be displayed and perform. This decision removed another potential barrier to participation, that being the need of the participant to take additional steps to participate.

It should be noted that there was no explicit framework or methodology guiding these decisions. This is an oversight may have introduced unnecessary complications. As will be discussed later in this chapter, there were some issues with the design of the games that may have been avoided had we utlised a framework such as the Mechanics Dynamics Aesthetics (MDA) model [112]. This may have given us some guidance on how to better integrate the material for learning with the gameplay itself.

The topics were selected as all three were either established invasive species or intercepted and eradicated on UK soil. Additionally, the RBGE had signage and an engagement focus on *P.ramorum.* The final version of the experiment includes Emerald Ash Borer, replacing *P.ramorum*, as the Borer not yet arrived in the UK and is a threat that is being watched for [168].

Having games designed in such a way has precedence in the literature, with Cowley et al. including these types of *mini-games* in their work on Green My Place [124]. We find similar styles of mini-games in the popular games such as the *Super Mario Party* game series [169] where players moving around a game board play these smaller games at the end of each turn to gain advantages on the board.

While the games we developed can be thought of as mini-games, We do not believe this is an appropriate categorisation as a mini-game must be present inside a larger game. For this experiment, these games are the only game experience that users will have. Therefore, calling them games is entirely appropriate.

As participants engaged with the game e.g. moving a puzzle piece, rotating a pipe, or matching a pair of cards, a fact-file would appear. These fact-files behave the same as described earlier in this Chapter. An example of a fact-file is shown in Figure 21: Associated Card Match - First Time Flip.

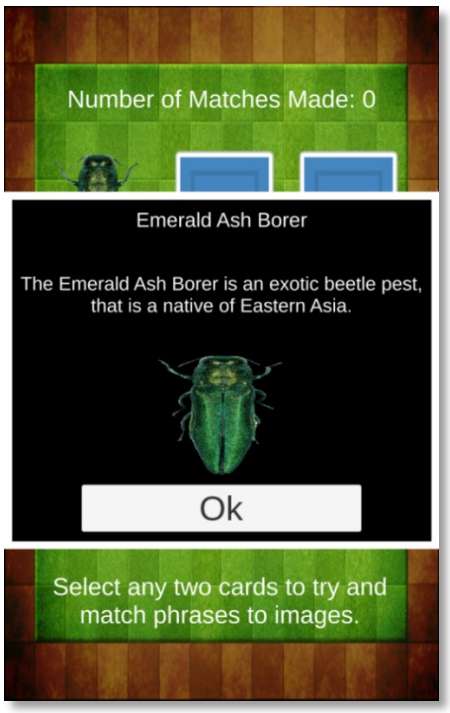


Figure 20: Associated Card Match - First Time Flip

When testing these three games at Gardening Scotland, through observing participants and discussing their experience with them, two themes emerged. Firstly the pipe rotation and picture slider games were too complicated to be used unaided. Secondly, the symbols participants matched in the card matching game were too disassociated from the learning materials.

Having games that were too complicated to play violated the requirement that games be simple. Additionally, that the experiment was designed to operate without direct research supervision made this untenable. Further constraints in terms of time meant that the most straightforward option was to remove these two games. We retained the Asian Longhorn Beetle information and replaced *P.ramorum* at this point.

The final game, Card Matching, was not fully ready to use in the experiment phase either. As criticism focused on the coupling of information to the gameplay,

we believed this to be the more straightforward problem to resolve, especially when coupled with the inclusion of two further information sets into the game.

The initial version had pairs of images to match (sun, earth, water, oak tree) which caused a fact-file to appear when successfully matched. This process would repeat for the next two matches as there were only three facts to learn. Given there are also three facts to learn, the fourth match was both unnecessary and a potential source of confusion as it broke expected behaviour.

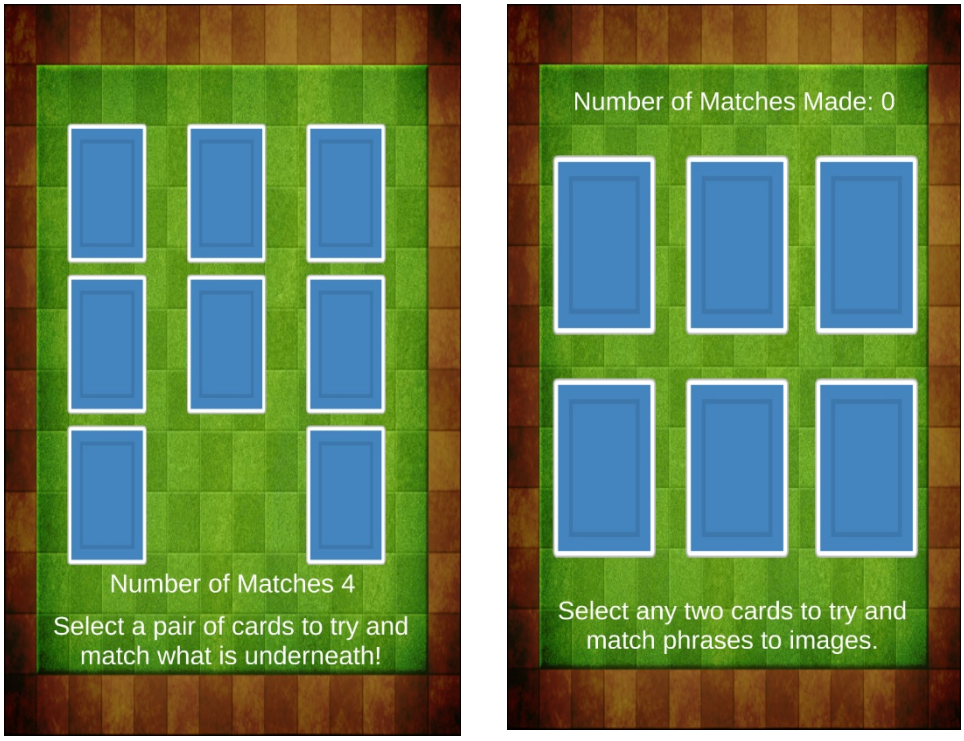


Figure 21: Card Matching Game - (L) Initial Layout (R) Associated Card Matching Layout

Therefore, the game was changed to be an associated card matching game and the number of potential matches were reduced to three from four. The different layouts can be viewed in Figure 22 above.

The difference between matching symbols and associated card matching is in the relationship to the fact-file. The pairs of cards comprise one with text and one with an image. Both the image and text originate in one of the information fact-files. When the participant selects one of the cards in a pair for the first time, they view an appropriate fact-file which will match content on the card they have flipped.

Participants must then find the matching card in the remaining set of unturned cards. Figure 23 shows this process, including information that would be shown on an associated pair of cards for the Oak Processionary Moth.

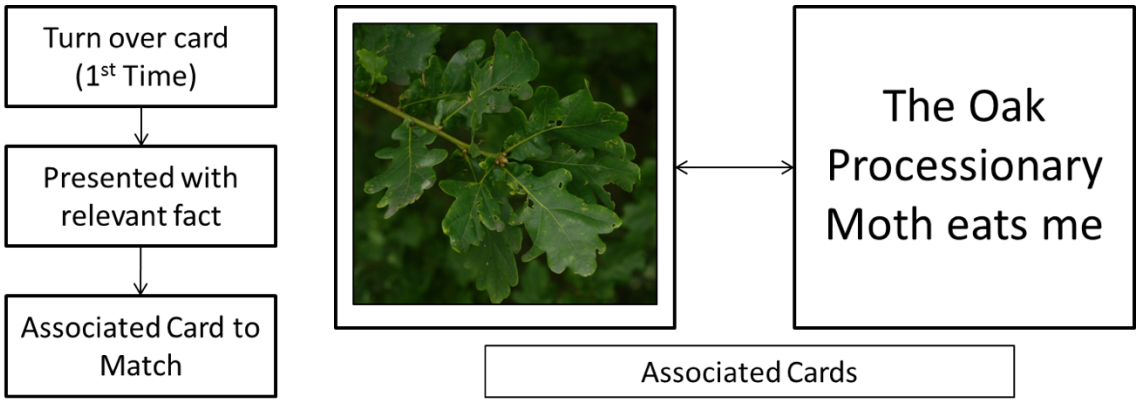


Figure 22: Associated Card Matching Description

5.1.4 *Locations and Recruitment*

There were two locations used during the playtest and experiment phases:

- Playtest: Gardening Scotland Show, Edinburgh
- Experiment: John Hope Gateway, RBGE

5.1.4.1 Playtest

The playest took place on the SASA (formerly Scottish Agriculture and Science Advice) & FCS (Forestry Commission Scotland) stall. The joint stall was part of a larger, multi-day gardening show that included commercial stalls, scientific advice, and demonstrations of gardening techniques and technologies. We conducted our playtest on the opening day of the Show. During the playtest the Scottish Government's Environment Secretary, Roseanna Cunningham visited the stall and participated, Figure 24.

Figure 23: Roseanna Cunningham, Scottish Environment Secretary visiting the experiment

5.1.4.2 Experiment

The John Hope Gateway is the main entrance to the RBGE comprising the central helpdesk, café, shop, permanent exhibits, interactive exhibits, and spaces for visiting exhibits.

Figure 24: The John Hope Gateway Interior

5.1.4.3 Recruitment

For the prototype phase, the researchers were in attendance for the entire day – actively recruiting participants from the show audience and helping/answering any questions that those participants may have had.

In the experiment phase, as shown in Figure 26, the installation was left alone, and no active recruitment took place in this location. The author, the RBGE, and other tree and plant health enthusiasts tweeted about the experiment for advertising and driving recruitment. The RBGE also included a short piece of information about the installation on their website.

Figure 25: Experiment Phase - John Hope Gateway, RBGE

5.1.5 *Materials and Experiment Software*

5.1.5.1 Materials

In both the prototype and experiment phases, we used the following equipment:

- Android Tablet
- Armour Dog secure tablet stand
- Debrief leaflets with contact information for the organisers

We were provided by stands from partners at both locations for the tablet and associated materials to sit on.

5.1.5.1.1 Prototype

The prototype stage used two additional pieces of equipment:

- Popup Banner (large)
- Popup Banner (A4 sized)

These banners are familiar sights at these events and as such, were appropriate advertising methods to entice members of the public to the experiment. An example of these banners can be found in Figure 27.

Figure 26: Scottish Gardening Show banner example

5.1.5.1.2 Experiment

The experiment stage used the following additional equipment:

- 3D printed case to stop users accessing the power and volume buttons, and secured the power cable
- Fast charging USB Plug
- 6ft Micro USB Cable

- Hexnode Software (Enabled a “kiosk mode” that stopped users accessing anything other than the experiment software)

These additional pieces of equipment were required to protect the experiment hardware. The experiment was left was an unsupervised installation. Therefore, protecting the tablet and stopping the experiment software from being interrupted was crucial.

5.1.6 *Data Collection*

As described earlier, we stored data both on the device itself and on a remote cloud. We describe the data collected in the table below.

Data	Direct\Background	Type of Response
Age	Direct	Single choice from pre-set age bands
Gender	Direct	Single choice from pre-set categories
Education	Direct	Single choice from pre-set categories
Order of fact-file Viewing	Background	Numerical ordering of fact-files
Time spent on each fact-file	Background	Time in seconds spent on each fact-file
Number of moves made	Background	Integer
Answer to question	Direct	Single choice from pre-set categories
Enjoyment	Direct	Single choice from pre-set categories
Prior Knowledge	Direct	Single choice from pre-set categories
Treatment	Background	Assigned by the software
Timestamp	Background	Time

Table 8: A list of the data and how it was gathered along with the response type allowed.

5.1.7 *Information*

We sourced the information that the participants would view from the websites of Forestry Commission England and DEFRA. We used a subset of this information to meet the requirement of a brief experience. This cut-down version was presented to and verified by our partners at APHA before the experiment commenced. The information we used is available in 11.1 Information Presented to Users.

5.1.8 *Statistical Analysis*

The software package Stata was selected for statistical analysis in this thesis. The package was used consistently between chapters 5 and 6 to perform all statistical

calculations. Stata is a multi-purpose statistical analysis package that is in use across multiple disciplines, including Education, Data Science, and Public Policy [170].

For all of the analysis models in this chapter an ordered logistic regression was utilised. This method of regression was selected as both the independent and dependent variables are categorical in nature. For these model specifications we include the number of observations (n), the Log Likelihood value, and the p-value. The Log Likelihood value is a value correlating to the best fit of the model.

The analysis is broken down into two distinct categories. The first two model sets uses whether the participants won or lost as the dependent variable, while the second focuses on the self-assessed levels of enjoyment the participants reported.

For the first model sets there are three model specifications. The second set comprises four model specifications. Specifications 1 to 3 across all models follow a consistent pattern. This is as follows:

- Specification 1: Dependent Variable, Treatment\Experience the participant was assigned
- Specification 2: Dependent Variable, Treatment\Experience the participant was assigned, participant gender, participant age
- Specification 3: Dependent Variable, Treatment\Experience the participant was assigned, participant gender, participant age, highest level of education, level of prior knowledge with the subject matter

Specification 4 includes whether or not the participant won or lost.

We group the specifications this way as we are interested in whether the experience alone has an impact on the ability of the participant to win or lose, or enjoy\not enjoy themselves (Specification 1). Gender and Age are natural characteristics of the participant and as such they are grouped (Specification 2), while levels of education and prior knowledge with the subject matter are characteristics within the participant’s control and are grouped together (Specification 3).

5.2 Results

5.2.1 *Prototype Stage*

There were 40 records collected by the application during the prototype phase. We also observed participant behaviour directly, and some spoke to the researchers during or after their engagement.

With regards to the behaviour and conversations, we made brief notes. We observed that participants struggled with the pipe and slider games. Additionally, two participants commented that they found the single question we asked them as patronising and that they did not like being asked about their education level.

The results of this prototype stage led to the material changes made to the software discussed elsewhere. However, it also demonstrated that the data collection systems and software could work outside of a laboratory setting.

5.2.1.1 Application Data

The 40 records were split between the game and non-game categories, with 20 in each category.

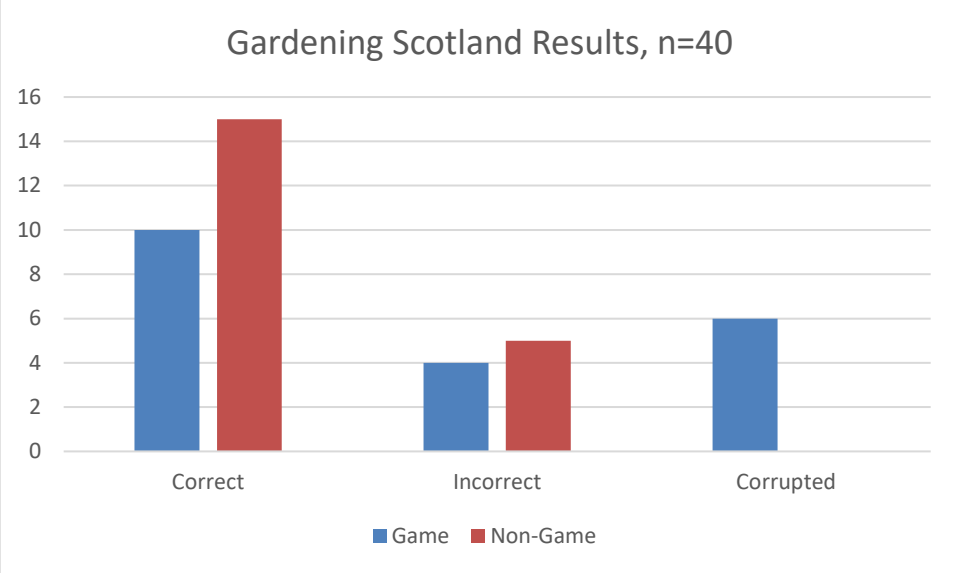


Figure 27: Gardening Scotland Prototype Test Results Spread

Unfortunately, some data gathered about the game treatments were corrupted. This was due to a programming error that was rectified on site after the issue was discovered.

5.2.2 *Experiment Stage*

There were 459 responses collected during this stage. A response is a single complete use of the software from giving consent through to submitting the data. Given the unsupervised nature of data collection, we cleaned the collected data. Data cleaning is the process by which *"dirty"* or *"unclean"* data that might not be in a usable form is made ready for analysis. We can clean the data through the removal of records, correcting spelling mistakes, adjusting incorrectly entered postcodes, and so on [171].

We wanted to remove any records where the same participant completed multiple experiences. We hoped to remove the impact of any learning effects that multiple playthroughs would afford.

We analysed the results for responses that had timestamps that were close together, or had similar demographic information, with the assumption being that the same person had completed each of those experiences. In that case, we retained the first complete experience. We also analysed the results for implausible answers, e.g. someone reporting that they were Under 18 and held a Postgraduate level of education. After cleaning, 396 usable responses remained.

5.2.2.1 Data Reporting

Demographic	**Under 18**	**18 to 27**	**28 to 37**	**38 to 47**	**48 to 57**	**58 to 67**	**68 and Above**	**Total**
Female	87	33	19	12	13	5	8	177
Male	73	24	18	13	10	10	7	155
Other	6	5	6	2	0	2	10	31
Rather Not Say	16	2	1	2	2	1	9	33
Total	**182**	**64**	**44**	**29**	**25**	**18**	**34**	**396**
Primary School	131	2	2	0	1	1	2	139
Secondary School	51	13	8	4	1	3	5	85
HNC or HND	0	6	7	3	4	4	6	30
Postgraduate	0	12	19	13	15	4	20	83
Undergraduate	0	31	8	9	4	6	1	59
Total	**182**	**64**	**44**	**29**	**25**	**18**	**34**	**396**

Table 9: RBGE Installation - Data Demographics Breakdown

Table 9 shows how participants reported their gender and their highest level of education, mapped against their reported age grouping. Having a majority of respondents report that they fell into the Under 18 age group is an expected result for this particular experiment. Given that the schools were on summer holidays, and the installation had other kid-friendly attractions nearby, it was naturally placed to attract a lot of young people.

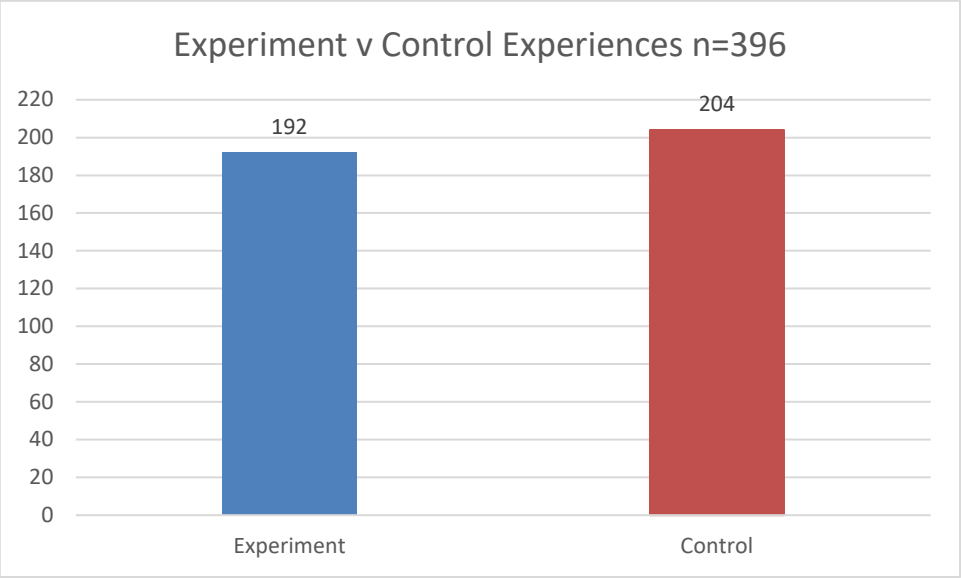


Figure 28: RBGE Experiment v Control breakdown

After cleaning, there was a difference of 12 between the number of control and experiment experiences left to analyse.

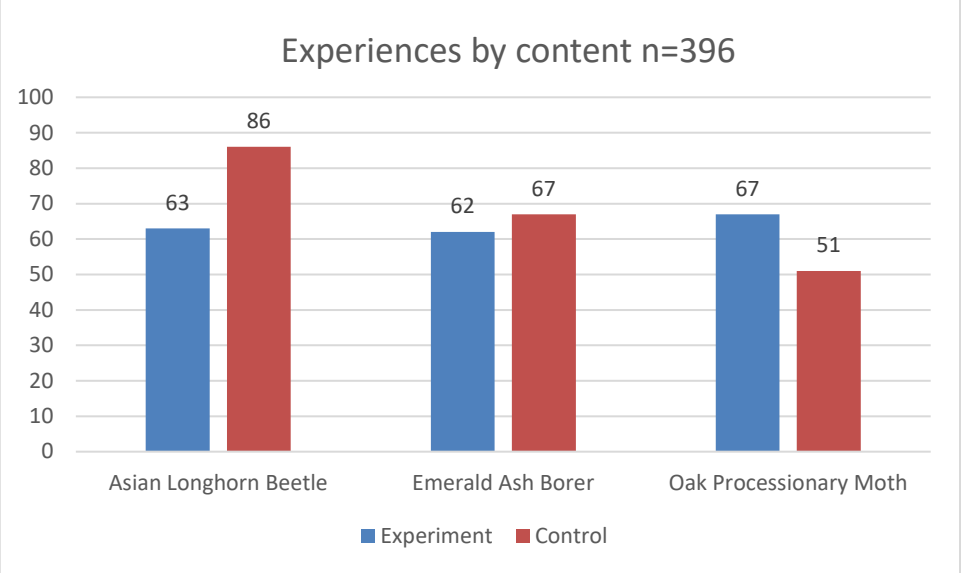


Figure 29: RBGE Experiences by content

While the difference is not overly pronounced in Figure 29, when we view the experiences by their content (Figure 30) it is possible to see that the Asian Longhorn Beetle and Oak Processionary Moth are much more imbalanced.

5.2.2.2 Statistical Analysis

We are interested in factors that may impact whether a participant “wins” or “loses” the experience they complete. We consider a participant to have won if they answer the quiz question correctly, with the inverse true for losing. We also have an interest in the perceived enjoyment of the overall experience.

Establishing if either treatment has an impact on the ability of a participant to win or lose is important in assessing the efficacy of the approach. Enjoyment of the experience will be an interesting outcome to use to start teasing out how different cross-sections of the public feel about the use of SGs.

We developed two sets of models to address these outcomes. The first set focused on factors that impact the ability of a participant to win or lose, while the second focused on factors impacting participant enjoyment. These models will be referenced as WinLossModel (WLM) and EnjoymentModel(EM) in this analysis. For all models level of significance will be represented at the levels of: * $p<0.05$; ** $p<0.01$; *** $p<0.001$. The WLM uses a linear regression while the EM uses an ordered logistic regression.

Each model has a simple configuration. This configuration contains only the outcome variable and the simple predictor, e.g. whether the likelihood of winning or losing when compared to the treatment only. The other models we present in each analysis add in factors like demographic and education variables.

5.2.2.2.1 Category Coding

The factors used in both sets of models, and their coding, are explained in the table below.

Variable	Explanation	Categories	Coding	Base Level
LossWin	Whether the participant has won or lost the game	- Loss - Win	- 0 - 1	Loss
Experience	The combination of game\non-game and content experienced by the participant	- ALB(G) - EAB(G) - OPM(G) - EAB(NG) - OPM(NG) - ALB (NG)	- 0 - 1 - 2 - 3 - 4 - 5	ALB(NG)
Treatment	Whether the participant received the Game (Experiment) or Non-Game (Control) treatment	- Control - Experiment	- 0 - 1	Control
Gender	The self-reported gender of the participant	- Female - Male - Other - Rather Not Say	- 0 - 1 - 2 - 3	Female
Age	The self-reported age bracket of the participant	- Under 18 - 18 to 27 - 28 to 37 - 38 to 47 - 48 to 57 - 58 to 67 - 68 and Over	- 0 - 1 - 2 - 3 - 4 - 5 - 6	Under 18
Education	The self-reported highest level of education completed by the participant	- Primary School - Secondary School - HNC or HND - Undergraduate - Postgraduate	- 0 - 1 - 2 - 3 - 4	Primary School
Prior knowledge	The self-reported level of prior knowledge that the participant had of the information they read	- None - A Little - Some - A Lot - Expert	- 0 - 1 - 2 - 3 - 4	None
Enjoyment	The self-reported level of enjoyment with the entire experience	- Disliked - Underwhelmed - It was ok - Liked	- 0 - 1 - 2 - 3	Disliked

Table 10: Variables and their Encoding

5.2.2.2.2 Models and Analysis

Variable	WLM1_Simple	WLM1_Added1	WLM1_Added2
LossWin			
Treatment			
Experiment	-.03488726	-.04903953	-.09827356
Gender			
Male		-.24749076	-.18551779
Other		**-1.191289****	-.74063186
Rather Not Say		**-1.2404371****	**-1.0642159***
Age			
18 to 27		.37042432	-.68937366
28 to 37		.38202316	-.68903061
38 to 47		**1.074696***	.06380117
48 to 57		.57783192	-.58260947
58 to 67		**-1.2434932***	**-2.3929157*****
68 and Above		.39866953	-.53845422
Education			
Secondary			.59448311
HNC or HND			**1.6714071****
Undergraduate			**1.445668****
Postgraduate			**1.2522652***
Prior knowledge			
2 – A Little			.01431583
3 - Some			.18535956
4 - A Lot			**-.99108243****
5 - Expert			-.64382938
_cons	.47957308***	.60975654**	.57352391*
n	396	396	396
Log Likelihood	-264.15482	-248.72775	-237.66814
p-value	0.8658	0.0006	0.0000

legend: * p<0.05; ** p<0.01; *** p<0.001

Table 11: RBGE Data – Ordered Logistic Regression – Loss compared to Control or Experient

When considering whether the Game treatment has any significant impact on the ability of participants to “win” the game, and therefore learn the information presented, we can conclude that there is no impact. None of the model specifications presented show any levels of significance for either a positive or negative impact.

Variable	WLM2_Simple	WLM2_Added1	WLM2_Added2
LossWin			
Experience			
ALB(G)	.06991827	.27108446	.34653548
EAB(G)	**-.94310195****	**-.87843761***	**-.99108088****
OPM(G)	**-.73735014***	**-.7445588***	**-.82989608***
EAB(NG)	**-.98794658****	**-.98794658****	**-1.0133907***
OPM(NG)	**-.88084844***	**-.88084844***	**-1.0476762***
Gender			
Male		-.27774307	-.23783576
Other		**-1.2612224****	-.8228119
Rather Not Say		**-1.242031****	**-1.0765328***
Age			
18 to 27		.40440238	-.62705525
28 to 37		.54728555	-.50336706
38 to 47		**1.1571387***	.23199835
48 to 57		.75948656	-.33759678
58 to 67		-.98951076	**-2.1129825****
68 and Above		.44678841	-.39201215
Education			
Secondary			.60147016
HNC or HND			**1.7769963****
Undergraduate			**1.4119766***
Postgraduate			**1.1766218***
Prior knowledge			
2 – A Little			-.09314452
3 - Some			.1299573
4 - A Lot			**-1.0688345****
5 - Expert			**-.85312681***
_cons	1.0076405***	1.0099095***	1.0336003**

n	396	396	396
Log Likelihood	-255.89525	-241.06079	-229.06394
p-value	0.0054	0.0000	0.0000

legend: * p<0.05; ** p<0.01; *** p<0.001

Table 12: RBGE Data – Ordered Logistic Regression – Loss compared to Experience

Taking each of the possible experiences, the combination of treatment and content, that a participant could be exposed to and comparing them to the Non-Game Asian Longhorn Beetle reveals an interesting result. Except for the Game treatment combined with the same content, all other experiences are significantly more likely to cause participants to lose. This suggests that there was some difference between the material for the Asian Longhorn Beetle and the other threats that caused a poorer performance.

Given the random distribution of demographics, we can conclude that significant results, e.g. the 58 to 67-year-old group being significantly more likely to lose as a result of the overall experiment design rather than an inherent property of the Game treatment alone. The results also indicate that those reporting a gender of Rather Not Say are more likely to lose.

Compared to those with a primary school level of education participants that had an HNC or HND, Undergraduate, or Postgraduate level of education were significantly more likely to win. These results are reflected across both sets of WLM models. While participants that believed they had higher levels of knowledge, A Lot or Expert, were significantly more likely to lose compared to those that had no prior knowledge. Participants reporting A Lot of prior knowledge being significantly more likely to lose in both sets of WLM models.

Variable	EM1_Simple	EM1_Added1	EM1_Added2	EM1_Added3
Enjoyment				
Treatment				
Experiment	-.03488726	**.36179152***	.3249361	**.40479154***
Gender				
Male		-.1765242	-.16192537	-.12379363
Other		**-1.8262191*****	**-2.0521573*****	**-1.928824*****
Rather Not Say		-.32123294	-.52504013	-.32076421
Age				
18 to 27		**-.59935123***	**-1.1183426****	**-.93968516***
28 to 37		**-.91878871****	**-1.4738049*****	**-1.3062739****
38 to 47		-.26061159	**-1.0095116***	-.90436414
48 to 57		. -.45993795	**-1.1307422***	-.89510088
58 to 67		-.17537416	-.92522721	-.39928935
68 and Above		. -.06941924	**-1.2019121***	**-1.0124493***
Education				
Secondary			.42108526	-.13556646
HNC or HND			**1.6714071****	.0432662
Undergraduate			.84000404	.48927897
Postgraduate			**.88947878***	.5197528
Prior knowledge				
2 – A Little			.01431583	.17211618
3 - Some			.18535956	.42963981
4 - A Lot			**-.99108243****	**1.0380496****
5 - Expert			-.64382938	**1.9872445*****
LossWin				
Win				**.97484735*****
/cut1	-1.9214665***	-2.5882647***	-2.3711353***	-1.8123185***
/cut2	-1.1073393***	-1.6977721***	-1.4625869***	-.8790645**
/cut3	.40776972**	-.05539219	.24024116	.8957468**
/cut3	1.5256867***	1.102509***	1.4789451***	2.1808032***
n	396	396	396	396
Log Likelihood	-597.62982	-579.99149	-564.88382	-553.85994
p-value	0.0220	0.0000	0.0000	0.0000

legend: * p<0.05; ** p<0.01; *** p<0.001

Table 13: RBGE Data – Ordered Logistic Regression – Enjoyment compared to Treatment

When we consider whether the treatment as a whole there are levels of significance in EM1_Added1 and EM1_Added3 that show participants receiving the experimental, game, treatment are more likely to enjoy themselves compared to those receiving the control treatment. It is, perhaps, unsurprising that those who won were also statistically more likely to enjoy themselves.

Variable	**EM2_Simple**	**EM2_Added1**	**EM2_Added2**	**EM2_Added3**
Enjoyment				
Experience				
ALB(G)	.53708018	.5711937	.42106777	.43077147
EAB(G)	.08220247	.14748641	.11267074	.35197199
OPM(G)	.21335952	.27036814	.31480118	.48060724
EAB(NG)	-.20321279	-.10299782	-.17016326	-.09315005
OPM(NG)	-.30975479	-.01254291	.04394963	.19148991
Gender				
Male		-.1694548	-.15537788	-.11825225
Other		**-1.8362204*** **	**-2.0719792*** **	**-1.9589752*** **
Rather Not Say		-.32086781	-.52442051	-.32319414
Age				
18 to 27		**-.60456692***	**-1.1595358** **	**-.98689597***
28 to 37		**-.87757701** **	**-1.451263*** **	**-1.3263943** **
38 to 47		-.26408047	**-1.0528849***	**-.96150726***
48 to 57		-.45784115	**-1.1483746***	-.93670018
58 to 67		-.1148869	-.85593428	-.37195207
68 and Above		-.06900956	**-1.2009289***	**-1.043314***
Education				
Secondary			.03390016	-.12470183
HNC or HND			.42014512	.0507389
Undergraduate			.87798797	.53218575
Postgraduate			.90326718*	.54816746
Prior knowledge				
2 – A Little			.1868628	.17492842
3 - Some			.44593304	.44480132
4 - A Lot			**.82851481***	**1.0682216** **
5 - Expert			**1.7234839*** **	**1.9832581*** **
LossWin				
Win				**.97941103*** **
/cut1	-2.0716433***	-2.6188516***	-2.4107706***	-1.7913218***
/cut2	-1.2541649***	-1.7278238***	-1.501826***	-.85731941**

/cut3	.26867898	-.08228894	.20397028	.92032536**
/cut3	1.3922049***	1.079179***	1.444865***	2.2069565***
n	396	396	396	396
Log Likelihood	-596.03918	-579.03083	-564.2263	-553.45862
p-value	0.1343	0.0001	0.0000	0.0000

legend: * p<0.05; ** p<0.01; *** p<0.001

Table 14: RBGE Data – Ordered Logistic Regression – Enjoyment compared to Experience

Compared to the Asian Longhorn Beetle Non-Game experience, no other experience that a participant could receive would be significantly more likely to make them enjoy or dislike their overall experience. This is in contrast to WLM2 where we did see particpants being significantly more likely to lose when presented with any Oak Processionary Moth or Emerald Ash Borer experience.

Interestingly, compared to the Under 18s several of the age groups were consistently significantly less likely to enjoy themselves. This may be a reflection on the relative lack of challenge in the game.

Additionally, those with advanced levels of prior knowledge were significantly more likely to enjoy themselves compared to those with no prior knowledge. This is in contrast to the WLM models where those levels of prior knowledge were an indicator of being more likely to lose.

5.3 Discussion

While no definitive results have emerged to indicate that presenting information via a serious game compared to the same information on its own leads to better performance during the end of experience quiz, there have been significant learnings from this experiment.

The assumption that participants would have limited time to spend with the experiment limited the number of questions we asked. Limiting, in turn, the analysis on winning or losing. While there were no significant results for individual experiences or the broad treatments to either positively or negatively, predict the likelihood of winning or losing, this caveat should be kept in mind. This particular shortcoming in the experiment would be challenged in future experiments by having pre and post-learning questions or by having more questions to answer.

Interestingly, when looking at factors that influence the ability of a participant to win or lose a level of achieved education at UK college (HNC or HND) or above

shows that participants are significantly more likely to win. However, when considering knowledge on the subject participants that believe they have A Lot or Expert knowledge on the threat are significantly more likely to lose.

While no definitive conclusions can be stated for why this is, it does raise an interesting question – what is the role of prior knowledge in the ability to win? It may be that participants who believe they know more are less likely to pay attention. However, this question goes beyond the scope of this study.

Considering whether participants enjoyed themselves also reveals a series of interesting questions and observations. In two of the four models that compare treatments, the SG treatment is significantly more likely to contribute to participants enjoying themselves compared to the Non-Game treatment.

Across both sets of enjoyment models when compared to Under 18s, all other age groups are either neutral or significantly more likely to lead to the participant disliking their experience. This result could be a function of the experiment design, given that it is a simple experience that does not offer much in the way of challenge. Another factor to consider is the immediate placement of the quiz question after learning the information needed to answer it. One person noted this in the playtest as patronising.

It is interesting to note that these results may reflect concerns raised by participants of the study in Chapter 4. There the respondents said that SGs were often designed for children and did not pose much of a challenge. If this is a root cause, then it runs counter to the experience of a Participant in Chapter 3. That Participant stated that in their experience, designing events for children ensured an enjoyable experience for everyone. However, when looking at factors that influence enjoyment, in nearly every age band, there was evidence of having a significantly less enjoyable experience compared to Under 18s. Future designs of the experiment may ask participants to comment on why they liked or disliked their experience.

What are the impacts of a participant enjoying their experience? Considering that having either A Lot or Expert levels of prior knowledge is an indicator of losing and are also an indicator of positively enjoying the experience, what does this mean?

Are participants that enjoy their experience more likely to remember the content?; to share it with others afterwards?; to change their habits and behaviours?

Enjoyment impact analysis appears to be limited to educational games in classroom environments [93]. Unfortunately, further exploration of enjoyment and what creates an enjoyable experience do go beyond the scope of this thesis.

From a design perspective, the need to closely link the content that is taught to the game world became evident [93]. Confusion over the symbols used and their relation to the facts in the card matching game highlighted this point. Similarly, having strong theming as in the pipe rotation game, where that pathogen attacks roots and water supplies, is not enough for a playable game. Games need to be accessible and understandable by the audience. This deeper embedding of information is something that will be a focus of the experiment discussed in Chapter 6.

Working with partners was beneficial in setting expectations for how participants would be likely to engage with our experiment. Certainly from the garden show perspective, which is their area of expertise, this proved to be very accurate.

However, the location for the second phase of the experiment was not one our partners had extensive knowledge of. Having a more extensive range of stakeholders in the design and development phase would have provided a more rounded picture of the environments where the experiment was conducted.

The number of participants that engaged with the experiment was sufficiently higher than was expected. We had estimated that between 50-100 completed experiences would be good based on the 40 participants recruited during the playtest. The fact that there were just under four times the upper amount was significantly beyond expectations.

6 Comparing Game v. Non-Game approaches in an online setting

In Chapter 5, we discussed a Game v. Non-Game experiment that we conducted in the Royal Botanic Garden Edinburgh. In that experiment, we discovered that neither the treatment, Game or Non-Game, nor the experience, the combination of treatment and material, had any significant impact on a player winning or losing. Investigating participant enjoyment, we discovered that the Game treatment, in half of the model specifications, had a statistically significant impact. This result posed the question: what does participants enjoying themselves mean?

In Chapter 6, we also compare a Game v. Non-Game presentation of information. This experiment is the culmination of the outcomes of previous chapters, shown in Figure 31 below.

The research questions we are interested in answering led to requirement gathering (RG) and game v. non-game experiment (G-NG) strands of work through this thesis. Chapter 3, the first of two RG chapters, revealed that the general public would be a practitioner preferred target audience and that those practitioners we interviewed were interested in the use of SGs. The highlighting of plant provenance as an area of interest also emerged in this study. These outcomes directly led to survey in Chapter 4, the second RG chapter, and Chapter 5, the first G-NG experiment.

Chapter 4 revealed that the members of the public surveyed felt that a SG would have an impact on their ability to learn information at a place like a botanic garden, they also suggested puzzle, strategy, and simulation genres as ones they would prefer to play.

Chapter 5 not only raised the question of what enjoyment means, but we learned that the information we want participants to learn must be tightly coupled to the gameplay. That is the actions players undertake in the game world must link to what we are teaching them, ideally using that information to reach a win state.

We also see evidence in both Chapters 4 and 5 that a simple game aimed at children may not be enjoyable for all. The game designed for Chapter 5 was very simple and designed for people to play without much challenge. Consequently, we

do see evidence that nearly all age groups, when compared to Under 18s, are significantly more likely to have a less enjoyable experience. However, we cannot say for sure that the design of the game was a reason for this as we did not collect that information from participants.

Two key differences between the experiments in Chapters 5 and this Chapter are the location used and the amount of time we expected the participant to spend on our experiment. We did not use a physical location for this experiment, instead opting to host it online. We also increased: the number of questions; the amount of information we present to the participant; the length of time the game will take to complete. This increase was in part due to the online nature of the experiment, and we felt we needed to ask participants more questions in the quiz phase to understand any impact that the treatment might have.

We also introduce a second phase in this experiment that we invited participants to complete three weeks after they participated in Phase 1. Three weeks sits between the two weeks used by All et al.[172] and the four week delay used by Carolyn Yang & Chang [173]. We are interested in exploring, alongside the immediate educational effectiveness, the longer-term retention of information. Given that participants do not, from Chapters 4 and 5, visit horticultural shows or botanic gardens regularly the ability to remember key points in-after visiting is essential.

6.1 Methods

6.1.1 Experiment Structure, Phases, and Recruitment

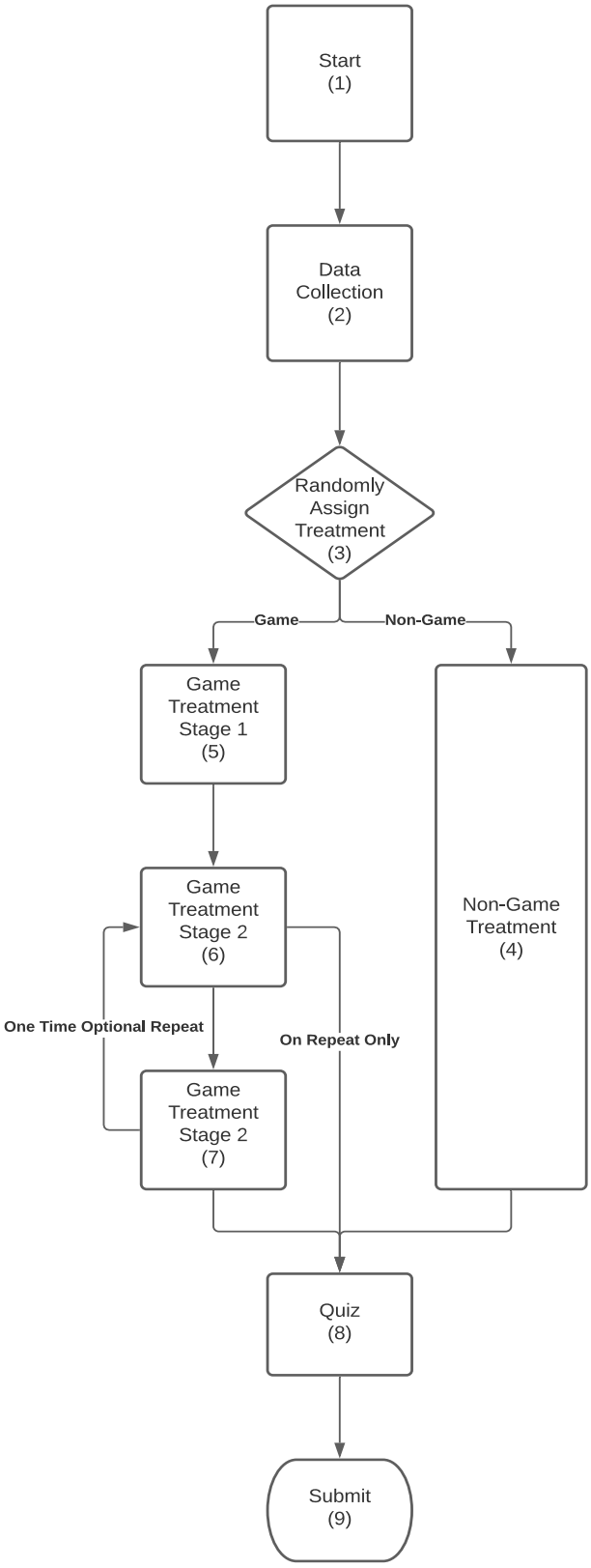


Figure 30: Phase 1 Experiment Structure

Figure 32 above shows the structure of the experiment, which was an online game developed using Unity3D. The participant is given an introductory message and asked for consent (1) before being asked for their age, gender, highest level of education, postcode, and email address (2). We then randomly assign the participant to either the non-game (control) or game (experiment) treatments (3).

We present participants that get the non-game treatment (4) with four sets of information. Participants must read each of the information sets once before they can move to the next step. Each information set contains a series of images and associated information across several screens. Although we ensure participants read the information a minimum of one time, they are free to re-read each set as many times as possible. After moving on from this step, participants cannot revisit the information. We present the same information to the participants receiving the game treatment.

Participants that receive the game treatment go through three distinct stages (5->7). In Stage 1(5) the participant must read the first of the four information sets – Plant Provenance – before being allowed to carry on, they cannot read any of the other information sets at this point. Stage 2 (6) is the game itself. Participants must choose from a selection of trees and plants, sourced from around the world, to complete a park renovation. We will give a complete description of the game in subsection 6.1.4.

Stage 3 (7) presents the same information screens as in (4), with the same restrictions to continuing in place. Before participants go to the quiz (8), they are offered the chance to replay the game. If this option is taken, then participants go back to Stage 2 (6) and upon completion, skip Stage 3 (7) and go straight to the quiz (8).

We present all participants with the same quiz (8) experience. The quiz consists of 16 multiple choice questions, split equally between the four information topics, and additional multiple-choice evaluation questions. Each quiz section has three questions on the presented information and one scenario-based question. The scenario questions ask the participant how they would behave in a given scenario. We do not show participants their quiz score or results. The evaluation questions are also multiple choice and cover the participant's enjoyment of their experience, whether they would engage with a similar experience in a physical setting, how

often they visited botanic gardens in a year, their perceived level of knowledge gain, and whether what they had learned might change their behaviour.

After completing the quiz, participants go to a submission screen (9) where we ask them to complete the experience by submitting the data gathered. Upon submitting, we show a thank you message and a reminder of how to retract their consent.

Phase 2 follows a much simpler process of participants completing another quiz. This quiz contains 22 multiple-choice questions. In addition to the original 16 questions the participant has already answered, we introduce two new questions each in three of the information sets. The plant provenance questions remain the same.

With regards to Phase 1, some unfortunate technical issues arose from limitations within the Unity3D platform and the author's own experience with the tool. For the former, the player used to show the game on the internet did not work on Safari browsers, which is a popular Apple browser. The latter issue was that the software was not compatible with mobile devices and emerged too late in the development process to be fixed. Future iterations of the experiment would fix this issue as a priority, especially given the mobile-friendly nature of the recruitment process.

6.1.2 *Experiment Phases*

These two phases took place over the following time periods:

1) Game v. Non-Game Treatment (18th February 2019 – 10th March 2019)
2) Time-Delayed Post-Treatment Quiz (11th March 2019 – 9th April 2019)

The earliest a participant could enter Phase 2 would be three weeks after they completed Phase 1. This time-lapse sits between the best practice suggested by All et al. where they suggest a 2-week minimum gap between the initial experience and a follow-up study [172] and the four weeks used by Carolyn Yang & Chang [173].

6.1.3 *Participant Recruitment*

Given the online nature of the experiment, physical recruitment opportunities were not possible. Therefore, as in Chapter 4, participant recruitment was focused on online channels.

We placed an advert on the University of Stirling's intranet as both many studies recruit participants this way, and University students and staff know it as a place to look for participation opportunities. Similarly, we emailed colleagues in our own and other departments that we thought would be interested in participating and asked them to share it with any relevant contacts they had.

We also turned to social media to recruit our participants. The author sent out a tweet, similar to that in Chapter 4, with 2,764 impressions and 137 engagements, Figure 33, including 76 direct click-throughs to the experiment.

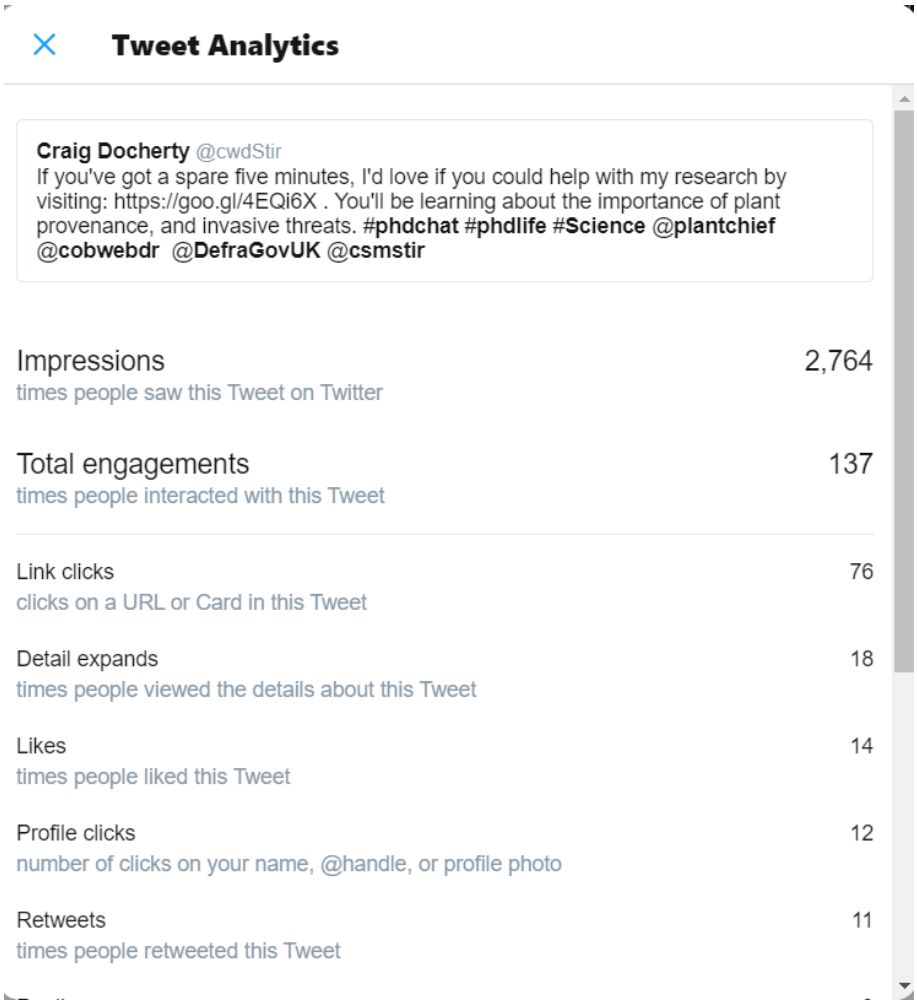


Figure 31: Twitter Engagement - Participant Recruitment

6.1.4 *Game Development Decisions and Game Design*

In this section we will discuss both the development decisions that went into creating the game as it appears in its final form, as well as discussing the overall design of the game itself.

6.1.4.1 Game Development Decisions

While we did not explicitly use a pre-set methodology to design the game, elements of the Learning Mechanics – Game Mechanics model [114] can be reflected in the development decisions that led to the final version of the game. Table 15, below, lists the Learning Mechanics and Game Mechanics present in the game, along with a brief description of how it relates to functionality within the game. The mechanics are drawn from the graphic shown in 2.4.1.4.

Learning Mechanic	**Game Mechanic**	**Relation to Game**
Instructional	Role Play	The player inhabits the role of a landscaper landscaping a park
Feedback	Selecting\Collecting	The player is given feedback on the product choices they make
Feedback	Goods\Information	The player is given feedback on the product choices they make
Plan	Strategy\Planning	The player needs to select the products that they want and where they want them from
Experimentation	Tiles\Grids	The players needs to place the products around the park, each planting location is a tile
Reflect\Discuss	Feedback	The player is given feedback on the threat each choice introduces
Analyse	Feedback	The player is given feedback on the threat each choice introduces
Simulation	Simulate\Response	The potential import of threat has been simulated based on real world information

Assessment	Assessment	The player's choices and the introduction of risk is assessed to give a ranking and title
Accountability	Ownership	The role playing aspect of the game gives the player some ownership and accountability over their decisions
Responsibility	Rewards\Penalties	Star ranking & title system

Table 15: Chapter 6 Game Learning Mechanics & Game Mechanics

These Mechanics were all introduced with one specific aim in mind; tightly coupling the information being learned, and the reason for learning it, to the gameplay.

We discovered in Chapter 5 that not having this coupling of information to the gameplay can be confusing to the player. Therefore all of the game design choices revolved around that principle. For example, we prime the player with an information set describing plant provenance and the importance of sourcing local products over international imports before they play the game. This is the key information that they are required to use to successfully "win" the game, e.g. achieving a maximum 3-star rating and the title of "Master Gardener".

While designing the game another key requirement was used as an assessment metric against design ideas, that being the game shouldn't be a barrier to learning. What we mean by this is that the game should be easy to play, accessible to a wide range of gaming experiences, and give feedback on gameplay aligned with the learning outcomes.

This was achieved through simplifying gameplay mechanics, e.g. having players view fixed viewpoints instead of walking around the game word, and providing dropdown menus for selecting products & locations. We also made the relationship between risk and location of product clear. If a product introduces risk to the park the level of risk is identified, as is a reminder of where the product has been sourced from. So the player may see feedback for one product that indicates no risk as the product is from Britain, sourced locally, and feedback for another that indicates medium\high levels of risk as it is from outside Britain.

From a broader technological perspective the decision was made to develop the game using Unity3D due to technical experience with that platform, e.g. in creating the game in Chapter 5.

We also decided to utilse a web based approach for this study rather than the physical installation seen in Chapter 5. This was a function of available time both from a research perspective, and the amount of time we would want the participant to spend engaging with the study.

We can summarise our development decisions as follows:

- Selection of game and learning mechanics that supported tightly coupling the information to be learned to gameplay;
- Creating game mechanics that attempted to remove barriers to play, e.g. prior gaming experience requirements;
- Providing feedback that reinforced the key learning points on plant provenance.

6.1.4.2 Game Design

Initial design discussions on the design of the game conceptualised the design of a show garden, of the type seen at Chelsea Flower Show, with participants following a tutorial on how to create a good garden and then creating one of their own. We, ultimately, deemed this too ambitious for a doctoral project.

Design of the game then switched to renovating, or landscaping, a park with the participant role-playing as an official that was making purchasing choices. Initially, this included the ability of the participant to walk around their park and view the decisions they made before being surveyed by DEFRA. This survey would look for any threats introduced to the park by the participant's choices.

Both of these design ideas centred around the concept of plant provenance, where trees and plants originate, and the importance this consideration plays in the introduction of new threats to the UK. This topic arose from conversations held with Participants in Chapter 3.

In both of the initial designs and the final game, participants would learn this information before playing the game and would have to make use of it to win. This

builds on learnings from Chapter 5, where the information to be learned was not initially required to “win” the game.

The final version of the game puts participants in the role of a landscaper given the task of selecting trees and plants to beautify a new park. Four different species must be selected, Figure 34 (a). Participants can select products from specific sites located within three different countries of origin, Figure 34 (b). The countries of origin vary between each product. Each option is either safe or associated with some level of risk of introducing one of three threats (Emerald Ash Borer, Oak Processionary Moth, and *Xylella fastidiosa*) into the UK.

In all cases, UK sources have the lowest risk, because they present no possibility of importing a threat, and the other sources have either high risk (because the threat is known to be present at the named site) or medium risk (because the threat is known to be in the country, but has not been reported at the named site). Making these choices encourages the participant to think about the information on plant provenance that they will have read before playing the game.

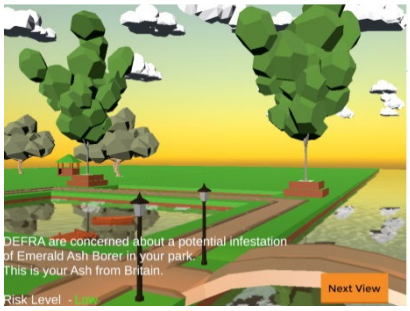
After purchasing the plants, participants can select locations in the park to put these, and are then shown a visualisation of the newly landscaped park, Figure 34 (c). An information panel gives feedback about each product selected and the risk level associated with that product. The feedback also includes the name of the exact pest\pathogen that it carries a potential risk of introducing.

After completing the game, participants are given a score representing the level of risk they introduced into the park, Figure 34 (d). The score a participant receives is represented via a 3 star system, and they may be awarded one of the following: 3 stars – Master Gardener, 2 stars – Rookie Gardner, and 1 star – Park Vandal.

We then present participants with four information screens, Figure 34 (e), where they can learn about the remaining three threats, as they will have viewed information on plant provenance before playing the game. The participant must visit each screen at least once before progressing. After viewing the information, the participant can choose to attempt the game again or move on to a final quiz and feedback section, Figure 34 (f).

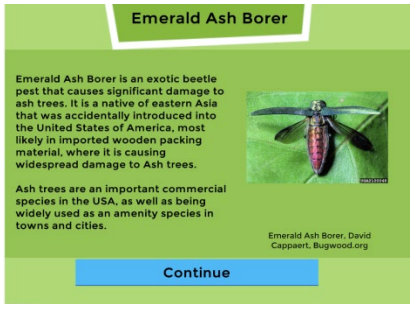
(a) Plant selection - Game

(b) Source selection - Game

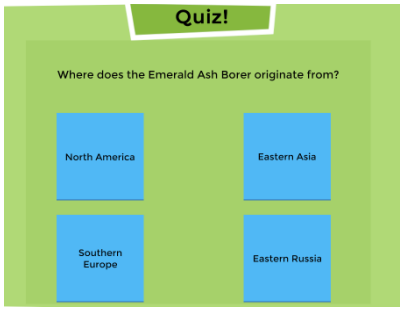


(c) Result feedback - Game

(d) Score feedback - Game



(e) Information screen



(f) Quiz screen

Figure 32: Software screenshots. (a)-(d) show the Game treatment. (e) and (f) are common to both Game and Non-Game treatments.

6.1.5 *Information*

Following on from Chapter 5, we retained two of the three threats presented to participants - Emerald Ash Borer and Oak Processionary Moth. Discussions with tree and plant health colleagues resulted in the Asian Longhorn Beetle being removed and replaced by *Xylella fastitidosa*. *Xylella* is considered to be a more significant threat to the United Kingdom and thus more important to include.

We also present information on Plant Provenance. This is a topic that emerged during Chapter 3 as an area of importance for future behaviour change. Briefly, changing attitudes around buying British and not importing as much tree material

would lessen the chances of introducing novel pests and pathogens. Importing material is driven by the needs of commercial landscapers and public interest in non-native species for their private gardens.

We sourced the information we present to the participant from a range of sources, including the Forestry Commission and DEFRA, with our partners reviewing the information before we launched the experiment. A full listing of the information we present can be found in Appendix D.

6.1.6 *Data Collection*

The data we collected from participants falls into two categories:

1) Directly asked for
2) Background gathering

We describe the data collected in Table 16 below.

Data	Direct\Background	Type of Response
Age	Direct	Single choice from pre-set age bands
Gender	Direct	Single choice from pre-set categories
Education	Direct	Single choice from pre-set categories
First half of postcode	Direct	Free entry
Email Address	Direct	Free entry
Enjoyment of Experience	Direct	Single choice from pre-set categories
Physical Engagement	Direct	Single choice from pre-set categories
Frequency of Visits to Botanic Gardens	Direct	Single choice from pre-set categories
Improved Knowledge of Threats	Direct	Single choice from pre-set categories
Treatment	Background	Game or Non-Game
Start and End Time	Background	Hours and Minutes
Time Spent Reading Each Information Set	Background	Seconds
Number of Times Each Information Set was Viewed	Background	Integer, minimum of 1 each
Products Selected	Background	Integer representation of the products
Round 1 Rank	Background	String – awarded title
Round 2 Rank (Optional)	Background	String – awarded title
Round 2 Products selected	Background	Integer representation of the products
Timestamp	Background	Time

Table 16: A list of the data and how it was gathered along with the response type allowed.

6.1.7 *Statistical Analysis*

For both Phase1 and Phase2 we utilised the statistics software package Stata, specifically Stata/IC 16.1. This is the same piece of software that was utilised in Chapter 5 to perform the statistical analysis.

The analysis for Phase1 looks at two sets of models with one looking at the overall score the participants obtained, and the other their overall enjoyment of the experience.

For the overall score model, we performed a linear regression. The linear regression was selected as the dependent variable, the score, was a continuous value. Conversely, an ordered logistic regression was selected for the enjoyment model as that dependent variable comprised discrete values that are non-linear in nature.

The models used for the analysis of Phase2 data used a linear regression. The dependent variable for these models comprised continuous, linear, data and as such a linear regression was appropriate.

For all models we include the number of observations for each model. The linear regression models include their r^2 value, while the ordered logistic regression model includes the Log likelihood value. Both of these values indicate goodness of fit within the model. We also include the p-value for each model.

The models follow a similar pattern of construction. The first model specification presented in each table is the primary comparison between the dependent variable and the treatment the participant received. We then build out the second and third specifications as follows:

- Specification 2: Dependent Variable, Treatment received, Gender of participant, Age of participant;
- Specification 3: Dependent Variable, Treatment received, Gender of Participant, Age of participant, participant's Highest Level of Education, participant's self-assessed Knowledge Gain via the experience.

For Phase1 there is one case of a 4th specification to look at whether winning in Phase 1 had an impact on enjoyment. In Phase2 there is a consistent 4th specification that adds the self reported level of enjoyment in Phase 1.

In order to create the tables showing the results of these models, we made use of the estimates feature in stata. The feature is a way to store the results of analyses for future use, it also provides functionality to condense multiple analyses into one table [174]. Both of these features were used to store and generate the output presented.

6.2 Results

There were 42 participants in Phase 1 (P1). Of these, the software randomly assigned 18 to the Game treatment and 24 to the Non-Game treatment. 23 P1 participants returned for Phase 2 (P2), and these were almost equally split between the two treatments. In both phases, there were roughly twice as many males as females (Table 17)

Most participants were aged 18-27 or 48-57 (Table 18). Most had received a university education at either undergraduate or postgraduate level (Table 19), 31 of 42 in P1 and 16 of 23 in P2. Most participants also reported visiting garden centres or botanical gardens at least once per year, though there were a substantial number (roughly one third) who reported no visits (Table 20). Almost all of those who made no visits were in the younger age groups (ages 18-27 and 28-37).

	Phase 1			**Phase 2**		
	Female	**Male**	**Total**	**Female**	**Male**	**Total**
Game	7	17	24	3	9	12
Non-Game	5	13	18	4	7	11
Total	12	30	42	7	16	23

Table 17: Gender distribution

	18-27	**28-37**	**38-47**	**48-57**	**57-67**	**Total**
Game (P1)	7	2	2	5	2	18
Non-Game (P1)	9	7	3	2	3	24
Total	16	9	5	7	5	42

Game (P2)	4	0	1	5	1	11
Non-Game (P2)	5	5	0	2	0	12
Total	9	5	1	7	1	23

Table 18: Age distribution

	Primary	Secondary	HNC/D	Undergraduate	Postgraduate	Total
Game (P1)	0	4	1	3	10	18
Non-Game (P1)	1	4	1	8	10	24
Total	1	8	2	11	20	42
Game (P2)	0	4	0	1	6	11
Non-Game (P2)	0	3	0	4	5	12
Total	0	7	0	5	11	23

Table 19: Highest Level of Education plotted against Treatment

	18-27	28-37	38-47	48-57	57-67	Total
None	6	5	0	2	0	0
Once or Twice	8	3	3	3	4	0
Several	2	1	2	2	1	0

Table 20: Frequency of Visits to Botanic Gardens plotted against Age Banding

Phase 1 participants that received the game treatment had the lowest (5) and highest (15) scores. However, the mean score for the non-game treatment (11.5) was slightly higher than the mean score for the game treatment (10.8). Although, the confidence intervals overlap (10.7 to 12.3 & 9.6 to 12.1, respectively) implying that there is no significance.

Interestingly, this is reversed in Phase 2 with the non-game treatment having a mean score of 12.8 compared to the game treatment mean of 14.3. Again, however, the confidence intervals of both means intersect, implying that there is no significant effect here. With both the Phase 1 and Phase 2 scores showing a

similar effect, we would expect to see no significant effect on the participant's score based on treatment assigned in Phase 1.

Prior to conducting the experiment no power sample size calculation was conducted. Therefore, we have conducted a reverse calculation to infer what size of result could be detected with the sample size we have.

Treatment	Mean	Standard Deviation (SD)
Non-Game	11.45833	1.910592
Game	10.83333	2.455486
Total	11.19048	2.155403

Table 21: Summary for variables: Phase1Score

Table 21 shows the mean calculation and standard deviation for the two treatment groups in the study. The total standard deviation will be used in all power calculations. The calculations are shown in Table 22 below. We start with our known results and work from that point to establish the size of difference we can reasonably detect.

These calculations were conducted using the twomeans command in Stata. Twomeans is a power calculation used to compare two groups with the following command syntax: power twomeans mean1 mean2, sd(value) nratio(value). Sd in this instance is Standard Deviation, and nratio is the ratio of group2/group1. In the case of the data in this study, a consistent value of 0.75 will be used as the ratio of our Game\Non-Game groups is 0.75.

Using Permutation 1, from Table 22, as an example this translates to: power twomeans 11.45833 10.83333, sd(2.155403) nratio(0.75), and gives the results in the Non-Game Sample Size required and Game Sample Size Required values in that row.

Permutation	Non-Game Mean	Game Mean	SD	Non-Game Sample Size Required	Game Sample Size Required	Total Sample Size Required
1	11.45833	10.83333	2.155403	219	165	384
2	11.5	10.83333	2.155403	193	145	338
3	11.6	10.83333	2.155403	146	110	256
4	11.7	10.83333	2.155403	115	87	202
5	11.8	10.83333	2.155403	93	70	163
6	11.9	10.83333	2.155403	76	57	133
7	12.0	10.83333	2.155403	64	48	112
8	12.1	10.83333	2.155403	55	42	97
9	12.2	10.83333	2.155403	47	36	83
10	12.3	10.83333	2.155403	41	31	72
11	12.4	10.83333	2.155403	27	36	63
12	12.5	10.83333	2.155403	32	24	56
13	12.6	10.83333	2.155403	29	22	51
14	12.7	10.83333	2.155403	26	20	46
15	12.8	10.83333	2.155403	24	18	42

Table 22: Power Size Calculations

As shown in Permutation 15, the sample size found in the study is sufficient to detect a difference of 1.9667. The actual difference between the means in the groups is 0.6250. Therefore it is reasonable to conclude that there may be effects in the study that are not detectable given the power level of the sample size.

A similar conclusion can be reached for Phase 2. Given the differences we see in the mean scores for both the Non-Game and Game groups across the different score groupings: All Phase 2 questions, questions common between Phase 1 and Phase 2, and new questions introduced for Phase 2 only. A common nratio value of 0.917 is used for these calculations.

Question Set	Non-Game Mean	Game Mean	SD	Non-Game Sample Size Required	Game Sample Size Required	Total Sample Size Required
Phase 2 Total	12.75	14.27273	2.591412	49	45	94
Phase 1 & 2 Common	10.33333	11.09091	2.42027	169	165	324
New to Phase 2	2.416667	3.181818	1.166055	40	37	77

Table 23: Sample sizes required for Phase 2 based on observed results

Therefore, while we may – and indeed do – see some evidence of significance within the results these findings must be balanced against the fact that there may be effects that cannot be detected by the sample size in this study.

6.2.1 *Variable Encoding Guide(s)*

The following variables and their encoding we used in the statistical analysis of the P1 and P2 data.

6.2.1.1 Phase 1 Analysis Variables

Variable	**Explanation**	**Categories**	**Coding**	**Base Level**
Phase1Score (Outcome)	The number of questions answered correctly in Phase 1	Continual integer scale from 0 - 16		
Treatment	Whether the participant received the Game (Experiment) or Non-Game (Control) treatment	- Control - Experiment	- 0 - 1	Control
Gender	The self-reported gender of the participant	- Female - Male - Other - Rather Not Say	- 0 - 1 - 2 - 3	Female
Age	The self-reported age bracket of the participant	- 18 to 27 - 28 to 37 - 38 to 47 - 48 to 57 - 58 to 67	- 0 - 1 - 2 - 3 - 4	18 to 27
Education	The self-reported highest level of education completed by the participant	- Primary School - Secondary School - HNC or HND - Undergraduate	- 0 - 1 - 2 - 3 - 4	Primary School

		-	Postgraduate			
Knowledge Increase	The self-reported level of increased knowledge on the presented information	- - -	None A Little A Lot	- - -	0 1 2	None
P1WinLoss	Whether the participant “won” or “lost”. Categorised as getting more questions correct than wrong	- -	Loss Win	- -	0 1	Loss
Enjoyment (Outcome)	The self-reported level of enjoyment with the entire experience	- - - -	Disliked Underwhelmed Enjoyed Very Enjoyable	- - - -	0 1 2 3	Disliked

Table 24: Chapter 6 - Phase 1 Variables

6.2.1.2 Phase 2 Analysis Variables

In addition to the variables defined for the Phase 1 analysis, we added the following variables for Phase 2.

Variable	Explanation	Categories
Common Questions (Outcome)	The questions present in Phase 1 and Phase 2	Continuous integer scale from 0 – 16
Phase 2 New (Outcome)	New questions introduced in Phase 2	Continuous integer scale from 0 – 6
Total Questions (Outcome)	All questions present in Phase 2	- Continuous integer scale from 0 – 22

Table 25: Chapter 6 - Phase 2 Additional Variables

6.2.2 *Phase 1 Analysis*

For the first outcome variable in Phase 1, Phase1Score, we conducted a linear regression across 3 model specifications. These specifications are the same as those used in Chapter 5, thus allowing for a comparison of results between experiments. The second outcome variable, Enjoyment, required an ordered logistic regression due to its categorical nature.

The models used are:

- Phase1Score:
    - P1Score_Simple: The outcome variable compared to the Treatment received only.
    - P1Score_Added1: P1Scorer_Simple with Gender and Age variables added.
    - P1Score_Added2: P1Score_Added1 with Education and Knowledge Increase variables added.
- Enjoyment:
    - P1Enjoyment_Simple: The Enjoyment outcome variable compared to the Treatment received only.
    - P1Enjoyment_Added1: P1Enjoyment_Simple with Gender and Age variables added.
    - P1Enjoyment_Added2: P1Enjoyment_Added1 with Education and Knowledge Increase variables added
    - P1Enjoyment_Added3: P1Enjoyment_Added2 with whether a Win or Loss state was recorded.

For the Phase1Score models, we performed a linear regression in Stata/IC 16, storing the results of each regression in an estimates variable. These estimates variables were turned into the tables presented below via the estimates table [variable1 variable2 variableN], star command. This command compared all of the estimates variables and highlighted areas of significance to <0.05, 0.01, and 0.001 levels of significance.

There are no consistent patterns of behaviour across the model specification in Table 26 below. We can conclude that treatment the participant receives has very weak to no impact on their ability to achieve a higher Phase1Score. The _Added2 specification suggests that participants receiving the Game treatment were

significantly more likely to get a lower score than the Non-Game treatment, and is the only model specification to do so.

Variable	P1Score_Simple	P1Score_Added1	P1Score_Added2
Phase1Score			
Treatment			
Experiment	-.625	-1.1287373	**-1.5346492***
Gender			
Male		.69760109	.97492103
Age			
2 – 28 to 37		-.62042523	-1.4619708
3 – 38 to 47		.35389237	-1.4107951
4 – 48 to 57		2.0966615*	1.0520355
5 – 58 to 67		1.4934126	.54212142
Education			
Secondary			-1.292328
HNC or HND			-2.8378461
Undergraduate			-2.8669334
Postgraduate			-.91484316
Knowledge Increase			
2 – A Little			1.8766036
3 – A Lot			1.3782775
			legend: * p<0.05; ** p<0.01; *** p<0.001
n	42	42	42
R^2	0.0211	0.2103	0.4022
p-value	0.3588	0.1900	0.1388

Table 26: Phase 1 – Phase1Score - Linear Regression Results

In specification _Added1 the 48 to 57 age group are statistically significantly more likely to get a higher score, although this does not carry into _Added2.

For the Phase1Enjoyment models, we performed an ordered logistic regression in Stata/IC 16, storing the results of each regression as was done for Phase1Score.

Variable	P1Enjoyment_ Simple	P1Enjoyment _Added1	P1Enjoyment _Added2	P1Enjoyment _Added3
Enjoyment				
Treatment				
Experiment	-.05285871	-.47607734	**-1.7277508***	-1.5710932
Gender				
Male		-.00672511	-.09207668	-.27783806
Age				
2 – 28 to 37		-1.3174813	**-2.4218404***	-1.6700188
3 – 38 to 47		-1.1265848	-1.850685	-1.6292048
4 – 48 to 57		.95617167	.72166374	.68874719
5 – 58 to 67		-.50775044	-.48071263	-.58525223
Education				
Secondary			2.4202285	2.4267384
HNC or HND			1.8533261	1.2126909
Under graduate			.31885826	1.1396461
Post graduate			1.9678407	1.7794588
Knowledge Increase				
2 – A Little			1.3097935	1.3263389
3 – A Lot			**3.695458***	**4.1713895***
P1LossWin				
Win				**3.9073978***

				legend: * p<0.05; ** p<0.01; *** p<0.001
n	42	42	42	42
Log Likelihood	-43.233048	-40.329003	-33.435731	-30.348295
p-value	0.9308	0.4442	0.0750	0.0182

Table 27: Phase 1 - Enjoyment - Ordered Logisitic Regression Results

Similar to the results seen for Phase1Score there are no consistent results of significance across the specifications for the treatment received and levels of participant enjoyment. In specification _Added2 we see that the Game treatment is significantly more likely to lead to lower levels of enjoyment compared to the control treatment. This result mirrors the the Phase1Score model specification for _Added2. So there is a consistency in the Game treatment leading to a significantly more likely lower score and lower levels of enjoyment.

Participants in the 28 to 37 age bracket are significantly more likely to have a lower enjoyment compared to the 18 to 27 age group.

In both specifications, _Added2 & _Added3, in which the increase in participant knowledge is present, we see that participants reporting A Lot of improved knowledge are more likely to report higher levels of enjoyment. Similarly, and perhaps more interestingly, those that Win are more likely to report higher levels of enjoyment than those who Lost. This outcome is interesting as participants were not given an indication as to how well they performed.

6.2.3 *Phase 2 Analysis*

The three outcome variables we assess in Phase 2 all use the same model specifications, with the only variant being the outcomes themselves. Their names follow a similar pattern, and in the specification list below [outcome] is used to represent the outcome variable:

- [outcome]_Simple; The outcome variable compared to the treatment received in Phase 1.
- [outcome]_Added1: [outcome]_Simple with Age and Gender added.
- [outcome]_Added2: [outcome]_Added1 with Education and Knowledge Increase added.
- [outcome]_Added3: [outcome]_Added2 with the Enjoyment of Phase 1 added.

Information on the treatment received, age, gender, the highest level of achieved education, reported levels of knowledge increase, and enjoyment were all taken from the Phase 1 result and matched with participants in Phase 2. The answers given in Phase 1 by the returning participants were also matched against their answers in Phase 2 to establish their Common Questions score.

Variable	P2Common_Questions_Simple	P2Common_Questions_Added1	P2Common_Questions_Added2	P2Common_Questions_Added3
Common Questions				
Treatment				
Experiment	.75757576	-.60825593	-.19727118	-.21127711
Gender				
Male		-.76883385	-.33225983	-.36794108
Age				
2 – 28 to 37		-1.1403509	-1.4732294	-1.6556742
3 – 38 to 47		4.1754386	2.723136	4.5194595
4 – 48 to 57		1.1007224	.58343158	-.77495791
5 – 58 to 67		1.1754386	-.27686402	1.5194595
Education				
Under graduate			.90165914	.94877189
Post graduate			.99046784	1.7590063
Knowledge Increase				
2 – A Little			1.4084165	1.1031042
3 – A Lot			.23659315	-1.5080942
Enjoyment				
3 - Enjoyed				**3.8693125***

4 – Very Enjoyable				**5.2840256***
				legend: * p<0.05; ** p<0.01; *** p<0.001
n	23	23	23	23
R^2	0.0256	0.1943	0.3079	0.6485
p-value	0.4662	0.6949	0.8358	0.2517

Table 28: Phase 2 - Common Questions - Linear Regression

When we look at the factors that may predict whether a participant achieves a higher or lower score in the repeated Phase 1 questions, it is only their enjoyment of Phase 1 that proves significant. Compared to those that reported being underwhelmed by their experience in Phase 1, those that report that they Enjoyed themselves, or had a Very Enjoyable experience, would be more likely to get a higher score.

Variable	P2New_ Questions_ Simple	P2New_ Questions_ Added1	P2New_ Questions_ Added2	P2New_ Questions_ Added3
Phase 2 New Questions				
Treatment				
Experiment	. .76515152	**1.3347781***	1.0786727	.93906066
Gender				
Male		.42621259	.23432153	.2411979
Age				
2 – 28 to 37		.49122807	.65589326	.40643096
3 – 38 to 47		-2.6140351*	-2.1517382	-2.1184226
4 – 48 to 57		.23570691	.36742675	.05996585
5 – 58 to 67		-1.6140351	-1.1517382	-1.1184226
Education				
Under graduate			-.85838341	-1.0572111
Post graduate			-.57618541	-.53454709
Knowledge Increase				
2 – A Little			.0719441	.17821984
3 – A Lot			.2499353	.53872807
Enjoyment				
3 - Enjoyed				.29793555
4 – Very Enjoyable				-.54394764
				legend: * p<0.05; ** p<0.01; *** p<0.001
n	23	23	23	23
R^2	0.1123	0.3993	0.4774	0.5031
p-value	0.1180	0.1685	0.4336	0.6153

Table 29: Phase 2 - Phase 2 New Questions - Linear Regression

Similarly to the results in Table 28, there are some weakly significant results in one of the specifications, _Added1. We see that compared to the non-game treatment being presented with the game treatment in Phase 1 is an indicator of answering more of the new questions correctly. Similarly, if the participant is in the 38 to 47 age band are more likely to get fewer questions correct compared to the 18 to 27 age group.

Variable	P2Total_ Questions_ Simple	P2Total_ Questions _Added1	P2Total_ Questions _Added2	P2Total_ Questions _Added3
Total Questions				
Treatment				
Experiment	1.5227273	.72652219	.8814015	.72778355
Gender				
Male		-.34262126	-.09793829	-.12674318
Age				
2 – 28 to 37		-.64912281	-.81733617	-1.2492433
3 – 38 to 47		1.5614035	.57139776	2.4010368
4 – 48 to 57		1.3364293	.95085833	-.71499206
5 – 58 to 67		-.43859649	-1.4286022	.40103681
Education				
Under graduate			.04327573	-.10843919
Post graduate			.41428243	1.2244592
Knowledge Increase				
2 – A Little			1.4803606	1.2813241
3 – A Lot			.48652845	-.96936611
Enjoyment				
3 - Enjoyed				**4.1672481***
4 – Very Enjoyable				4.7400779
				legend: * p<0.05; ** p<0.01; *** p<0.001
n	23	23	23	23
R^2	0.0901	0.1730	0.2245	0.5394
p-value	0.1641	0.7574	0.9482	0.5230

Table 30: Phase 2 - Phase 2 All Questions - Linear Regression

Continuing the trend established in Table 28 & Table 29, when assessing the overall score for Phase 2, there is only one suggestion of significance. If a

participant reported they Enjoyed themselves in Phase 1, then they are significantly more likely to score higher in Phase 2.

When considering Phase 2 alone, we can conclude that the treatment the participant was presented in Phase 1 has no significant role to play when we combine the repeated and new questions. Although, as has been noted with respect to the new questions, there is some weak evidence that participants presented with the game being more likely to perform better compared to the non-game. While there are only 42 participants in the study, this is in keeping with the number of participants in other published works, e.g. [76], [88], [94], [109], [126], [128].

6.3 Discussion

The most notable observation from our study is that although participants who played the game got lower scores in Phase 1 than those who did not, they reported a higher perceived increase in knowledge. We previously observed a similar phenomenon in a study [99] involving a serious game for use in teaching Marine Ecology, where students reported that they preferred to explore the game independently, but got better test results if the game was instead demonstrated to them by an expert.

These results suggest that players of serious games may not be the best judge of the kind of experience that is most effective for their own learning. The introduction of tutor-led engagement, as seen in [99], combined with the design of this study, would be an exciting course of action to take if this experiment were to be rerun. It does pose the question of whether or not SGs can be used as stand-alone learning experiences that are not supported by other materials or methods?

Considering the analysis for the common questions asked between phase 1 and phase 2, we see evidence that those who enjoyed the experience are more likely to have a higher score than those who did not enjoy themselves. This result may be similar to one of those found by Poullis et al. in their 2019 paper evaluating a SG teaching seaborne trade in the Mediterranean in the Classical period. They discovered that if the player is engaged in the game then they have a better chance of longer term retention of information [175]. It may be that to enjoy an experience is to be engaged, future work on understanding these concepts with regards to SGs will be required to draw stronger conclusions.

Lessons were also learned from Chapter 5's experiment, with the information being much more closely related to the gameplay. Putting one information set before the game also primed participants to think of plant provenance as they were completing their park. Despite this, not all participants took the message on-board, with several achieving 1 and 2-star scoring ranks, indicating that risk was introduced to their parks.

The study suffered from a number of limitations. The software used for Phase 1 was not usable from mobile devices, which may have impacted participant recruitment due to advertising the study through mobile-friendly social media platforms.

The broadly weak results from the analysis are indicative of further work being required to understand the types of games that work with the target audience, along with a tightening of the actual target audience themselves. Looking at the general public as a whole is too broad a group, with too diverse a range of interests and preferences, to engage with effectively through one SG.

The study also had a small sample size in both phases, and although this is consistent with other published works the power calculations conducted after data collection indicate that the sample size wasn't large enough. Therefore, there may be effects from the study that the sample size isn't large enough to detect. If the experiment was to be repeated, then these calculations would be conducted ahead of the study running to estimate the overall sample size required to detect effects at a small enough level of granularity.

The participants themselves may not have been representative of the target audience (plant purchasers in the UK) instead being a convenience sample recruited through personal contacts and social media connections.

Future work would look to create a mobile friendly website that would enable participants engaging on a mobile device to take part. Re-running the study with a larger sample size that is more representative of the target audience would also be an aim for future work. An alternate method to running the experiment that addresses the limitations of this study would be to redevelop the software for use in a physical installation in a setting like a botanical garden or garden centre, where members of the target audience are likely to be present.

7 Future Experiments & Conclusion

In the introduction to this thesis, we described two research questions that we were interested in answering. These questions were:

- **To what extent is there an appetite for using Serious Games among plant health professionals and the general public?**
- **When compared to traditional methods of presenting information in public engagement, can Serious Games improve participant engagement and retention of information?**

Chapters 3 and 4 addressed the first question. In Chapter 3, we interviewed tree and plant health practitioners to understand their current practices and attitudes towards the use of Serious Games. Chapter 4 described an online survey conducted with the general public that we designed to understand their experiences with and opinions on Serious Games and learn more about what types of games they would want to play.

Chapters 5 and 6 addressed the second research question. Both chapters utilised game v. non-game approaches that would present the same education material either via a game or on its own. Chapter 5 used a short experience in a physical location, while Chapter 6 had a longer experience that we conducted online. In both experiments, we used end of experience quizzes to evaluate immediate learning with the experiment. Chapter 6 also employed a second post-experience quiz completed three weeks after the initial experience.

If we consider that the research questions contribute to the larger theme of the efficacy of Serious Games in helping the public learn information, then three conclusions could present themselves:

1) Serious Games are not effective at helping members of the public learn information
2) Serious Games may be effective, but we did not have sufficiently well-designed games
3) Serious Games may be effective, but we did not have sufficiently rigorously designed experiments

Within our experiments, we can change multiple factors that may lead to a better-designed game or experiment. While there are factors that can be changed, we cannot say that conclusion 1 is applicable. This rest of this Chapter will explore the changes that could be made either to the experiment design or the Serious Game. We will also suggest areas on which future research could focus.

7.1 Discussion

If we start by looking at whether practitioners or the general public are interested in the use of Serious Games, we can broadly say that those interviewed and surveyed have shown an interest. However, we cannot say this is true for all practitioners nor all members of the public.

We engaged only a small subset of the tree and plant health practitioners from around the United Kingdom. Whilst they were keen to see Serious Games used with the public their reticence to utilise them with a professional audience gives pause for thought.

There was a feeling that games were too childish to be used with professionals that are paying for training. Given that there are Serious Games in the literature designed expressly for training professionals, e.g. D-Cite used for airport management [108], then those concerns may be unfounded.

Having conversations with paying professionals to understand what their expectations of a training session would be should be a natural extension of understanding the practitioners. It may be that those professionals are entirely opposed to the use of Serious Games, but it may also be possible that they would be open to a tool that would enhance their training.

While more work is required to understand the audiences, messages, and approaches that practitioners would want to be engaged or represented in Serious Games, the needs of the audience(s) themselves also needs to be understood.

While we did not engage paying professionals during this thesis, we did work with the general public. Although we have engaged a broad sweep of the public in our surveys and experiments, future work should be far more targeted. If we consider the issue of plant provenance, then the general public as a whole cannot be considered an appropriate audience.

If we consider, for example, the planting of imported species in gardens, then people under the age of 18 generally do not have the purchasing or decision-making power in selecting the origin of said plants. Similarly, members of the public that live in high-density housing are less likely to have gardens that they can introduce non-native species to.

However, if we were to consider plant provenance in public beautification projects, e.g. replanting a public park, then the target audience can be less restrictive. A serious game project that raised awareness of the importance of sourcing native\UK reared plants compared to imported products would be suitable for the general public. Primarily because any campaigning pressure emerging from that serious game would be placed on the local council, or responsible authority, to make bio-secure decisions, and this is something to which any member of the public can contribute.

While we recognise that a deeper level of understanding is required, we also recognise that this body of work is one that will require cross-discipline involvement to deliver. Psychology and the social sciences are, due to the often human-centric component of their work, two disciplines that we would look to for relevant frameworks and collaboration.

When developing this understanding, there are lessons learned in this thesis that can be incorporated. We know that the practitioners are hesitant to use Serious Games with paying professionals in training sessions, that they use games in their work already, and that they have a deep understanding and respect for their audience.

We also know that members of the public have experienced Serious Games and feel that there could be an impact on their ability to learn from them. There also appears to be conflicting views as to what constitutes a good or bad Serious Game experience, reinforcing the lack of a one-size-fits-all approach. We have also begun to understand the types of games that members of the public might like to play, which gives a foundation on which to develop Serious Game concepts.

When we consider the second research question, whether Serious Games can enhance learning, we conclude that there is no evidence that in our experiments

that the Serious Game treatment compared to the non-Serious Game treatment had any significant learning benefits. We do, however, see some weak evidence to support the hypothesis that a Serious Game provides some advantages to learning.

While we developed the Serious Game experiments with the best knowledge of the audience we had, the more in-depth understanding of practitioners and audience we have identified will lead to the development of more appropriate Serious Games. However, we do have some exciting learnings to build on in future work, and there are new research questions that have been raised by our work.

Ensuring that there is a clear relationship between the gameplay and the material we want the participant to learn is a vital component to include in future work. We also see some evidence that a perceived level of learning does not correlate to better performance, as discussed in Chapter 5.

Findings of this nature are not new, indeed recent papers, e.g. [54], [93] find that self-reported levels of learning are anti-correlated with actual performance. That is to say that higher levels of reported learning do not corollate to higher levels of performance. Therefore this finding in and of itself is not new, rather it supports documented findings in the literature.

For Iten and Petko [93], this self-assessment was conducted with respect to how much fun a participant believed they had, whereas Deslauriers et Al [54]. were assessing with respect to active v. passive teaching methods. We may conclude that the participant is an unreliable judge of their own performance, indeed this is a conclusion reached by Deslauriers et Al. [54].

A future challenge that will need to be overcome is exploring how perceived levels of learning do corollate with actual learning. That is, how do we design experiences that both enable participants to feel like they are learning whilst actually imparting that learning.

There may be several reasons that perceived learning does not corollate with increased learning outcomes. It is possible that the game, or material presented, is too complicated and overloads the participant. Such that while they do learn, not all information presented is retained. Additionally, it may also be that the base

level of knowledge held by participants is so low that they have indeed learned a lot and so would be justified in reporting that fact.

Understanding the likely baseline of knowledge in the audience could be an outcome of understanding the audience better, as previously described. We have seen evidence that having a human guide for complex topics does improve learning [99], where the instructor-led group performed better than those who experimented by themselves.

Enjoyment, however, may be a predictor of better performance, as seen in Chapters 5 and 6. How we can explore the concept of enjoyment in future research does raise some questions.

Does a participant having an enjoyable experience have any measurable impact on their performance? Although this also poses the question of what is an enjoyable experience? Is it a function of “winning” the game, engaging with a topic the participant already enjoys, learning something new, being able to share in the experience with others? Similarly, what are the dangers of a participant not enjoying their experience?

Developing the definition of enjoyment and how that relates to Serious Games used for tree and plant health will be crucial in understanding the role it plays. If an eventual outcome of research in this field is for a Serious Game that can be used by tree and plant health practitioners, then having a Serious Game that the audience enjoys, and engages with, is paramount. We have seen evidence in the literature that having a more engaged audience when playing the game leads to better long term knowledge retention [175].

The knowledge that we want the participants to learn may not be used in their everyday lives, e.g. recognizing the caterpillar stage of the oak processionary moth. Given that this stage of the moth’s lifespan only happens at a certain point in the year retaining and recalling that information a period of time after learning will be vital.

While not discussed elsewhere in this thesis, there is another element that we would recommend for consideration in future Serious Game tree and plant health research. We have not discussed the topic in any preceding Chapter as it has emerged after reflection on this body of work as a whole.

Specifically, any Serious Game developed for tree and plant health aims cannot operate in a vacuum and would require an encompassing message. We can find these messages in campaigns like those that are present at border ports, e.g. airports, telling travellers not to travel with restricted material to stop the incursion of pests and pathogens. These kinds of campaigns can give the participant a less abstract concept to engage with and invoke the authority of organisations such as the RHS.

Research in this particular domain will naturally focus on behaviour change. Returning to plant provenance, we may be asking gardeners to consider eschewing prettier, more exotic, species for more traditional species. At present they have a wide selection of choices in garden centres and nurseries around the country. We cannot stop companies importing those products as importing them is perfectly legal, albeit risky from a plant biosecurity perspective, so we must convince the public to make the change first.

So, if we reduce this idea to the most straightforward question, then we arrive at why? Why should the public care about what we want them to?; why should they listen?; why does this game matter to their lives? To paraphrase Dr Seuss, we need to establish how to make them care a whole awful lot. All work, whether understanding the audience to the types of Serious Game that most effectively engages them, is in service of this sole question.

7.1.1 *Technological Limitations*

We discussed the limits of the games developed in Chapters 5 and 6, specifically with respect to programming defects and platform compatibility. The limiting factors of games as a public engagement tool were also discussed in Chapters 3 and 4, where participants raised issues ranging from a lack of technical skills to develop games on their own to the graphical quality and game mechanics used.

Addressing these technical limitations will contribute to creating an enjoyable experience for the participant. However, it may be that collaboration with external game design studios is required to overcome them. Game studios have the expert knowledge to create games that will be compatible with different platforms and deliver the expected visual and gameplay experiences.

However, outsourcing development in this way is expensive. A simple commercial 2D game can cost between $50,000 to $100,000 while a larger, more complex game can cost between $250,000 to $700,000 [176]. There are platforms like Unity, utilised in this thesis, and Unreal that offer game design and development capabilities for free – although there is a cost for individual asset packs, e.g. pre-made 3D models.

Many Serious Game papers read during the literature review were proof of concept papers. The research questions being asked were around the viability of the concept, rather than reporting on a Serious Game that was in real-world usage. This is important as there are far cheaper ways to develop a proof of concept than engaging a professional studio.

It may be possible to collaborate, in Scottish Universities, with Honours students that have an interest in Serious Games to develop the concept. Additionally, there may be specific game design courses that look for these types of opportunities for students to develop their skills. While the result is not guaranteed to be as professional as a game studio's output, the cost-saving would be substantial.

Considering the discussion we have had around understanding the practitioners, audience, and enjoyment, opting for the least expensive option would be the better choice. Until we understand what combination of factors are likely to lead to the desired outcome using a Serious Game, then a significant investment of resources should be avoided.

7.1.2 *Future Research*

From the above discussion, three future research themes are evident. Future work around these themes will lead to Serious Game experiments that are better designed for their intended audience. While we have also identified the need for an overarching message for tree and plant health Serious Games to operate under, this would be within the remit of the practitioners or government to establish.

7.1.2.1 Theme 1 - Understanding the Practitioners

Understanding the practitioners would involve sampling a greater number of tree and plant health engagement practitioners from around the United Kingdom. We would be interested in learning more about the types of work they carry out, the

audiences they work with, and the tools and techniques they employ. We would also have a focused discussion on the potential role Serious Games could play in helping them achieve their aims. This would be a continuation of the first research question asked in this thesis, is there an appetite for the use of Serious Games in the tree and plant health engagement practitioner community?

7.1.2.2 Theme 2 – Understanding the Audience

The potential audiences that tree and plant health engagement practitioners work with will be the end users of the Serious Game interventions. We took a very broad view of the general public, although more focused sub-divisions of that group may be a more sensible target audience.

Part of the understanding of these audiences will come from the practitioners themselves, specifically the various ways in which the audience could be identified, e.g. a subset of the public that would be the target audience of a plant provenance message.

However, we also need to understand the experiences and interests of those audience groups. In order to develop a Serious Game that they would be interested in playing, we need to know more about their gaming interests, experiences, and feelings. We would expect research questions in this theme to be something like: To what extent are members of the plant purchasing public interested in playing games to learn about tree and plant health issues?

7.1.2.3 Theme 3 – Understanding Enjoyment

What constitutes an enjoyable experience, or even if one is required, is an exciting area of future research. We do not know what impact this variable has on participants. An outcome that we would want to see from any Tree and Plant Health Serious Game intervention would be long term retention of information.

Long term retention is vital as participants may encounter a situation several months after being exposed to important information, e.g. do not touch an Oak Processionary Moth caterpillar or else injury will occur. Enjoyment may have a role to play in achieving this.

We need to understand what impacts both a positively enjoyed and negatively enjoyed experience has on the participant. We see some evidence that having an enjoyable experience has a positive impact on the participant, in Chapter 6,

leading to a higher number of questions correctly answered in both experiment phases. Given that we want participants to learn and remember as much information as possible, better understanding a factor that appears to support that aim is essential.

7.2 Concluding Remarks

In conclusion, we believe that this thesis contributes positively to the broader field of Serious Games research and specifically to tree and plant health applications. While we have not developed a game that the practitioners can use with predictable levels of success, we have developed a concrete basis on which we can develop future work.

We have also, crucially, discovered that the tree and plant health practitioner community are interested in the application of Serious Games to their work. Working with this community going forward will be essential in understanding how Serious Games can be utilised and developed in this field.

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9 *Appendix A – Public Engagement Practitioners Requirements Gathering*

9.1 Participant Interview Schedule & Definitions:

9.1.1 *Definitions*

Definition of Gamification: Gamification can be thought of as applying "...game design elements to non-game contexts"(Deterding). This can be through points, leaderboards, and badges. Further elements include player avatars, an explorable world, or a narrative structure in which the player's choices have consequences. The purpose of Gamification is to add value to any given system; encouraging the user to: remain with or return to a system, whilst motivating them to engage widely with features contained within it, complete goals/tasks, and be social (where appropriate to do so).

Definition of Serious Games: Serious Games are games that are designed for a purpose other than entertainment. They are playable as games, but will focus on outcomes such as educating the players on a particular topic.

Both serious games and gamification can exist in digital and physical forms.

9.1.2 *Public Facing Body*

Questions:

1. What is the purpose of your organisation?
2. How do you see yourself working towards that purpose?
3. What do you do in your role?
4. Why do you carry out outreach and engagement work
    a. Do you think enough is being done?
    b. Would you like to see more activities taking place?
5. What messages are you currently putting out to the public?
    a. What messages would you like to see communicated in the future?
6. What activities do you carry out?
7. What do you seek to educate on with those activities?
8. What audience do you target?

    a. How old are they
    b. Previous education in the field?
    c. Expected level of education?
    d. Do they voluntarily attend?
9. Do you use interactive teaching methods?
    a. If so, what are they?
10. Based on the explanation of Gamification and Serious Games, would you say that elements of either currently take place in your education?
    a. If yes, what?
11. If there isn't a use of Gamification/Serious Games - do you think that there is a place for these methodologies to be deployed in your education?
    a. If yes, where?
    b. If no - why not?

9.1.3 *Volunteering Organisation*

Questions:

1. What is the purpose of your organisation?
2. How do you see yourself working towards that purpose?
3. What do you do in your role?
4. Why do you carry out outreach and engagement work
    a. Do you think enough is being done?
    b. Would you like to see more activities taking place?
5. What messages are you currently putting out to the public?
    a. What messages would you like to see communicated in the future?
6. What activities do you carry out?
7. What do you seek to educate on with those activities?
8. What audience do you target?
    a. How old are they
    b. Previous education in the field?
    c. Expected level of education?
    d. Do they voluntarily attend?
9. Do you use interactive teaching methods?
    a. If so, what are they?

10. Based on the explanation of Gamification and Serious Games, would you say that elements of either currently take place in your education?
    a. If yes, what?
11. If there isn't a use of Gamification/Serious Games - do you think that there is a place for these methodologies to be deployed in your education?
    a. If yes, where?
    b. If no - why not?

9.1.4 *University*

Questions:

1. What is the purpose of your organisation?
2. How do you see yourself working towards that purpose?
3. What do you do in your role?
4. What modules do you teach?
5. How are those modules taught?
6. Is there the possibility of fieldwork in those modules?
7. Are there industrial links over the course of the degree?
8. Is any of the content taught by external experts?
9. Does your degree lead directly to a forestry career?
10. Based on the explanation of Gamification and Serious Games, would you say that elements of either currently take place in your education?
    a. If yes, what?
11. If there isn't a use of Gamification/Serious Games - do you think that there is a place for these methodologies to be deployed in your education?
    a. If yes, where?
    b. If no - why not?

10 Appendix B – Game Players Requirements Gathering

10.1 Participant Information:

This survey is being carried out to understand what members of the public look for when engaging with games designed for public engagement. We are interested in what game(s), if any, would attract you to use them, and what would attract you to an installation that uses tablet(s).

You may exit this survey at any time.

It will take you approximately 10-15 minutes to complete.

Any data collected during this survey will be held securely by the researchers, and will not be passed on to third parties. No personally identifying information i.e. an email address will be used in any analysis of the data.

You will be asked to provide an email address at the conclusion of this survey. This will enable us to be GDPR compliant by being able to provide you with the information stored about you after this survey has been completed – or to remove any data held if you wish to revoke consent by the 24th September, 2018.

By completing this survey you are signalling consent for your data to be used. Your email address, as the unique identifier, will be deleted after publication of a paper from this work or completion of the PhD – whichever comes first. The remaining anonymised data will be held by the University of Stirling for a period of 10 years in line with their research data retention policy.

This survey is being carried out by:

- Craig Docherty, University of Stirling : craig.docherty@stir.ac.uk
- Dr. Savi Maharaj, University of Stirling: savitri.maharaj@stir.ac.uk

You may contact either of these persons with questions, comments, or to revoke consent for your data being used.

This survey has been subjected to ethical consideration by the University of Stirling's General University Ethics Panel. It has achieved ethical approval under GUEP-CODE.

10.2 Survey Questions:

- What is your age?:
    - This will be a range of possible bands i.e. Under 18, 28 to 37, Over 68 etc
    - There will be no opportunity to put a clear age in as an answer
- What is your gender?:
    - Multiple choice options: Male, Female, Other, Rather not Say.
- Highest level of Education completed?:
    - Multiple Choice Options: Primary School, Secondary School, College (UK), Undergraduate, Postgraduate.
- What country are you residing in?
    - Free text answer
    - As we are looking at UK based installations and public engagement, filtering out responses from other countries will be necessary.
- How often do you play video games a week?
    - Multiple choice answer: 0 hours, 1 – 2 hours, 2 – 5 hours, 5- 10 hours, 10+ hours
- How often do you attend museums, botanic gardens, etc:
    - Multiple choice options: several times a year, once or twice a year, never.
- How often do you attend gardening or agricultural shows?
    - Multiple choice options: several times a year, once or twice a year, never.
- Have you ever played an educational game at a museum, botanical garden, or gardening/agricultural show?
    - Yes/No Answer:
        - If Yes:
            - How long did the game last?
                - Multiple choice (less than 5 minutes, 5-10 minutes, longer than 10 minutes)
            - Describe it briefly:
                - Free text answer.

        - Text guidance would be given to suggest things like content, setting, the type of game i.e. puzzle, platformer, strategy etc
    - How effectively did it communicate the educational content?
        - Multiple choice question: I understood it well, I understood it a little, it was confusing, I don't remember
    - Did you enjoy it?
        - Yes/no question
- What kind of educational game would you like to play when visiting a museum etc?
    - Multiple choice answer (with more than one choice selectable): Answers will include the different genres of games i.e. puzzle, platformer, strategy, etc.
- When visiting museums etc how likely are you to engage with information presented on a printed poster?
    - Likert scale: 1-4 -> Very Likely -> Very Unlikely
- When visiting museums etc how likely are you to engage with information presented via an interactive touch screen?
    - Likert scale: 1-4 -> Very Likely -> Very Unlikely
- Do you think that playing a game would impact you learning the content that the museum etc would want you to learn?
    - Yes/no question
        - Why? (optional answer).
- What is your email address?
    - Email entry answer
- Would you like to be contacted with the analysed results from this survey?
    - Yes/No option

10.3 Debrief Information:

Thank you for completing this survey, we appreciate you taking the time to do so.

If you wish to revoke consent at any point up to, and including, the 24th September 2018 you may email either:

- Craig Docherty – craig.docherty@stir.ac.uk
- Dr Savi Maharaj – savitri.maharaj@stir.ac.uk

If you indicated you would like to see the results after the data has been analysed, this will be emailed to you when the analysis is completed.

Enjoy the rest of your day!

11 Appendix C – Comparing Game v. Non-Game approaches in a public installation

11.1 Information Presented to Users

11.1.1 *Oak Processionary Moth*

Fact 1: "The Oak Processionary Moth is a native species of central and southern Europe, with the move northwards being attributed to climate change.";

Fact 2: "They feed on oak leaves, and large populations can strip trees bare, leaving them weakened and vulnerable to other threats.";

Fact 3: "The larvae, or caterpillars, of the oak processionary moth can affect the health of oak trees, people and animals.";

11.1.2 *Asian Longhorn Beetle*

Fact 1 : "This is the Asian Longhorn Beetle. It is a non-native invasive species of wood-boring beetle.";

Fact 2 : "It can cause damage to a wide range of broadleaf trees. It originates from China and the Korean peninsula.";

Fact 3 : "Untreated wood packaging is a known pathway for Asian longhorn beetles.";

11.1.3 *Emerald Ash Borer*

Fact 1 : "The Emerald Ash Borer is an exotic beetle pest, that is a native of Eastern Asia.";

Fact 2 : "The beetle damages Ash trees, which are the second most common tree in the UK. Symptoms include yellowing, and thinning foliage.";

Fact 3 : "The Emerald Ash Borer may enter the country in many ways. For example, in untreated wood packaging materials, and wood products.";

11.2 Information Flyer

Note: This is also the debrief information for the participant.

Thank you for taking part in this study on the use of Gamification for Public Engagement. This experiment has been carried out by Craig Docherty, under the supervision of Dr. Savi Maharaj, from the University of Stirling.

The aim of the experiment is to explore whether there is more enjoyment and better learning from information given as a static page or through a game.

If you have any questions, comments, or would like to know the results of the study once it has been completed, please don't hesitate to email:

Craig Docherty – craig.docherty@stir.ac.uk

Dr. Savi Maharaj - savitri.maharaj@stir.ac.uk

12 Appendix D – Comparing Game v. Non-Game approaches in an online setting

12.1 Information Presented to Users

12.1.1 *Plant Provenance*

Plant provenance means where tree and plant products originate from, whether that is from inside the UK or from another country. It is important to understand how plant provenance can affect the biosecurity of our country, in order to ensure that our parks and countryside are kept safe for generations to come.

When trees and plants are purchased from outside of the UK they bring with them a chance of introducing new pests and pathogens. These can cause great damage to native trees and plants that do not have any defences against them. We call these non-native pests and pathogens invasive.

Some plants that we might want for our gardens aren't grown in the UK, or are only available at particular times of the year, or may be less expensive from outside the country. Councils and other organisations may want to improve public spaces with nice horticultural displays that require out of season or out of country products, while keeping to a tight budget.

Sometimes we may see plants for sale on the side of the road, at car boot sales, or other events. We can also buy plants very easily on the internet. In both cases, the provenance of the product cannot be guaranteed.

By paying attention to where plants come from, buying British where possible, and purchasing from reputable sources e.g. garden centres, and plant nurseries, we have a much greater chance of stopping unwanted pests and pathogens entering the UK.

The rest of this experience will showcase three invasive pests and pathogens. One is already in the UK and the other two are not here - yet. You will learn about these threats, the damage that they can do, where they come from, and how they entered, or might enter, the country.

12.1.2 *Emerald Ash Borer*

Emerald Ash Borer is an exotic beetle pest that causes significant damage to ash trees. The Emerald Ash Borer is a native of eastern Asia that was accidentally introduced into North America, probably in the 1990s and most likely in imported wooden packing material, where it is causing widespread damage to Ash trees. Ash trees are an important commercial species there, as well as being widely used as an amenity species in towns and cities.

Ash is an important broadleaf tree in the UK, being the second most commonly planted species in the country, and makes up nearly 15% of all broad-leaved woodlands. Its wood is used in a number of commercial applications including the manufacture of ladders, flooring, and furniture. Ash in the UK performs the same role as in the US, covering a range of important commercial and amenity roles.

Ash trees in the UK are already under threat from Chalara Ash Dieback, which was first discovered in the country in 2012. This is one of a number of diebacks that the ash tree can suffer from. Due to this, Ash is no longer allowed to be imported into the United Kingdom.

Emerald Ash Borer infestation is usually difficult to detect until the symptoms become severe. Trees show a general yellowing and thinning of foliage, dying branches and crown dieback, typically from the top down. Trees can take one to four years to die. Characteristic serpentine insect galleries can be exposed when pieces of bark fall from damaged trees which have been infested for 1-2 years. However, several of the symptoms of Emerald Ash Borer infestation are also common to other infections that ash trees can suffer, making detection of the threat difficult.

12.1.3 *Oak Processionary Moth*

The caterpillars of the Oak Processionary Moth can affect the health of oak trees, people and animals. They feed on oak leaves, and large populations can strip trees bare, leaving them weakened and vulnerable to other threats. A protein in the caterpillars' tiny hairs can cause skin and eye irritations, sore throats and breathing difficulties in people and animals that come into contact with them.

Oak Processionary Moth is a native of southern Europe, where predators and environmental factors usually keep its numbers in check and minimise its impact.

However, aided by the movement of live oak plants in trade, its range has been expanding northwards over the past 20 years, and it has become established as far north as The Netherlands and northern Germany.

In the United Kingdom, Oak Processionary Moth is known to be present in London and some neighbouring counties. The greatest risk period to humans and animals is between May and July, although Oak Processionary Moth nests should always be avoided as they may contain thousands of hairs.

Oak Processionary Moth was first accidentally introduced to Britain in 2005, almost certainly as eggs which had been laid on live oak plants imported from continental Europe. The current distribution of the pest has probably arisen from a number of subsequent, similar introductions as well as spread from the original points of introduction. It is theoretically possible that if it were to spread it could survive and breed in much of England and Wales.

In early summer the caterpillars build distinctive white, silken webbing nests on the trunks and branches of oak trees (almost never among the leaves), and leave white, silken trails on the trunks and branches. These nests and trails become discoloured after a short time, and are more difficult to see as a result. The caterpillars also often form arrow-headed processions.

12.1.4 *Xylella fastidiosa*

Xylella fastidiosa is a bacterium which causes disease in a wide range of woody commercial plants such as grapevine, citrus and olive plants, lavender, and several species of broadleaf trees widely grown in the UK, and many herbaceous plants. Xylella affects its host plants by invading their water-conducting systems. In so doing, it restricts or blocks the movement of water and nutrients through the plant, with serious consequences, including death, for some host plants.

Although Xylella is not known to be present in the UK, there is a heightened risk of its being accidentally introduced since it was discovered in Italy in 2013, and Corsica and mainland France in 2015. There are four known sub-species of Xylella, of which the Multiplex sub-species can probably infect the widest range of host plants. This includes native British oak and wych elm, as well as plane and northern red oak trees.

Xylella is exclusively transmitted by insects that feed on the plants' xylem fluid. There are several species of insect in the UK which could spread Xylella, including the common froghopper; although they usually only fly short distances of up to 100 meters, the wind can carry them further. Long-distance spread can occur by the movement of infected plants for planting. There can also be some transfer Xylella between neighbouring plants via root grafts.

The outbreak on Italian olive trees is related to a similar strain of the virus found on ornamental coffee plants imported into France, Germany, The Netherlands, and Italy. In Corsica, the outbreak was found on imported plants from Italy and mainland France.

Symptoms range from leaf scorch (browning) to dieback and death. Symptoms vary depending on the host plant species and its degree of susceptibility, but include marginal leaf scorch, wilting of foliage and withering of branches. Severe infections in some of the most damaging combinations of host plant and Xylella sub-species can result in dieback, stunting and eventual death, e.g. with olive trees or grape vines (on which it is known as Pierce's disease).