

A Phenomenological Framework for the Design of an Augmented Reality Experience

Hudson Tell Mears

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Learning outcome	The markers will assess	Pages ¹	Hours spent
Learning outcome 1 Conduct a literature search using an appropriate range of information sources and produce a critical review of the findings.	* Range of materials; list of references * The literature review/exposition/background information chapter	10-23; 40-41	~150
Learning outcome 2 Demonstrate professional competence by sound project management and (a) by applying appropriate theoretical and practical computing concepts and techniques to a non-trivial problem, <u>or</u> (b) by undertaking an approved project of equivalent standard.	* Evidence of project management (Gantt chart, diary, etc.) * Depending on the topic: chapters on design, implementation, methods, experiments, results, etc.	17-26; 32-36; 47-52	~300
Learning outcome 3 Show a capacity for self-appraisal by analysing the strengths and weakness of the project outcomes with reference to the initial objectives, and to the work of others.	* Chapter on evaluation (assessing your outcomes against the project aims and objectives) * Discussion of your project's output compared to the work of others.	37-39	~50
Learning outcome 4 Provide evidence of the meeting learning outcomes 1-3 in the form of a dissertation which complies with the requirements of the School of Computing both in style and content.	* Is the dissertation well-written (academic writing style, grammatical), spell-checked, free of typos, neatly formatted. * Does the dissertation contain all relevant chapters, appendices, title and contents pages, etc. * Style and content of the dissertation.		~200
Learning outcome 5 Defend the work orally at a viva voce examination.	* Performance * Confirm authorship		1 hour

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If my research follows on from previous work or is part of a larger collaborative research project I have made clear exactly what was done by others and what I have contributed myself;

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Abstract

This dissertation outlines the implementation of a phenomenological framework for designing and analysing augmented reality applications. A review of phenomenology and phenomenological design within user experience design is presented. A phenomenological framework that focuses on themes of place is then created. This framework is tested on a new prototype application that builds on the blended space design of a garden at Edinburgh Napier University. The application is tested using semi-structured interviews, which are then analysed according to the phenomenological criteria we created.

We found the framework to be an effective method of encouraging embodied experiences using augmented reality. However, we determined that further study of phenomenology and further user testing is necessary to confirm the effectiveness of this method of analysing augmented reality technologies.

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1 Introduction

This dissertation describes a project which aims to evaluate the embodied user experience of a garden featuring an augmented-reality education software, building up a phenomenological framework to do so. We will explore the augmented reality technology and the theoretical framework for analysing the embodied experience.

The project at hand has been developed as a part of The Lion's Gate Project. The Lion's Gate Project is a work at Edinburgh Napier University which aims to develop a garden on campus which blends natural and digital spaces together. This will be achieved by creating working spaces, using digital sensors, and implementing digital content that will coexist in the space with a designed system of plants and other natural features (The Lions' Gate - Urban Interactive Permaculture, 2019).

The garden's ecological foundation is in permaculture design principles, which it uses in combination with user experience and interaction design principles in an attempt to improve the experience of the space by visitors. This forms a type of blended space design, and research on this specific corner of blended space design has been studied in (Egan, Benyon, & Thompson, 2017). Where that research aims to examine the concept of blended spaces via a physical, prototype implementation, this research aims to examine how the virtual component of the blended space of the garden is best able to integrate into the physical space.

It was deemed that there are two key parts central to the design of this software: an effective method of designing the interactions, and an effective method of analysing the software according to our own requirements. We will first explore the analysis, so that we can then design the software to respond to this analytical framework.

2 Background

We identified three key areas of research relevant to this project: phenomenology, interactive museum design, and permaculture.

2.1 Phenomenology

Phenomenology is a philosophy which aims to study the world “untainted by scientific, metaphysical, religious or cultural presuppositions or attitudes---at the fundamental and essential features of human experience in and of the world” (Mooney & Moran, 2002).

The place for phenomenological understanding in the field of user experience is historied (Dourish, 2001; Thompson, Locander, & Pollio, 1989; Pallud & Monod, 2010; Monod, Klein, Isari, & Missikoff, 2006). Monod, Klein, Isari, & Missikoff (2006) in particular offers a framework for analysis. In the presented study, the researchers introduce a phenomenological framework for analysing technologies’ user experience according to several categories of phenomenological understanding such as Embodiment, Context, and Self-Projection. Table 1 "An Interpretive and Phenomenological Framework for the Evaluation of e-Heritage Systems" (Monod, Klein, Isari, and Missikoff (2006) presents a table listing the researchers’ categories and associated interview and questionnaire questions.

	Criteria	Question for IS evaluation (e-Heritage Systems)
ENTERTAINMENT	1. Re-enactment	Does the e-HS help the visitors to re-live the historical events in their mind? Does it help them to picture themselves as part of the historical events? Can they grasp the mindset of the historical characters?
	2. Embodiment	Does the e-HS give an opportunity of a bodily experience of the past to the visitors?
	3. Self-projection	How does the e-HS stimulate the visitors to project themselves into in the past so that the past gives meaning to their current conditions of existence?
	4. Possibilities of being	Does the e-HS present the past “in terms of its many possibilities” so that the visitor is lead to wonder what specific historical characters could have done and what the constraints of their situation were?
EDUCATION	5. Context	Does the e-HS give an occasion for a ‘reflexive experience of history’? Which pre-understandings (intuitions) does the e-HS interface presume and does it provide tutorial aids to acquire the necessary background knowledge? Does it lead the user to engage in hermeneutic circles, which reduce the distance between the present and the past contexts of understanding?
	6. Historical self	How does the e-HS help the visitors understand themselves as historically constituted so that they can learn the possible meanings of their existence from the values, actions and life situations of historical characters?
	7. Inquiring being	Does the e-HS give an opportunity to the visitor to reflect "alternative modes of being", e.g. by investigating his or her own possibilities of existence or does the current era afford the kind of life that corresponds to what he or she feels is true and right?
	8. Universality in uniqueness	Does the e-HS identify for the visitors how to see “the universal in what is historically unique” and thereby help them to see alternative possibilities for their own existence in the present?

Table 1 "An Interpretive and Phenomenological Framework for the Evaluation of e-Heritage Systems" (Monod, Klein, Isari, and Missikoff (2006)

The study by Pallud and Monod (2010) returns to these criteria. In both studies, the researchers are observing historically significant sites and artefacts which have been enhanced by some form of technology. The criteria, therefore, are rooted in the relationship between users and the history of a place.

What, then, of phenomenological criteria which are fundamentally related to the ecology of a place rather than the history? We might turn to the article “What is ecophenomenology?” by David Wood (2001), which attempts to merge phenomenological ideas with ideas of naturalism. We find, however, that its ideas are much more accessible in the book “The Spell of the Sensuous” (Abram, 1997) and well-represented by the anthropologist Tim Ingold in two books (Being Alive: Essays on Movement, Knowledge and Description, 2011; The Perception of the Environment: Essays on Livelihood, Dwelling and Skill, 2000). We will return to this literature below, but we must first examine how Paul Dourish, an interaction designer, approaches this domain.

Starting with embodiment, we find that its definition is varied, as it has been used in different ways in the field of user experience (Dourish, 2001). We therefore start with Dourish's own definition, found in chapter 5, which "focuses primarily on meaning and coupling", where meaning includes "intentionality, ontology and intersubjectivity" and coupling involves "not just how we can understand and interpret interactive systems, but how we can operate through them." (Dourish, 2001, ch. 5).

Intentionality here refers to "the directedness of our actions and their effects". Ontology "concerns the ways in which we come to understand the computational world in which and through which we operate" and intersubjectivity concerns the way our understanding of technology "emerges in concert with other people" (Dourish, 2001, ch. 5). Coupling refers to the way in which we operate through technology.

Before we can use these criteria effectively, we must understand the significance of each of them, especially with reference to the design of interactive technology.

Beginning with ontology, we can look to Maurice Merleau-Ponty, who, in looking at the nature of the world, asks us to consider the nature of objects in the world (Merleau-Ponty, 1945). More specifically, we find that the issue of perception complicates the definitions of objects in the world; we can only ask whether something is "real" (as opposed to imagined or constructed within the mind or consciousness); whether we can determine it to be real according to our experience of it. We can understand this better by referring to Dourish's definition of virtual reality in contrast with the real world (Husserl's lifeworld), as he attempts to distinguish between virtual and augmented reality:

"Even in an immersive virtual-reality environment, users are disconnected observers of a world they do not inhabit directly. They peer out at it, figure out what's going on, decide on some course of action, and enact it through the narrow interface of the keyboard or the data-glove, carefully monitoring the result to see if it turns out the way they expected. Our experience in the everyday world is not of that sort. There is no homunculus sitting inside our heads, staring out at the world through our eyes, enacting some plan of action by manipulating our hands, and checking carefully to make sure we don't overshoot when reaching for

the coffee cup. We inhabit our bodies and they in turn inhabit the world, with seamless connections back and forth.”

(Dourish, 2001)

In intersubjectivity we look not just to the emergence of technology “in concert with other people” but also “in concert with other actors”, where actors can be any animate entity. From Tim Ingold’s essay “Naming as Storytelling” (Ingold, 2011) we are presented with the following question: “What if we were to think of the earth’s surface not as already laid out, only awaiting discovery and occupation, but rather as continually unfolding in the course of life itself, through the movements of people and animals, wind and currents, celestial bodies and so on?” (ibid. p. 168). He goes on to say: “every person would come into being as an enfoldment of the experience of the places they have inhabited, and of the journeys between them (ibid.)” This draws the focus of intersubjectivity into the experience of the environment a person inhabits. Sartre (1957) describes it thus: “consciousness is defined by intentionality. Through intentionality it transcends itself, it unifies itself by going outside itself.”

In intentionality we turn to David Abram, who himself refers often to Merleau-Ponty. He says, “each presence presents some facet that catches my eye while the rest of it lies hidden behind the horizon of my current position, each one inviting me to focus my senses upon it, to let the other objects fall into the background as I enter into its particular depth (Abram, 1997, p. 52).” For the phenomenologist, intentionality is the act of focus upon an object; this attention is a transformative act. Indeed, Ingold (ibid.) relates this to the cultural practices of the Koyukon and Australian Aborigines, noting that in these cultures, the process of passing on knowledge is performed by directing the attention of the mentee to some particular object, such that they can learn by careful observation.

Finally, coupling is a term well-defined by Dourish (ibid.), which he describes using Heidegger’s example: if I am using a hammer, it can either be (present-at-hand” or “ready-to-hand”. The latter occurs when the hammer is being used; the object of focus is the thing being hammered, and the hammer becomes an extension of the arm. When something is present-at-hand, in contrast, the hammer is separate from the hand; the user may be readjusting its position in the palm, and thus the hammer is the object of focus and attention (Dourish, ibid. p. 138-9). The role of coupling in the present project

is as a measure of users' focus: is the focus on the garden, as we intend, or is it on the technology which is mediating the experience? In practical terms, the user will focus on the technology if it is not intuitive to use; a coupled technology will be seamless, permitting no boundary between the garden and the user, and we will see positive responses to questions in the other criteria, particularly intentionality and ontology.

2.2 Interactive Museum Design

The garden and the augmented reality experience that we wish to create is in effect like a museum that features interactive technologies. (Pallud & Monod, 2010) conducted a phenomenological analysis of user experience in such museums. They identified context, re-enactment, and embodiment as key features for the success of a museum visit; visitors should be able to understand the historical context of the artefacts, should feel that they can relive historical events, and that the senses (especially touch) are a factor in user experience. In the same study, a second museum (National Centre of the History of Immigration; NCHI) featured technological media as a major component of the experience. In the NCHI, self-projection (the capacity to project oneself into the life of a character), embodiment, and re-enactment were the most important factors for a positive user experience for visitors.

Ciolfi & Bannon (2002) conducted a focused analysis of visitor behavior in a museum which encouraged physical interaction with the exhibits. They produced a set of 'design sensitivities':

- Visitors should be encouraged to interact with the exhibit *and* with each other.
- The exhibit should provide clues and affordances to hint at what interactions are possible.
- The exhibit should provide insights into the historical contexts of the items (prior to exhibition).
- The exhibit should work well for casual and expert visitors and should integrate with prior informational technologies and installations.
- The exhibit should allow visitors to leave their own trace on the exhibit.

Monod, Klein, Isari, & Missikoff (2006), which examined possibilities for the design of a technologically augmented experience of cultural heritage sights, does not provide

specific guidelines. However, they do emphasize a phenomenological approach and suggest that experiences should increase interactivity and should be self-led.

Tost and Economou's (2007) studied a museum with several different types of technologically enhanced exhibits. They make some specific and useful observations about visitors' experience of these technologies. For example, in examining where problems with technology might arise, they state that "this indicates that the usability of the interface constitutes a major problem especially for those with little experience or a negative attitude towards computers, because it is usually neither evident nor natural." Regarding mobile devices in the exhibit, they suggest that mobile devices can "absorb the attention of the visitor" and contains its own context that may be separate from the overall context of the exhibit.

Finally, regarding examples from museums, we may look at Borchers (2001), which lays out interaction design patterns with a specific focus on exhibitions.

2.3 Permaculture

We must also ensure that we examine properly the design principles of permaculture, which is a major feature of the garden's design language.

Permaculture is an agricultural design framework created by Bill Mollison. In brief, permaculture emulates native ecological systems like temperate forests, but maximises the number of food-producing species within the system. Permaculture touts twelve design principles, many of which surpass the realm of agriculture and implement permaculture as a design philosophy that can be used across domains.

1. Observe and Interact
2. Catch and Store Energy
3. Obtain a Yield
4. Apply Self-regulation and Accept Feedback
5. Use and Value Renewable Resources and Services
6. Produce no Waste
7. Design from Patterns to Details

8. Integrate Rather than Segregate
9. Use Small and Slow Solutions
10. Use and Value Diversity
11. Use Edges and Value the Marginal
12. Creatively Use and Respond to Change

(Whitefield, 2005)

At the face of it, many of these principles are easily connected to already-established user experience design principles, namely 1, 4, 8, 10, 11, and 12. In addition to these, we find that some are easily applicable to the design of digital products, namely 3, 5, 6, 7, and 9. We find immediately that permaculture's domain is not limited to agriculture, or even to the design of 'natural' spaces.

In addition to these, we find that Mollison (1988) focuses intensely on the capture, storage, and integration of information in the landscape. This is evident in principle 1: the purpose of observation and interaction is to obtain information; this information will later help the designer to make better and more effective decisions. Information is a crucial part of Mollison's philosophy, insofar as the direct experience of the environment is integral to the permaculture design process. Mollison describes nature as the only infinite resource; an excess of information is not pollution, unlike other yields (ibid.)

The same source also proposes a language of patterns present in the natural environment. Mollison examines such patterns as spirals, dendritic branching, and the torus and shows how they are repeated often in the environment. The thesis of this discussion is to suggest that designing with these patterns has several benefits on agriculture.

3 Design

3.1 Design Criteria

The phenomenological categories that we have described above can now be redefined as is relevant to the project we are developing. These four criteria thus constitute the parameters of our analysis, and we can create focused questions from them:

1. Intentionality

What actions did the user intend to perform? What was the focus of their attention whilst using the technology?

2. Ontology

Did the users consider their experience to be real? Did the technology aid the users in reifying unseen phenomena in the garden?

3. Intersubjectivity

Did the user's understanding of the world change because of their experience? Did they feel that their presence in the garden acted upon them? Did they feel that their presence acted upon the garden?

4. Coupling

Did the users find the technology cumbersome to operate? Was the technology intuitive to use?

From the literature on interactive museums, we can take the advice of previous research on designing this type of experience. Tost and Economou (2007) makes some important conclusions for this project. They state that virtual reality (in this case, encompassing some technologies that may be considered augmented reality) may be useful for “the possibility to reconstruct and manipulate elements or phenomena which are not available anymore” and for “learning about processes which are not visible anymore, but in this case images need to be supported by a verbal discourse.”

We must also return to those principles identified by Ciolfi and Bannon (2002), which are stated in the previous section.

Finally, we identified the following patterns from Borchers (2001) as particularly relevant to our project:

H1. Design the interaction so that it takes place in three phases: attracting users, engaging them, and delivering one of the “messages” to them which the system wants to convey.

H2. Define an attraction space around your system that is as large as possible, but without penetrating the attraction spaces of neighbouring exhibits.

H5. Make the user interface of your interactive exhibit as simple as possible.

H6. Initially, present only a very concise and simple overview of the system functionality.

H8. Instead of trying to recreate all aspects of reality inside an artificial environment, augment the real environment with interactive technology that is not usually available otherwise.

H9. After two to four minutes of interaction, explain to the user what she has just seen or learned from your system, guide her back to a central starting point in it.

(Borchers, 2001)

Given these criteria, we can now begin to examine how we might design an augmented reality software that can satisfy them. We also invite readers to examine Appendix 2, where we have laid out scenarios based on these criteria and hypothesized the complex interrelation between each of them.

As a part of this experience, visitors should be able to understand some of the ecological principles that underlie permaculture and, in coordination with such, the garden itself. However, the space will be freely available for anyone to visit for any amount of time; a solution to educating visitors on these principles should therefore be flexible, self-led, and entertaining. The experience is comparable to that of a museum exhibition: visitors can enter at any time and move through an intentionally designed area. In the garden, the artefacts are the plants and installations themselves. To further the comparison, the exhibition has the potential for educating visitors (as in the plaques in front of museum artefacts), but the choice of attending to the information is left to the visitor.

As the space is already designed, the main purpose of the present project is to implement one aspect of the digital, educational experience. This experience should provide information on the design principles of the garden, namely permaculture, and should do so in a way that incorporates the garden itself. A restriction that we placed

on this technology was that it should not interfere with the experience of the garden; it should be an opt-in experience, and therefore any visitors who do not wish to take part should be able to observe and inhabit the garden without the digital experience interfering in any way. We believed that visual media such as plaques would be such an interference; visitors would likely feel compelled to read the information, even if that is not the purpose of the visit.

The product therefore needed to be functionally invisible to all those who were not partaking in the experience.

Mobile Augmented Reality is a technology by which a device's direct camera feed is overlaid with digital information. Such technology is available in various forms; some of the primary development kits are ARCore, ARKit, and Vuforia (ARCore, 2019; Augmented Reality - ARKit 3, 2019; Vuforia Engine, 2019).

The uses of mobile augmented reality are varied, and it has been applied in entertainment, industry, and education. This last use is of primary concern to this project.

As such, mobile augmented reality was deemed to be an effective technology to fulfill these specifications, as it is a technology that:

- is available on many smartphones, and potential visitors are likely to have compatible devices.
- can utilize the space itself as part of the design.
- is easy to develop due to several available development frameworks, such as ARCore.
- does not interfere with the experience of the garden for those who are not partaking.

3.2 Design Methodology

To design the application, an iterative process was used, akin to Bret Victor's "Ladder of Abstraction" (Victor, 2011), a concrete problem and concrete solution are identified, and the problem is abstracted to get a more general idea of how to address it. From

this point, the problem can be abstracted again, or more concrete parameters of the problem can be identified, thus emulating climbing up and down a ladder.

For this project, the identified problem was: “How can users best be educated within a dedicated, real-world place?” In addition to this question, there were constraints on this design problem: that the solution must incorporate the garden, that the solution must incorporate digital technology, and that the solution must focus on the user experience.

The simplest and most common solution to this problem lies in museum experiences, which are in nature spaces designed to address it. However, museums typically rely on simple media to educate visitors: plaques or brochures with text-based descriptions of artefacts and or audio guides on which the user can key-in a number corresponding to the artefact and listen to a more in-depth explanation.

We first abstract the problem out to its foundation from a user-centric standpoint. This forms a type of user story (Benyon, 2018):

Jeff is a visitor to a museum and wishes to learn about the types of plants on display in the garden. He locates a flower bed and observes the plant. Wishing to understand more about it, he reads the plaque below it. Wishing to know more, he keys in the number 112 on his audio guide and listens to a pre-recorded explanation of the plant’s significance by the gardener. Once complete, Jeff moves on to the next plant.

By observing the situation from the user’s perspective, we identify two potential issues with this typical museum experience:

1. In order to identify the plant, Jeff must look away from it to read the plaque.
2. To listen to a detailed explanation, Jeff must locate the audio guide, the key code associated with the plant, and operate the technology, all of which further removes his attention from the plant.

Can this experience be improved? We can use this insight to refine the design of our technology:

1. The educational text should not direct the user's vision away from the topic artefact, therefore a plaque or brochure is inadequate.
2. The technology which provides the educational text should provide affordances which do not inhibit attention paid to the artefact, therefore any technology used should not require lengthy processes like keying in codes.

We can repeat the process once again with several user stories:

Mary enjoys looking at the plants in the garden, but does not care to learn about the history or significance of them; she is interested purely in their aesthetic quality. She goes to the garden bed she finds most appealing but discovers that when viewing the plants, she is drawn to read the plaques rather than observe the plant. When she leaves the gardens, she finds that she does not remember the qualities of the plants which she observed.

Linda wishes to sit in the garden to relax and enjoy the scenery. She enjoys chatting with people when she is there. Upon entering the garden, she finds that other visitors are too busy reading the plaques and listening to the audio guides to sit and chat. Furthermore, the plaques obstruct the scenery which she wishes to observe.

3. The educational aspect of the experience should be opt-in rather than opt-out so as not to disturb those who are not interested in it.
4. The educational aspect of the experience must encourage interaction between users.

Which leads to further refinement:

3. The technology should be invisible until utilized, therefore a new device or tags on specific plants must be avoided.
4. Multiple users should be able to experience the same thing and interactions should be short, therefore lengthy descriptions or privatized material must be minimized.

We find that mobile augmented reality is able to address the issues with the following assumptions:

Mobile augmented reality utilizes smartphones, which we expect our visitors to already have on their persons (criterion 4).

Mobile augmented reality overlays information on a camera feed, therefore the focus artefact can be kept in the user's view (criterion 1).

Mobile augmented reality can make use of common smartphone gestures and powerful computations, providing potential for a minimization of operation procedures which are lengthy and must be learned (criterion 2).

A framework such as ARCore does not require the use of tags or images in the real world to display information (criterion 3).

This solidifies our decision to use ARCore to create the experience.

3.3 Prototype Design

We have envisioned the application that we have created as a sort of microscope or lens through which users will be able to observe the unseen phenomena of the garden. That is, there is information inherent in the garden (especially given that it was creatively designed to maximise systemic efficiency) but this information is stretched across space and time. While the bees may be essential to pollinating the flowers, a visitor to the garden might not see the bees doing so; even if they do, they may not understand the process that is occurring.

In order to reify this information as required by our parameter of ontology, we have created 3D models of rowan tree branches that can be placed around the garden using standard ARCore methods.

The branches are interactive; users can pick them up and place them back down with a pinch-zooming gesture. This gesture was chosen because it is a common gesture on mobile phones and best emulates the sensation of bringing something closer. We hope that by using gestures that are common in mobile software design, we will succeed in ensuring the technology is coupled to the user.

Once the branches are ‘picked-up’, they are ‘held’ onto the user’s camera; the object inhabits the majority of the screen space and moves with the device. This gives the sensation of holding the branch.

Finally, the user is able to listen to a pre-recorded audio message. Audio messages were chosen based on the museum studies above. Originally, we envisioned that the audio would play through the small speaker at the top of the phone that is normally used for phone calls. This would give the impression that the branch (and, by proxy, the garden) is speaking to the user, and would also move the screen out of the user’s field of view and open up a hand for use. We believed that this would aid in both intentionality and intersubjectivity: the latter coming from the sensation of speaking with the garden, and the former because by moving the device out of sight, the user is better able to focus on the garden and the space where the phenomena being discussed in the audio is taking place. Unfortunately, the technical implementation of this feature proved difficult as accessing the volume on the device from Unity3D proved to be outside the technical capabilities of the designer. As such, headphones were used instead. We expect that this had serious implications within the realm of intersubjectivity for the application.

Once the user has listened to the message, the branch can be placed again by pinching it. This returns the branch to its original location.

We can also use concrete scenarios to better predict what kind of issues might be created by the technology from a user standpoint and find ways to respond to them. This process is best described in Benyon (2018); here we are predicting potential experiences with the app to understand how it will flow. Diagrams displaying our scenarios are available in Appendix 2 along with potential solutions to the problems they create. This was extremely useful in iterating over the design before presenting it to test participants, and indeed we found that some of these scenarios were close to the real experienced described by our users.

3.4 Location Design

The objects will be arranged in such a way as to mimic the general core model in Mollison (1988) (Figure 1). Objects were placed around a perimeter mimicking the shape of this model; ten objects were placed, which should allow for organic movement

throughout the garden. Moreover, this organization method allows for sightlines from each object to at least one other.

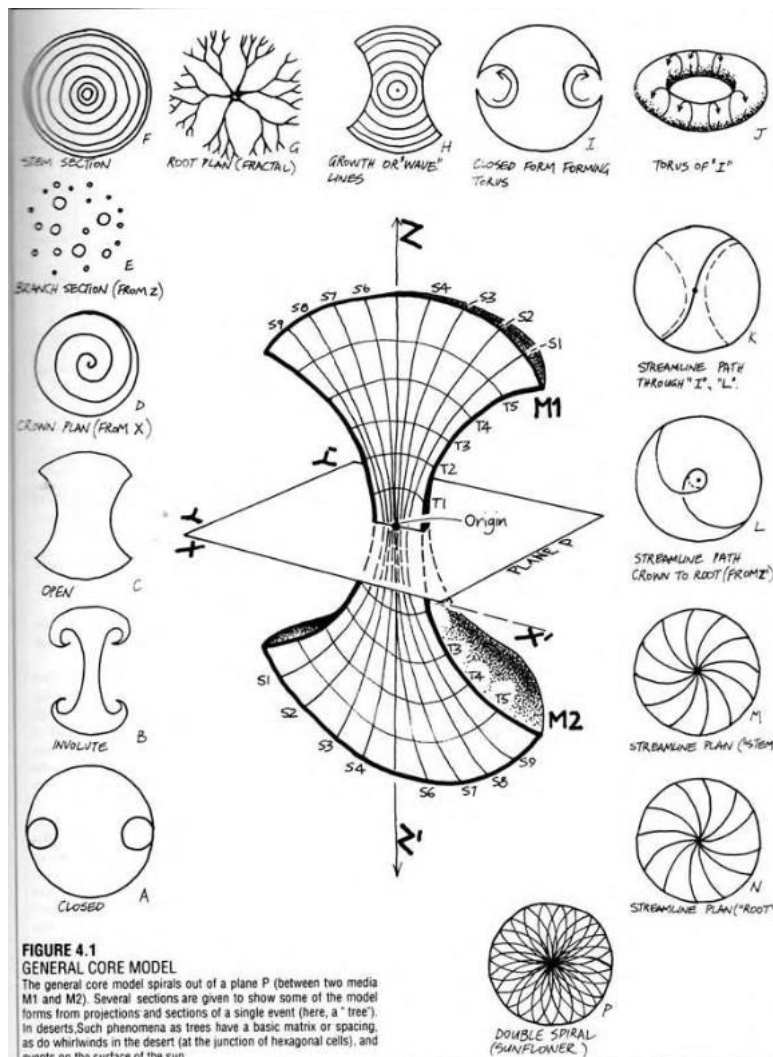


Figure 1 "General Core Model" (Mollison, 1988)

The audio messages attached to each object are less than 30 seconds in length each. Each pertains to some topic of permaculture design with a focus on the natural systems that exist within the garden. The content of the messages is reworded from passages in Whitefield (2011) and relate to the real phenomena happening at that location. Importantly, we refer to Ingold's (2000) description of the Koyukon mentoring technique, in that the messages we have included here are structured so as to draw attention to a phenomenon and give it a name and context without definitively telling the listener what they should be learning from it. This was done so as to ensure that users create their own understanding by observing the garden and piecing together information from different parts of it.

The messages were recorded in situ in the garden to include typical background noise within the messages. This should aid in coupling as the ambient noise in the user's ear that is listening to the message will be comparable to the noise in the other ear. We hope that this will act as a small touch to encourage embodied experience of the garden and technology.

4 Test Methodology

Participants were told to explore the garden on their own for about five minutes. Following this, they were given a device with the app installed and briefly shown how to perform the gestures and listen to audio messages. They then explored the garden area with the app for up to 15 minutes or until they decided that they were finished. Following this session was a brief interview.

The process of interviewing and analysing the responses by participants is based on the phenomenological methodology presented in Thompson, Locander, and Pollio (1989), though due to time constraints the interviews were perhaps not as thorough as these researchers advise. We address potential issues with our interview process in the Evaluation section of this paper. Nonetheless, we found that the interviews did provide good insight into the user experience and helped us to understand whether our application performed well under the framework we present in this study.

Questions that were used in the interviews are available in Appendix 5. The questions were designed to be as neutral as possible and permit the participant to describe the parts of the experience that were most relevant to them. The interviews were semi-structured; tangential topics could be explored should the participant wish to veer away from the question. Following the questions, the user was asked if there was anything which they would like to add from their experience. The interviews were recorded for later analysis.

There are some key considerations to note for the testing phase:

1. Due to the nature of the prototype, the placement of digital objects was performed while participants were exploring the garden on their own.
2. Because of this, the participants used the same version of the app as the researcher placing the objects. In rare instances, it was possible for participants to place objects themselves. The objects they placed had an associated test recording and looked identical to the other objects.

In total, five participants were tested for this experience. Participants were recruited from the School of Computing, and consent was obtained prior to each session. A copy of the informed consent form is available in Appendix 4.

5 Results

The results from the testing portion were audio recordings of semi-structured interviews with participants. These recordings were transcribed and are available in Appendix 5.

The nature of this data is therefore entirely qualitative. Our goal was to use the categories of analysis presented in the section “Framework for Analysis” as a lens for understanding participant responses to the questions.

The questions presented were aimed to elicit responses related to one of each of the phenomenological criteria (Intentionality, Ontology, Intersubjectivity, and Coupling). However, because the questions were also designed to be vague and minimize the interviewer’s biases, often the responses included phrases related to any of the four criteria.

The transcribed interviews were annotated by reading the interviews and looking for phrases that related to each of the criteria. We will now examine some of these results.

5.1 Intentionality

The criterion of Intentionality examines the goal of the user whilst using the app. It aims to understand what the user wants to achieve with the technology as well as what the focus of their attention is while using it.

In general, participants aimed either to acquire information or find and listen to all the audio messages. These are distinct; the focus of the participants while aiming to acquire information was on the garden itself, whereas the focus of participants while aiming to find the objects was the app. All participants fluctuated between both goals.

Specific excerpts from the interviews demonstrate this:

Goal: Acquire information

(P1) “I was basically trying to search for and find all the nodes and listen to them all and get all of the information.”

(P1) “...you could take that sort of idea in terms of sort of edutainment if you like...”

(P2) “...it sort of subconsciously made me take a tour of the garden...”

(P3) “it felt like a story, you were like going through... I was like searching, turning around and looking for the next little yellow thing to come and, you know, go and investigate what was going on in that part...”

(P3) “I was really interested to listen to what they had to say.”

(P4) [In response to a question about goals] “...learning about the garden, which I felt like it did very well...”

(P5) [In response to a question about goals] “...being more acknowledged of what’s in the garden.”

Goal: Find all objects

(P1) “I want to find out everything and like, access all the nodes... Because I wanted to test it properly, you know, and see everything that the app had to offer.”

(P1) “Again, probably just to find out more and use the app to find out more.”

(P2) “I was searching... For more things to interact, basically. That’s how I would say I spent most of my time.”

(P3) “it felt like a story, you were like going through... I was like searching, turning around and looking for the next little yellow thing to come and, you know, go and investigate what was going on in that part...”

(P3) “But yeah, I was just navigating to each point, so it was like it made a little trail for me, and I kind of navigated around clockwise.”

(P4) “I was very focused on trying to find these leaves on the app, and not really as much on what was around me...”

(P5) “I was more interested by the things where I can click, and I should admit I didn’t really take time to look at things that were not [pointed out] by the app. That’s it, I just walked from point to point I saw [in] the application.”

5.2 Ontology

The criterion of ontology examines how users understand the nature of the digital objects they were interacting with. It aims to understand whether users consider the objects to be “real” and a part of the lived experience of the world.

Once again, participants’ responses indicated a mixed result. At some times, participants indicated that they understood the objects as part of the garden and primarily composed of information. At other times, participants indicated a clear distinction between the virtual and real aspects of the experience. Participant 1 emphasized this especially, referring to all the digital objects as “nodes”.

In general, however, there were several indications that participants understood the digital objects as a part of the garden itself. Some examples are shown below, however, we invite you to study the transcriptions in the appendices for a better indication of this result.

Objects as part of the virtual world

(P1) "...it's interesting interacting with stuff in the shared virtual space and then you're moving around in the 3D--in the real world and things are changing, like the perspective you have on the virtual object is changing."

(P1) "I was basically trying to search for and find all the nodes..."

(P1) "...if you have sort of more generalized ideas expressed in a node..."

(P2) "I knew I had it in my, you know, virtual hand, and I was selecting it..."

(P4) "I was looking more at the screen than what was around me."

(P5) "I have looked in great part at the garden through the app..."

Objects as part of the garden itself

(P2) "I noticed that there's that one pot and it's talking about polycultures..."

(P3) "I was standing around looking at the plants and appreciating them much more, because there was information..."

(P3) "I thought this added another dimension to the garden..."

5.3 Intersubjectivity

The criterion of intersubjectivity aims to examine how users interact with the experience and how it interacts with them. It focuses primarily on the emotional and thoughtful changes that occur when undergoing the experience.

Participants generally indicated that they left the garden feeling more informed, and in some cases felt a change in mood. A positive result in intersubjectivity is an indication of this type of change; a negative result is an indication that the users did not feel the interaction between the garden and themselves.

Transformative interaction was direct

(P1) "It was interesting because it sort of gives a different flavor to the garden...putting things in a bit more context."

(P1) "I thought it was really interesting and a novel experience."

(P2) "...it sort of subconsciously made me take a tour of the garden...that relaxed me."

(P3) “I was standing around looking at the plants and appreciating them much more, because there was information...”

(P3) “...lots of interesting information that I wasn’t aware of...”

(P4) “I feel...yeah, impressed...”

(P5) “I know more things about what is in the garden...”

Transformative interaction was indirect

(P2) “...I wasn’t interacting directly with the plants...Like not touching them and rubbing them and stuff like that.”

(P3) “I was kind of avoid--not avoiding--maybe I wasn’t taking in the garden that didn’t have the speech, at parts.”

(P4) “I was very focused on trying to find these leaves on the app, and not really as much on what was around me...”

5.4 Coupling

The criterion of coupling aims to understand how intuitive the user experience of the technology was by examining whether participants experienced the technology as an extension of themselves or of the garden. Its primary focus is on obstacles that may occur during the use of the technology (for example, a technical bug) which take the user out of the experience.

Coupling is closely related to ontology, as a positive indication of coupling relates to the user experiencing the virtual objects as real. However, the focus of coupling is more on intuition than on the nature of the technology.

The experience was intuitive

(P1) “...it was clearly obvious what was the thing to click on...”

The experience was not intuitive

(P1) “...sometimes you would sort of zoom in too far and end up inside it [the object]...”

(P1) “...some things were interesting but like, they didn’t seem necessarily connected to the position or plants that were nearby.”

(P2) “...you’ve got to zoom in with the pinch out movement. But that was quite, quite cumbersome.”

(P2) “...it was a bit awkward at first.”

(P3) “Oh I just had like some random issues when I was picking and pinching the plants...”

(P3) “the zooming was a little bit---I don’t know, buggy’s not the term...it felt like you had to be very precise.”

(P4) “...difficult to grasp the control...”

(P5) “...it’s a bit frustrating at the beginning...”

6 Analysis

Given these results we can now analyse how the application has performed under each of the phenomenological criteria. This will provide us with a foundation upon which a better version of the prototype could be built, if this were to occur. In essence, the testing and interview stage of this project acts as one of the rungs in the aforementioned ladder of abstraction: we have now built a concrete prototype and examined it through an abstract lens. The next stage is to climb down again to iterate on the concrete prototype.

As the criterion of coupling informs many possible issues with the implementation of the prototype, we will therefore examine this criterion first.

6.1 Coupling

In general, our results showed that users had difficulties understanding and intuitively operating the application, especially at the start. Participants indicated that the app was not intuitive for several reasons:

1. The gestures were difficult to use; the app did not always respond to user input.
2. The movement of objects towards the device (to simulate 'picking up' the leaves) often overshoot its final position; this meant the object could sometimes be invisible or behind the camera when held.
3. The positioning of the objects was not always clear; objects occasionally migrated from their intended positions.

Issues 1 and 2 can be solved concretely and should be considered bugs; this underlies the importance of high technical quality on user experience.

Improving the positioning of objects is a two-part issue; ensuring that the positions do not migrate is purely technical and solving it would require a different architecture for the technology.

The current prototype uses the relatively simple Unity3D and ARCore coordinate system to keep objects locked to detected planes at specific positions. However, a more robust and reliable system would use image recognition to detect specific real-world locations via visual data. This is used in Vuforia (Vuforia Engine, 2019) and is

used in ARCore's Cloud Anchor feature (ARCore, 2019), but implementing these may require a redesign of the prototype.

6.2 Intentionality

Judging the success of our application under the lens of intentionality is more difficult than with coupling, though there are key insights we can gain from the interview results.

To begin with, there was a general problem across all participants whereby their goal was to find all of the audio messages contained within the app. This conflicts with the goal we intended to impart to the users; we had hoped to ensure that users did not consider the app as a means unto itself.

It should be noted here that each user will have a different goal, and this cannot be avoided. However, we believe that a technology which is an end unto itself will conflict with the more general aims and design of the garden. The app is a part of the ecosystem of the garden, and therefore should not conflict with the other members of that system.

We believe that there are some potential causes of this user intention:

1. Participants were told to explore the garden 'until they feel satisfied'. For some, this instruction may have been interpreted as 'until you complete it'.
2. The garden is a small space, and objects were easily visible from any vantage point. Therefore, users could easily see every piece of content in the app.
3. The content of the app was purely instructional, and users had no means of adding content to the app.

These problems may reveal a disconnect between the current prototype and the imagined final product. As the app is intended to be a part of the general garden ecosystem, and therefore would not be the sole focus of the garden experience, the final product would therefore be less likely to fall prey to 1.

Problem 2 may be solvable with technical means, though important design decisions must be made: should the objects be easy or difficult to find? We chose to make them easy to find because we did not want to add any level of difficulty; if the goal is to educate users, then it should be easy for them to find the information. However, we

may recall Ingold's description of the mentor and mentee (Ingold, *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*, 2000). If our app is the mentor, then it should not fall on the mentee to discover which objects to pay attention to. Therefore, an improvement on this design may be to use the device's location to send a vibration to the device, alerting the user to a new audio message. This would allow for more difficult-to-find objects while still assisting users in actually finding them.

Problem 3 presents another complex problem. However, we believe that this is best covered under the following criteria.

6.3 Ontology

The results under the lens of ontology indicated a closer result to what we were aiming to achieve, namely that the users' experience of the technological aspect of the environment were blended strongly with the physical and 'real' aspect of the garden. However, there were some indications from the interviews that participants experienced a separation between the virtual and real content of the experience. Where some participants (especially P3) understood the audio messages to be coming from the garden rather than the application, most participants made reference at least once to the application as a separate, virtual entity.

A major flaw in the design of the application is that it relies heavily on the use of the mobile device's screen and camera. Because of this, while using the app, the user is always looking at the device. This forms a barrier between the user and the plants.

The idea presented in the section on Intentionality, in which users may put away the device and wait for a vibration before searching for an object, may improve this. This would allow users to explore the garden without the barrier of the screen until it is required.

A key insight can be taken from these results: even when the technology is designed to integrate into the real world, care must be taken to ensure that this integration is done seamlessly. The method of interfacing with the technology is a crucial part of the experience; digital screens seem to form a barrier by nature, and their use should be minimized.

In our original design plans, the audio messages would be delivered using the small speaker on the device normally used for phone calls. However, due to difficulties in the

technical implementation of this feature, headphones were used instead. It is as yet undetermined whether this feature would improve our results ontologically, though this should also be considered as a potential improvement for the application.

6.4 Intersubjectivity

We found that participants generally found that the experience had a direct and positive effect on them, though there was a caveat to these results: some participants only directly interacted with those parts of the garden which had associated audio messages. This calls back to the user intentions we found, whereby participants often aimed only to experience all of the content of the application rather than gain a greater appreciation of the garden.

Though P3 indicated that they did appreciate the garden more after using the application, they also indicated that they did not interact with the entirety of the garden. We turn again to the idea of a vibration alert sent to the user to ensure that they are not looking at the phone screen for the entirety of the experience, as this may help them to reflect on the garden as a whole rather than on individual plants and entities within the garden.

Participant 3 also indicated that they would appreciate a feature allowing users to place their own audio messages within the garden, and this was considered during the design process. We believe that allowing participants to place their own messages would improve intersubjectivity, as it would allow users to leave their mark on the real world (Persson, Espinoza, Fagerberg, Sandin, & Cöster, 2003; Dourish, 2001). Furthermore, it would encourage interaction between users. However, this feature was not implemented due to time constraints. It should be considered for future prototypes.

6.5 Potential Solutions

Overall, there are several fixes and features to implement for the next iteration of this prototype, should it continue. Technically, the input gestures and movement of objects should be fixed to ensure that they work as intended, even if this requires a full redesign of the codebase.

The app should implement features to ensure that less time is spent looking at the phone screen, possibly using a vibration alert feature which would allow users to put the device away until they are close to a new audio message. This could alter the general intention of users from 'find all the objects' to 'experience and learn about the

garden'. It may also improve the experience ontologically by utilizing another sense (tactile feedback) and removing the barrier of the device screen, thus moving user focus to the garden itself.

Finally, the app should consider and test the possibility of allowing users to place their own audio messages. This may improve user experience of intersubjectivity by permitting them to leave their own influence on the garden and experience the social aspect of it.

Importantly, it should be stated that this analysis of the technology relates to the phenomenological goals of the app: to provide an educational experience which blends the virtual and physical worlds, allowing users to 'see the unseen information' inherit in the garden. While we suggest that these improvements may have implications for augmented reality experiences in general, each individual experience should first consider its own goals and needs.

7 Evaluation

This project aimed to achieve two goals: to develop an application that educates users on the permaculture theory that underlies the garden's design; and, to design and assess the application's success according to phenomenological principles.

On the former we believe that we have developed a successful application, where success is given by an overall positive indication that the project is achieving its goals. All participants indicated that their knowledge and understanding of the garden improved after using the application, giving it more context. This is particularly notable given that the total educational content delivered to the participants was under 4 minutes of speaking time.

That said, we believe that there is much to learn from the design and analysis process as described in this paper.

Overall, phenomenology appears to be a strong foundation on which to build and analyse augmented reality experiences. In particular, the phenomenological categories that we identified aided us in prototyping an experience according to our overall design goals. They helped us to deliver a technology that integrates well with the garden and encourages users to interact with the application in the way we wish while still allowing them to use it as they wish.

There are some key considerations, however, before this framework can be used in further projects.

While we referred to phenomenological thinkers like Maurice Merleau-Ponty, Edmund Husserl, and Martin Heidegger, we must acknowledge that there are other bodies of work by each of these philosophers and that there are, of course, other phenomenological thinkers whose works may provide great ideas and frameworks for understanding augmented reality. In particular, the post-phenomenologists and postmodern thinkers such as Don Ihde (2002), who focuses upon technological issues. This is a wide realm of post-phenomenological thought and should not be ignored within our domain.

In addition to this, we may have been too eager to explore phenomenological ideas at the expense of foundational user experience design principles. For example, the

process of creating our initial design was “idea first, user testing later”. This is not suggested by, for example, David Benyon (2018); we should always look first to study what users are looking to experience before creating a prototype. We chose not to do so for two reasons, namely that we were constrained for time and interviewing potential users would have had to infringe on our development time; and that we envisioned an iterative design process in which users would help us to improve on our initial prototype. Therefore, the design process outlined here should be evaluated as a first step: the input we received from our user testing would be linked directly to the development of a future prototype.

Of course, all future research should take the time to evaluate interview questions and explore multiple methods of analysis. We chose short, semi-structured interviews because, while we needed qualitative data to understand the project according to our own framework, we could not expend the necessary time to review a multitude of users or questions. Furthermore, the experience itself was very short. We believe that further research should examine augmented reality under the same lens but under much lengthier conditions. If, for example, the end goal is an experience that can comfortably exist in a large garden or museum, and users can pick up and put down the technology as they wish, then a five-minute session cannot hope to explain the full story of the user experience.

It must be stated here that while we made an attempt to remain unbiased in our observations and analysis of the results, this can never be completed fully, and we believe that a better attempt could have been made to ensure that we were unbiased. Thompson, Locander and Pollio (1989) suggest using a group of researchers to each individually analyse participant responses and compare in order to minimize bias. They also suggest that interview questions are more open-ended than what we have presented here. Should further research be conducted using this framework, close attention should be paid to the construction of interview questions and the entire analytical process.

Tangential to this observation is that we have not closely examined other technologies or experiences with this framework. That is, what experience would the user have, with reference to the phenomenological categories presented here, in a garden that uses traditional media to educate visitors? Is this framework valid for non-educational augmented reality experiences, or AR apps with different goals? Does the user

perceive an experience as inherently better where the augmented reality application aims explicitly not to integrate with the real world in the ways that we have described? Can this framework be used to analyse experiences that do not use augmented reality at all?

While we may find some answers to these questions in some of the literature that we have reviewed (Dourish, 2001; Pallud & Monod, 2010; Monod, Klein, Isari, & Missikoff, 2006; Borchers, 2001), further research in this area is necessary. Vuforia numbers their developer community at “over half a million” (Vuforia Engine, 2019), the number of devices which support ARCore is growing in device support and ARKit is now available on iPhone and iPad devices (ARCore, 2019; Augmented Reality - ARKit 3, 2019), and companies such as IKEA (IKEA, 2019) and American Airlines (Groove Jones LLC, 2017) are already deploying augmented reality applications commercially. As this technology grows, there is a need for deep understanding of the user experience of this technology.

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Appendix 1

EDINBURGH NAPIER UNIVERSITY SCHOOL OF COMPUTING

MSc RESEARCH PROPOSAL

The process of completing and reviewing the contents of this form is intended ensure that the proposed project is viable. It is also intended to increase the chances of a good pass. Much of the material produced while completing this form may be reused in the dissertation itself. 1. **Student details**

First name	Hudson
Last (family) name	Miears
Napier matriculation number	40408121

1. **Details of your programme of study**

MSc Programme title	MSc Computing
Year that you started your diploma modules	2018
Month that you started your diploma modules	September
Mode of study of diploma modules	Full-time
Date that you completed/will complete your diploma modules at Napier	August 2019

2. **Project outline details**

Please suggest a title for your proposed project. If you have worked with a supervisor on this proposal, please provide the name. You are strongly advised to work with a member of staff when putting your proposal together.

Title of the proposed project	An audio-based augmented reality application: utilising eco-phenomenology to enhance user experiences in blended spaces
Is your project appropriate to your programme of study?	Yes
Name of supervisor	Callum Egan

3. **Brief description of the research area - background**

Please do not describe your project in this section. Instead, provide background information in the box below on the broad research area in which your project sits. You should write in narrative (not bullet points). The academic/theoretical basis of your description of the research area should be evident through the use of citations and references. Your description should be between half and one page in length.

The Lion's Gate project consists of a garden in Edinburgh Napier University which attempts to integrate the digital and ecological worlds (The Lion's Gate, 2018). This integration comes from the
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theory of blended spaces (Benyon, 2018; Egan and Benyon, 2017); the particular type of blended space here is best explained by (Egan and Benyon, *ibid.*). The ecological portion of the garden is

based on permaculture design principles (Mollison, 1988), whereas the digital portion attempts to merge these principles with more classical user experience design principles.

Mobile Augmented Reality is a technology by which digital information can be overlaid on the realworld via mobile phones. For example, 3D models can be overlaid on a live camera feed in such a way that they look to be placed in the real world. ARCore, a development library created by Google for use in Android devices (Google, 2019), implements the functionality needed to achieve this.

In a similar vein to blended spaces, user experience designers have examined how technology can enhance museum experiences (Abate et al., 2018; Ciolfi and Bannon, 2002; Efstratios et al., 2018; Monod et al., 2006; Pallud and Monod, 2010). Pallud and Monod (*ibid.*) used a phenomenological approach to determine whether modern technology enhanced users' feelings of relationship to history.

Eco-phenomenology is a philosophy with roots in both positivism and phenomenology (Wood, 2001). Where Husserl's phenomenology separates the conscious and perceptive self from the world, eco-phenomenology integrates the surrounding environment as a key element of perception (Abram, 1997). As such, eco-phenomenology provides a stronger foundation for evaluating the effect of technology on user experience in a natural space than does Husserl's phenomenology. Furthermore, eco-phenomenology's principles match easily to many of the permaculture principles laid out by Mollison; this allows for an analytical framework rooted in a philosophy compatible with the philosophy of The Lion's Gate itself.

This leads to some core design principles:

- Blending spaces as informed by Mollison's boundary conditions and eco-phenomenology's boundaries between objects.
- Digital information as a layer in the permaculture space; digital software as an invisible layer that blends with the physical space rather than distracts, as in ubiquitous computing (Dourish and Bell, 2011).
- Technology as a means to aid in understanding a space, its context, and its ecology.

It also leads to particular methods of evaluation, ie. An evaluation of the user perspective in reference to feeling present in an environment, a member of the ecosystem, an actor in a his or her environmental context.

4. Project outline for the work that you propose to complete

Please complete the project outline in the box below. You should use the emboldened text as a framework. Your project outline should be between half and one page in length.

The idea for this research arose from: Callum Egan expressed an interest in implementing some type of AR experience in The Lions' Gate garden project. The experience would use mobile AR such as Google's ARCore, and it would integrate core principles from The Lions' Gate's theoretical foundation, including David Benyon's Blended Spaces framework and the permaculture design principles.

Based on these characteristics, the idea arose to examine experimentally how AR can improve user experience in a physical space as compared to other media. Exploratory research revealed the phenomenological approach used in Pallud and Monod (2010). In response to The Lions' Gate's use of permaculture, eco-phenomenology seemed a better foundation than Husserl's phenomenology.

The aims of the project are as follows:

- Compare the effectiveness of educational material using traditional media with that using mobile AR.
- Design and evaluate a mobile AR application according to user engagement with physical space.

The main research questions that this work will address include:

- How can AR be designed and evaluated according to design and philosophy principles that incorporate the environment?

The software development/design work/other deliverable of the project will be:

- A Unity3D-built augmented reality application prototype.
- Statistical and descriptive comparisons between users' experiences of the garden with traditional media and AR.

The project deliverable will be evaluated as follows:

- Did users report that the AR application improved their experience of the garden over traditional media?
- Does the application successfully adhere to the design principles outlined in the theoretical research?

The project will involve the following research/field work/experimentation/evaluation:

Lickert Scale questionnaires and semi-structured interviews with experimental participants. Participants will be led through the garden first with traditional media (ie., a pamphlet or informational signs), then with the AR application. Questionnaires will be filled out after each of these; all will be followed by semi-structured interviews.

This work will require the use of specialist software:

Unity3D, ARCore, Android Studio

This work will require the use of specialist hardware:

ARCore-compatible Android device

The project is being undertaken in collaboration with: Not applicable

5. References

Please supply details of all the material that you have referenced in sections 4 and 5 above. You should include at least three references, and these should be to high quality sources such as refereed journal and conference papers, standards or white papers. Please ensure that you use a standardised referencing style for the presentation of your references, e.g. APA, as outlined in the yellow booklet available from the School of Computing office and

http://www.soc.napier.ac.uk/~cs104/mscdiss/moodlemirror/d2/2005_hall_referencing.pdf.

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6. Ethics

If your research involves other people, privacy or controversial research there may be ethical issues to consider (please see the information on the module website). If the answer below is YES then you need to complete a research Ethics and Governance Approval form, available on the website:

<http://www.ethics.napier.ac.uk> .

Does this project have any ethical or governance issues related to working with, studying or observing other people? (YES/NO)	Yes
---	-----

7. Confidentiality

If your research is being done in conjunction with an outside firm or organisation, there may be issues of confidentiality or intellectual property.

Does this project have any issues of confidentiality or intellectual property? (YES/NO)	No
---	----

8. Supervision timescale

Please indicate the mode of supervision that you are anticipating. If you expect to be away from the university during the supervision period and may need remote supervision please indicate.

Weekly meetings over 1 trimester	X
Meetings every other week over 2 trimesters	
Other (what?)	

9. Submitting your proposal

10. Please save this file using your surname, e.g. macdonald_proposal.docx, and e-mail it to your supervisor, who will discuss it with you and suggest possible improvements.
 11. When your supervisor is content with your proposal, email it to your internal examiner, who will provide feedback and possibly suggestions for improving your idea.
 12. Discuss your feedback from the internal examiner with your supervisor and if necessary make final changes to your proposal.
 13. Upload the final version to the dissertation learning space on Moodle.
 14. When you produce your dissertation, add your finalised proposal as an appendix.
-

Appendix 2: Phenomenological Design Strategies

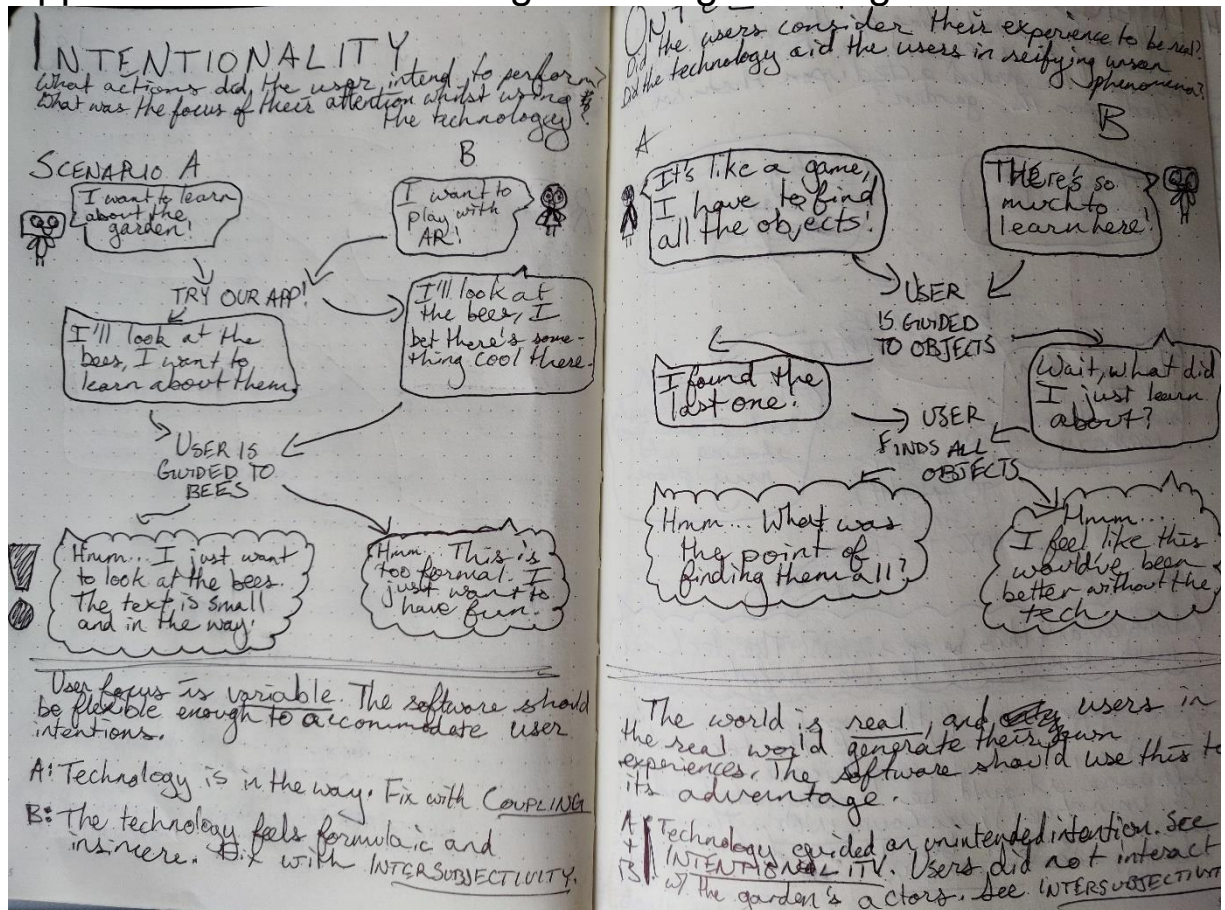


Figure 2: Scenarios focused on criterion of Intentionality (left) and Ontology (right)

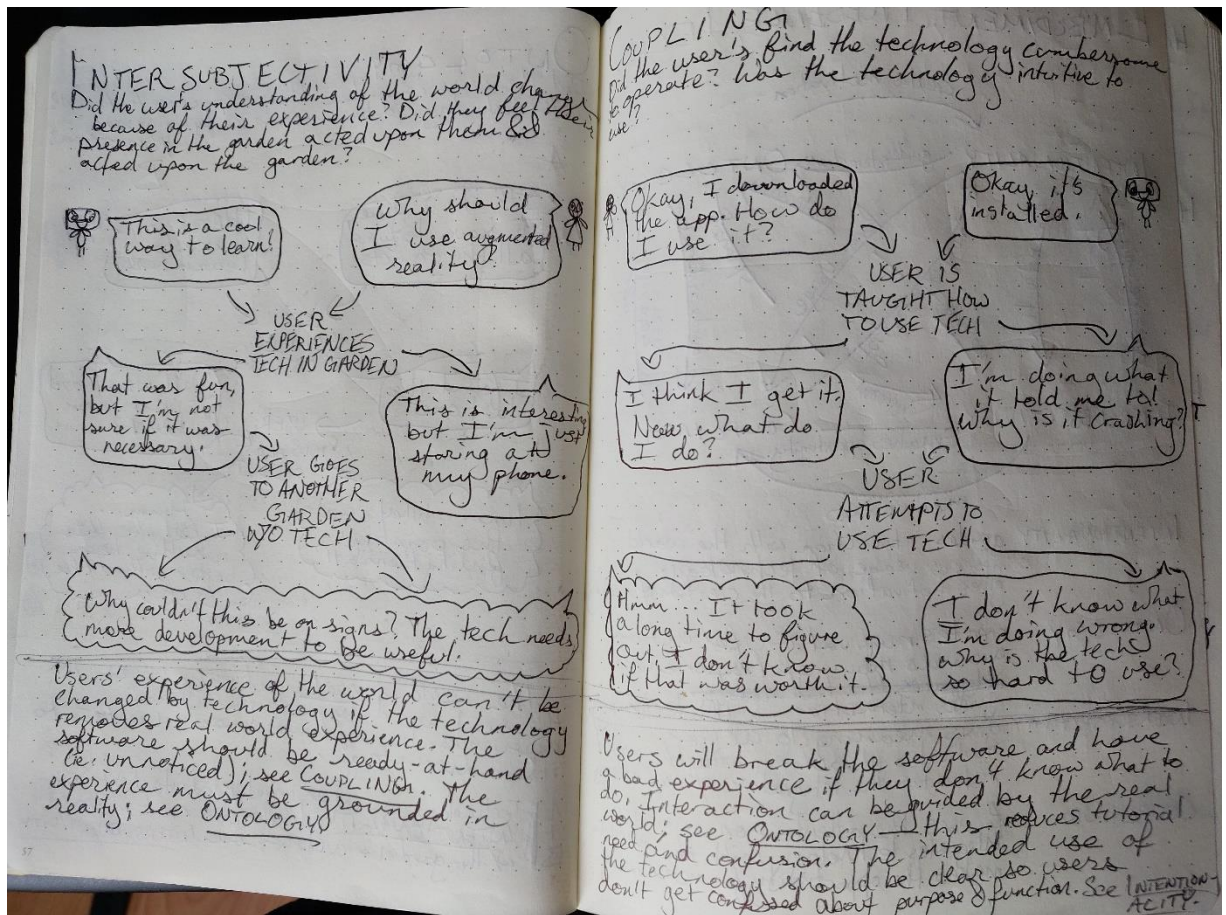


Figure 3: Scenarios focused on criterion of Intersubjectivity (left) and Coupling (right)

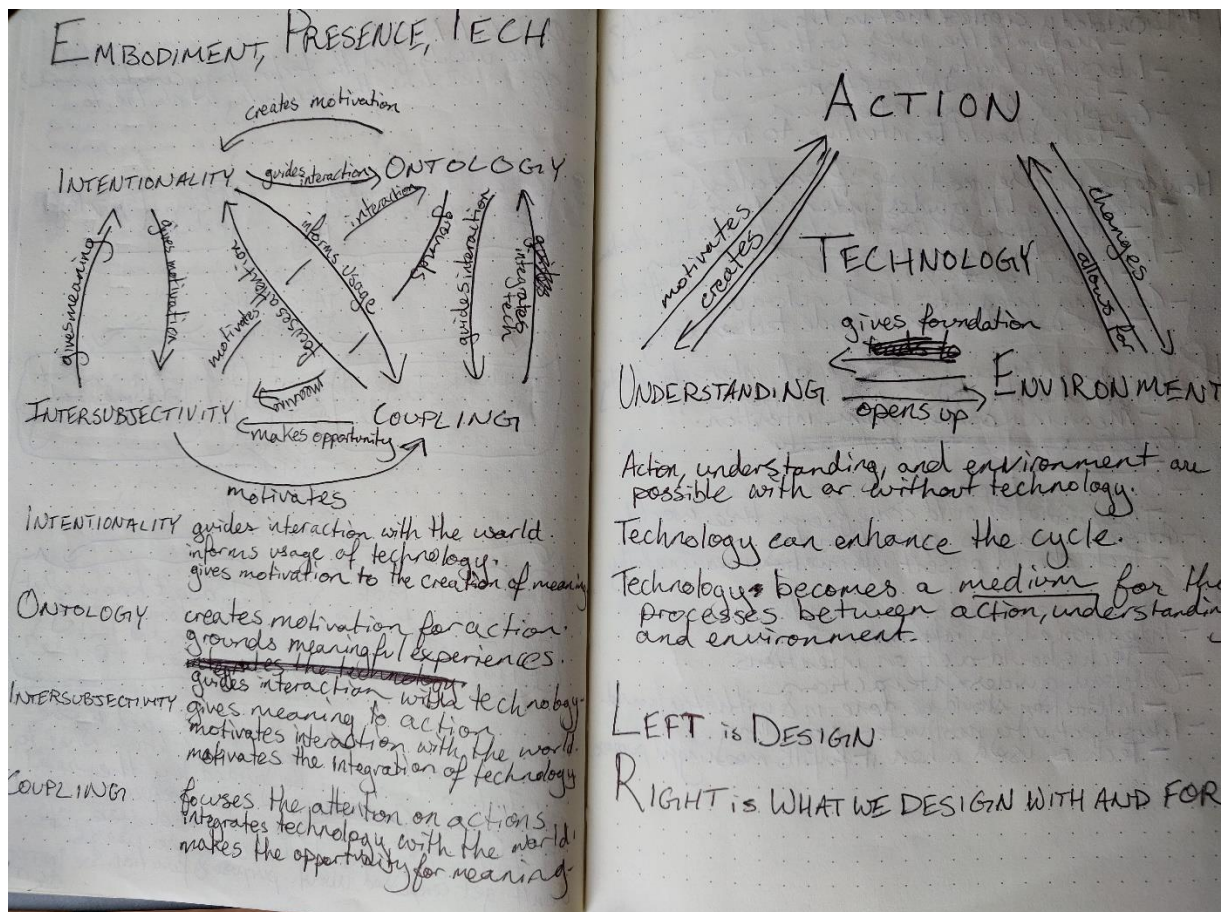


Figure 4: Analysis of criteria and their interrelations.

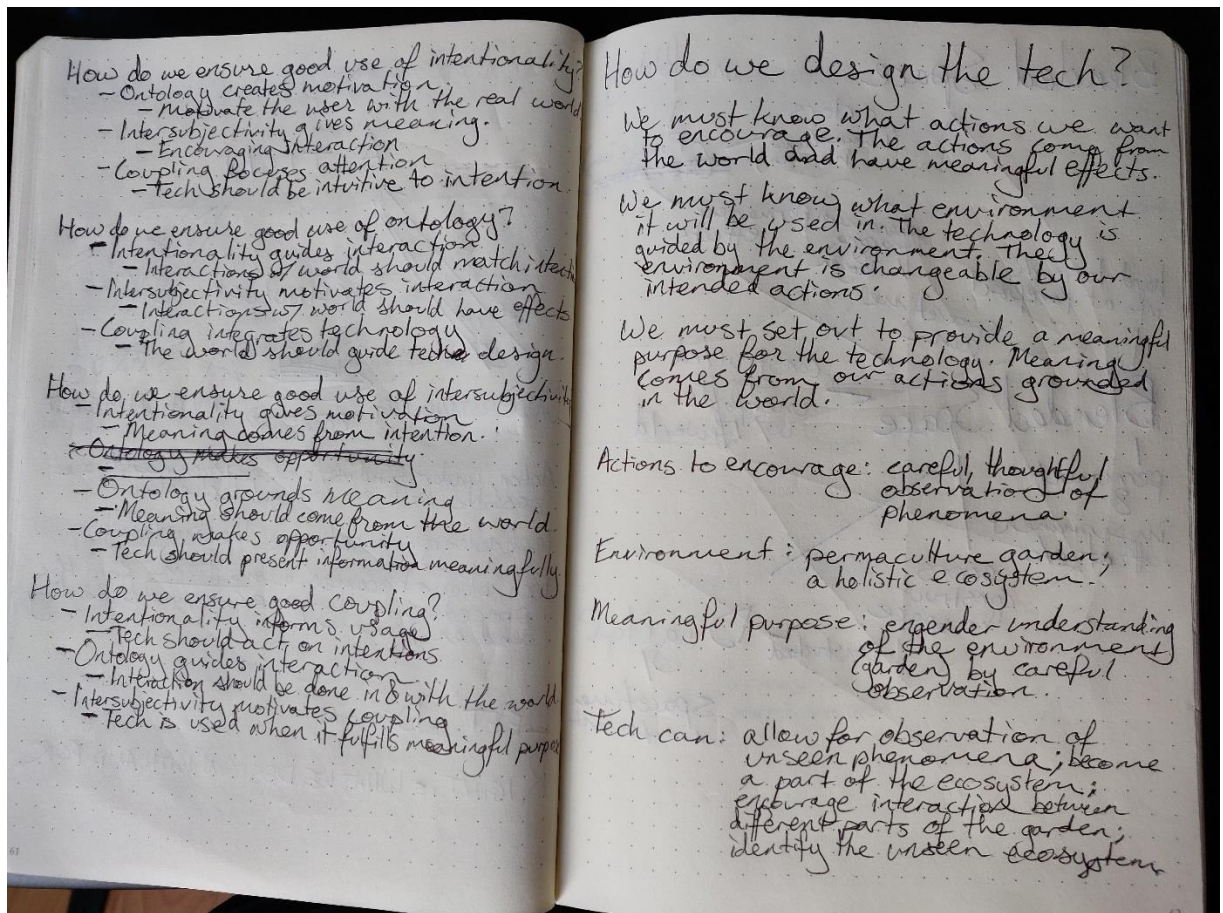


Figure 5: Analysis of criteria and their implications on technological design.

Appendix 3: Evidence of Organization

Educational Backlog

- Unity AR: complete all Unity AR tutorials. 2 working days
- Research maps API for Unity options. >1 working day
- Chosen maps API tutorials. >2 working days
- Database solution. >2 working days
- Audio encoding & storage. 1 working day
- Unity/Android touch gestures. 1 working day
- Android: play from phone ear speaker. 1 working day
- Unity/Android UI design basics. 1 working day
- Map/AR storage of location w/ surface elevation. >3 working days
- Firebase API for Unity. 2 working days
- How to record audio in Unity. 2 working days

Working tally

III I I I I I

days to learn Android/AR/Unity skills

Dev Log

- 21/5/19: Learning Unity + AR
- ARCore Device holds a FP camera which uses the phone camera
 - Update Application Lifecycle handles eg. timeout, quitting, permission popup
 - Planes detected using a raycast; hitinfo is a TrackableHit
 - check if detecting back of the plane
 - Anchor is a transform-type thing which locks things to the real world
 - Pose is the actual post-orientation from which anchors are created
 - objects are children of anchors
- 22/5/19: Reviewing object manipulation example
- learned further ARCore terms
 - see Hough's 17-19
- 23/5/19: Researched (briefly) Firebase. Decided against maps API in favor of simpler physical location. Read from UX book (see Persson et al. 2003).
- 24/5/19: Modified object manipulation example to move objects using the scale manipulator. Enable the manipulator initial obj position, then continue to calculate how to move
1. Calc where to move towards
 - a. get cam position
 - b. project point onto camera frustum forward
 - c. return the objects original pos minus that
 2. Calc between initial position and final position
- ARCore positions can be very unreliable

It seems that positions are not consistently updated, incl dev the camera

Objects now lock to the camera, if they pass a threshold of clamped scale ratio. They unlock if they are locked but pass below the threshold

Quick movement and unsteady plane detection can still cause problems

Placing new objects deselects the locked obj - which makes it basically impossible to unlock. This needs to be fixed urgently

27/5/19: Missing w/ Firebase Storage. Set up & authorized in Unity. Possibly must remove build's Created an init script on AR device. This creates a DDOL object. Firebase storage uses a file system. Uploading can be done with files or byte[] Unfortunately Android file access requires some sort of server via Unity's Web class (deprecated). In final build, audio will probably be in memory anyway, but, if not, it's very difficult to test as a dummy file.

Uploading now works, depends on the code already in there. Downloading is a problem - how to convert downloaded into playable audio clip?

Appendix 4: Informed Consent Form

Phenomenological Design of an Augmented Reality Project

This experiment is being conducted as part of a Master's dissertation project at Edinburgh Napier University. It aims to understand the user experience of a learning space (the garden at Edinburgh Napier University) mediated with the use of an augmented reality application.

You have a right to participate in this experiment regardless of age, gender, orientation, race, or health as long as you are giving willing consent. The researcher is not aware of any risks associated with the use of the application or with the interview process. The entire procedure should take no longer than 30 minutes.

You will be asked a few questions before beginning and will participate in a brief interview after using the application. The interview will be audio recorded. The data will be anonymized as much as possible, but you may be identifiable from a tape recording. It will be accessible only to the researchers (ie. Hudson Miers, the present researcher) and kept in a secure, password-protected hard drive. The data will be destroyed following the completion of this project and its examination.

You have a right to withdraw your consent and quit the experiment at any time without giving a reason. If you wish your data be destroyed, you need only ask the researcher.

If you would like to contact an independent person who knows about this project but is not involved in it, please feel welcome to contact Callum Egan. His contact details are given below:

Telephone: 0131 455 2790

Email: callum.egan@napier.ac.uk

If you have read and understood this information sheet, any questions you had have been answered, and you would like to participate in this study, please now see the consent form.

Informed Consent Form

Phenomenological Design of an Augmented Reality Project

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in this research to be conducted by Hudson Miers, who is a postgraduate student in the Edinburgh Napier School of Computing.
2. I have been informed of the broad goal of this research study. I have been told what is expected of me and that the study should take no longer than 30 minutes to complete.
3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher. I have been told that these data are for internal use only.
4. I also understand that if at any time during the session or interview.

If I feel unable or unwilling to continue, I am free to leave. That is, my participation in this study is completely voluntary, and I may withdraw from it at any time without negative consequences.

5. In addition, should I not wish to answer any particular question or questions, I am free to decline.
6. I have been given the opportunity to ask questions regarding the session and interview and my questions have been answered to my satisfaction.
7. I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of this consent form for my records.

Participant's Signature

Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature

Date

Appendix 5: Interview Questions and Transcribed Interviews

Questions

1. How did you feel before using the application?
2. How do you feel now?
3. Describe the garden and what you found in it.
4. Describe your actions in the garden while using the app.
5. Describe your experience from a technological standpoint.

Transcribed Interviews

Key

N = interviewer

P = participant

Intentionality

Ontology

Intersubjectivity

Coupling

Participant 1

N: Could you just describe before we start how did you feel after walking through the garden before using the app?

P: Before using the app? Ah, I felt pretty relaxed and you know, uh, chilled out, you know. It's quite nice after being locked inside to just potter around a wee garden for a bit and see the bees and the hoverflies flying about. So yes, just felt...but a lot of, was sort of thinking what is everything? Yes, everything has labels, but it's all polycultures, so yes, what exactly? But yeah, it was nice. It's come on a long way.

N: What about after using the app?

P: After using the app? It was interesting because it sort of gives a different flavor to the garden by like pointing out what everything is being used for and what the purpose is and putting things in a bit more context like the whole part about the bee hotels. So is that what Mark is doing?

N: I believe that's what Mark is doing.

P: But, aye, it's just interesting having that sort of augmented reality experience. Um, yeah. Oh, and also it's interesting interacting...I know this isn't quite the question you're asking but it's occurred to me it's interesting interacting with stuff in the shared virtual space and then you're moving around in the 3D--in the real world and things are changing, like the perspective you have on the virtual object is changing. So, just found that interesting as well.

N: How much of a distinction would you say there was between the virtual object and the real world?

P: Um, well, like, uh, enough that it was clearly obvious what was the thing to click on because from an interface point of view you to an extent want that. I mean, I can understand there's the other thing, you don't want it to be too abstract and artificial and the fact that it was actually a plant leaf was useful. I suppose, one thing that might have been quite nice---this is probably going onto your other questions--what would you prefer adding or something?--but since they were all the same leaf it would be interesting if like, you had, a leaf of a plant which was relevant for that specific point.

N: I completely agree.

P: And like, or some other thing, like even if it was like a bee for a bee hotel or, I don't know, a piece of lavender or whatever that plant is that the bees are loving. It would be interesting if like, the plants were thematically related...um, but yeah.

N: I agree. That was the original plan.

N: Could you just describe your actions while you were using the app?

P: Well, I was basically trying to search for and find all the nodes and listen to them all and get all of the information. I mean, it did help that you know, I could see through walls, so that was good because it would be really much more difficult without that. Um, yeah but it was basically, when I was using it was like, ooh I want to find out everything and like, access all the nodes was the sort of..uh...thing that was going through my mind. Because I wanted to test it properly, you know, and see everything that the app had to offer.

N: So then, kinda following on from that, what would you say your goal was?

P: My goal was...um? Again, probably just to find out more and use the app to find out more. In this sort of way, I mean there are parallels with things like museums where you know you've got the headphones and you go boo boo boo boo boo because it's object number 119 but this is a bit more organic, if you pardon the pun, because the things are actually in 3D space. You're not having too ...though it is interesting, even looking at the screen and then looking at it with your eyes is drastically different. So sometimes I was like, 'some people call this a weed' and so I was like, you know, going between the screen and reality when I was trying to work out the specific thing that was the weed and things like that.

N: And then next could you just kind of describe the garden itself?

P: Describe the garden itself?

N: As you experienced it.

P: As I experienced it, well, first coming in I saw a couple of trees over there, I think there was an oak and a rowan and I came along the path past all these lovely wildflowers. Then there were more trees. I went up the steps onto the, not mezzanine, whatever you, the raised area. Again just, I think there's the three sisters over there, there's a lot more trees, quite a few perennials, so it's clearly a permaculture garden because I didn't see any real annuals or anything so, yeah it was very clear that it was a permaculture rather than anything else.

N: And is there anything you would like to say, while using the app, anything that you would like to say about kind of the technical aspects of it?

P: One thing was that the interface where you click an item and then you sort of drag it towards you until it's in range. I think that's an interesting idea to have a multi-step activation sequence, it's just that sometimes you would sort of zoom in too far and end up inside it and then you'd have to sort of walk back in order to listen to it. Which is interesting because it's sort of a novel interaction but I don't know, if you were in, I don't know, a situation where you had time pressures or something ...I know that this is the antithesis of time pressure, you know just chilling in a garden. But if I don't know, you for whatever reason wanted to get the information quickly, getting stuck inside the node and going 'uh, well, it's too close now and I can't see it's...yes, I mean there's a few things technically that you could possibly do to it. But again, a lot of it is some of the limitations of technology in terms of making sure things are existing in a certain space and you know, continue to remain in that same space no matter what strange translations and rotations you put the camera through. And aye, I don't know, I suppose you could have other things like, if for example instead of you zoom in for it to sort of come towards you and then you let go and that's sort of plucking it and then it sort of plays. that might be an interesting thing, so you sort of select it and then go mmmm and then

pluck and then it plays. Yeah, I don't know and that would probably be annoying to do though in terms of 3D---I don't know though.

N: It may be worth trying...

N: Is there anything else you want to add?

P: Um...Other than that, I thought it was really interesting and a novel experience. And I can think there's probably a lot of different directions that you could take that sort of idea in terms of sort of edutainment if you like, to sort of more straightforward education about these things...especially if you had like a very dense garden with a lot of nodes. I suppose if you had an awful lot of nodes I'm not sure if you might want to have a breadcrumb trail between nodes just in case some people got too overwhelmed and like 'i don't know where to go next' but because there were relatively few nodes that was never a problem. But if there were say like 40 nodes or something, then you'd be like mmmm. Yeah, so...But aye, some things were interesting but like, they didn't seem necessarily connected to the position or plants that were nearby. Like the part where you were talking about corn, maize, and rice being the three dominant seeds and everything, and food crops, and that obviously you know..permaculture you're gonna have smaller overall volumes but far greater individual productivity. But the thing is that it just...was didn't seem to relate specifically to that area. So I guess that's the thing, if you have sort of more generalized ideas expressed in a node you're like hmm, how do I actually, I mean for example if that was near some sort of artwork or something that kind of represented that or something...that would be...I suppose you'd draw more of a semantic link between the audio and the environm---whereas it was over by some plants and flowers over there, which didn't make me think of food crops. Um, like, I suppose there's the thing where you could maybe go, I don't know, you could have it like near the three sisters or some---but then again that's polycul--but yeah it's an interesting idea and it's an interesting problem of seeing exactly what you'd want to have where and exactly what you'd want to have in a program like that.

N: Okay, thank you very much.

Participant 2

N: Thank you very much for participating. Before we get into it, can I just ask how did you feel before you started using the app when you were just exploring the garden?

P: In one word or generally?

N: Generally.

P: Um, curious as to what the app was and how...uh because I didn't really sort of see a clear purpose for an app somewhat of this...because they're almost like two different things you know like technology and nature...so I was quite curious to see what you've...curious, yeah, that's the word.

N: And how about after using the app?

P: Uh...weirdly relaxed actually. I don't remember much of the content, but I think it was because I was uh..walking--I wasn't interacting directly with the plants, but it's the fact that it made me walk around the entire garden and have a look at everything. That was quite--- yeah so, it sort of subconsciously made me take a tour of the garden, so yeah that relaxed me.

N: So you say you weren't interacting directly with the plants. Could you expand on that?

P: Like not touching them and rubbing them and stuff like that. Uh, just looking at them and yeah.

N: Could you just kind of describe the garden, kind of after using the app?

P: Uh...it's not, it's definitely not a traditional garden. I noticed there's...uh, because I've seen a few articles on this about wildflowers and councils not cutting down wildflowers on verges and roundabouts. They just let them grow because it's good for bees and stuff like that. I noticed there's a lot here and they're intermingled with other plants, um, and I noticed that yeah there's that one pot and it's talking about polycultures and how, having different plants--not just the wildflowers, the weeds, they're like normal plants---you plant---that interact with each other and apparently it gives you more food, something like that.

N: Could you describe your actions here while using the app?

P: Uh...searching? I was searching for the...for the little plants, I mean sometimes they were quite difficult to find, because they're green and everything else is green...um, but yeah I was sort of searching for...for stuff there. For more things to interact, basically. That's how I would say I spent most of my time.

N: And once you found something while you were searching, could you kind of describe that process.

P: Yeah like you taught me, you have to click on it and then the...yeah, so you find the plant. You click on it. Then, to see what you've clicked on it's uh...there's the white ring around it

and you've got to zoom in with the pinch out movement. But that was quite, quite cumbersome. Uh...like there didn't seem to be a limit to how much you could zoom into the plant so sometimes it just went off the screen. But I knew, like conceptually, I still had it in my hands because of that other button you told me about, where it's a play audio. Um, but yeah that was quite, uh, confusing that I knew that I had it, but I couldn't see it. I knew I had it in my, you know, virtual hand, and I was selecting it, but because I couldn't see it, at the same time my subconscious was like, oh I don't know whether I have it or not. So that was a bit-- but I think there's a trick to it with everything, and in the end it was okay. I think once I'd learned how to do it properly, um, yeah, so I can't---yeah I did know what to do in the end, but it was a bit awkward at first.

N: And just, finally...I suppose you already answered that question. I think that's about it, thank you very much.

Participant 3

N: Okay, keep saying what you were about to say.

P: Oh I just had like some random issues when I was picking and pinching the plants, because it felt like you had to get--to like a, specific point where it would allow you to play and sometimes I thought I'd went far enough and it wasn't turning white and I was a bit confused, but it was just like a silly little pinching thing.

N: Okay, so just to start, can I ask how did you feel kind of before you started using the app.

P: What with the garden?

N: How did you feel while you were here in the garden.

P: Just a bit lifeless? Hahaha, you know it's just, it's been heavy rain obviously, so the plants don't look that exciting when they're just, on their own, not accompanied by...interaction.

N: So, then, how would you say you felt after using the app?

P: Yeah, I really enjoyed it. I thought it was, I was standing around looking at the plants and appreciating it them much more, because there was information about---you know like, even from the beginning, saying that this is going to grow into like a large tree one day, that's really interesting. I also really liked the...poly...hm, terrible I don't remember the name already.

N: Polyculture?

P: Polyculture, yeah. That was super interesting, like to see...you know, to have that little bit of information because if you didn't know that, then maybe you wouldn't appreciate that, which I thought was really interesting.

N: Could you just, kind of describe the garden and what you found in it?

P: Well...lot's of interesting information that I wasn't aware of, so that was really cool. I liked that the...because it felt like a story, you were like going through...what's, you know, it's not the most exciting garden at this moment in time... Having the sort of visual, you know I was like searching, turning around and looking for the next little yellow thing to come and, you know, go and investigate what was going on in that part, and sort of story that was always accompanied was really interesting. Really enjoyed it.

n: So, just kind of leading on from that, could you describe your actions while you were using the app in the garden?

P What as in how I was using it?

N: Just what your actions were?

P: So straight away when I realized that I was, you know looking for these yellow dots, I would sort of find one and then I would sort of scan around looking for the next and just, I was kind of avoid--not avoiding--maybe I wasn't taking in the garden that didn't have the speech, at parts. I don't know if that was on purpose, or I just went like that.

N: And from a technical aspect, could you describe kind of how the app seemed to you technically?

P: Yeah, I, so I really liked the visual little plants, um...that was really cool to---you know, cause some of them like they kinda looked like it camouflaged in with the real plants. The...the zooming was a little bit---I don't know, buggy's not the term, it was a little bit, um...what's the word, not clunky, you know, something like that. It just, it felt like you had to be very precise---sometimes if you just zoomed it where you couldn't even see the plant it would work, so I started doing that instead. But it was---no, it was really good. And I liked the audio was great, it was nice sounding. And they weren't too long, they weren't too short. I wasn't like, standing here thinking 'when is this going to end?' that was definitely not--I was really interested to listen to what they had to say.....Um, I don't know. Technical, what else?

N: That's okay. Is there anything you'd just like to add about the experience?

P: Um...well, I already told you, I really enjoyed it. I thought this added another dimension to the garden, and it made it very interesting and something that's not that interesting...at this precise moment, you know, because it is...the weathers not been that great. But yeah, it was really--really interesting.. The only, you know, with, maybe, I like placed some random plants here and there which was a bit--I had no idea what I was doing, and then I wasn't sure if I'd found---I started listening to the test recording a couple of times. But I think that was, um, I don't know. Would people be allowed to---would you have people allowed to pop down stuff?

N: That is..as yet undecided.

P: Cause yeah. Yeah, I really enjoyed it.

N: Would you like that?

P: Well I think it would be cool, but I think you would have to somehow monitor it because it could get ridiculous. Cause I was just putting them down by mistake when I was trying to pick up another plant, and I put like a couple plants next to one. But that was...I only did that once, over there, and it didn't happen to me, so I don't know if it was just, if it was me.

N: Ok.

P: But it was really good.

N: Okay, thank you very much.

Participant 4

N: Just to start, can I ask how you felt before you started using the app?

P: Um, I felt like I had a good idea of what was coming up because we've talked previously about it. But in terms of, augmented reality, I don't have much experience with that, so I felt interested and engaged.

N: Can you describe kind of how you feel now, afterwards?

P: I feel...yeah, impressed, I would say. It's a good app. Uh, there was nothing really that, um, made the experience not good about the app, sort of thing.

N: Thank you, could you just sort of describe, after experiencing the app, could you just sort of describe the garden and what you found in it.

P: Well those bushes over there are gonna be overgrown, um, the compost mainly made out of waste, then there's the bee hotel up there on the shelves, tires that are another form of waste but have been recycled to do something different, likes of weeds with how we don't actually understand, um, exactly their impact on the garden, and greenhouse, um, that you can grow stuff in colder months, so yeah.

N: Awesome, and can you describe your actions while you were using the app.

P: Um, just walked around--at the start, I was very focused on trying to find these leaves on the app, and not really as much on what was around me, but as soon as I picked up the leaf, that first leaf, and I was looking more at the screen than what was around me. So I was like, I didn't really understand exactly what it was talking about, but then when I came to the compost and I already noticed the compost sign when I was walking around when you were setting it up first, and I realized alright, okay, it's just the general vicinity, and then if you look closer, there's the other keys around that direct you to exactly where the speaker, well the subject of what the speaker's talking about.

N: And could you just say, how would you describe the technical experience of using the app?

P: Again, at the start, difficult to grasp the control, it wasn't, it didn't seem to be working. But then I realized that you have to click on the leaf first, then spread your fingers---and then, after that it was quite easy. The one thing, the fact that you could blow up the leaf to mag--a huge size that was a bit, haha, the first time I did that I was a bit taken aback, um, but apart from that, yeah, it was quite simple to use, and um, eh, the way it was set up made sense, yeah.

N: Okay, and was there anything else that you would like to add?

P: I think, if there's any way of putting annotations on the leaves, that would be good, and obviously, it doesn't always have to be a leaf, it could be um, different, eh, different images for different areas, more specific to what you're looking at. There was one thing I, so I went back to a leaf that I'd already done, been to previously, and um, it played the 'I'm testing

android volume', um, again that's something that could be fixed farther down the line. The only other thing as well is if there was a cue once the audio had finished playing that would put down the leaf, because I was always---yeah, it would just take out that extra little step between the user and what the app is trying to achieve.

N: There's one more thing because I forgot to ask--Could you sort of describe your goals, the goals that you had in mind while you were using the app?

P: Learning about this garden, I mean I've not been in this garden before, so it was a learning experience about what was here. It was a point of interest for getting to use a bit more AR that I've not used before, but yeah, mainly learning, learning about the garden, which I felt like it did very well and I picked up things very quickly.

N: Okay, thank you very much.

Participant 5

N: Before we start, can I just ask: How did you feel before you were using the app, when you were just walking through the garden?

P: I mean, I don't know if it's what you asked me, but when I didn't have the app, I didn't know what's the type of thing I saw in the garden and what is what.

N: And what about after using the app?

P: I know more things about what is in the garden, but obviously it was not an interaction for each stuff in the garden, so I don't know everything, but I know more things, yeah.

N: And could you just kind of describe the garden and what kind of things you found in it?

P: Yeah. It's a garden with stairs and there's some vegetables, and fruit and plants and trees. And all of this is growing and made by human hands. And that's it, I think.

N: And then now could you describe your actions in the garden while you were using the app?

P: Yeah, I mean I have looked in great part at the garden through the app and not myself, um, I was more interested by the things where I can click and I should admit I didn't really take time to look at things that were not point by the app. That's it, I just walked from point to point I saw of the application.

N: And just kind of following on from that, could you say, while you were using the app, what were your goals?

P: I assume that it's for being more acknowledged of what's in the garden. Yeah.

N: And speaking on a technical level, could you describe the experience?

P: I mean, if I encounter some issue with the application?

N: Yeah, sure.

P: At the point I have to click there were two I think where I had to click two or three times to open the thing and I thought that for all the buttons on the stairs when I tried to open it, the things grow and left the screen. But you can still play the audio, but it's a bit frustrating at the beginning, but the audio was quite good and it was easy to understand.

N: And is there anything else that you would like to add about your experience?

P: No, that's okay.