EyeDuino Project:

a study of community-engaged

automated gardening systems

powered by renewable energy

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BSc

Thesis presented for the award of MA

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September 2023

Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Master by Artefact is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ___________________________

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Date: 07 September 2023

Acknowledgments

First and foremost, I wish to express my gratitude to my main supervisor, Dr Declan Tuite, for his professionalism, friendship and for supporting me during the five years of this research project while I embarked on a path unknown to me. His practical advice on how to revise the material I wrote was an invaluable resource, as the task of compiling this document without his guidance would have been an impossible task for me.

I also want to convey my appreciation to my second supervisor, Dr Trish Morgan, who provided me with useful insights about the academic world and specific literature, and helped me with my academic writing skills, relentlessly trying to drag me back onto the main path.

Many thanks to all the people who participated and offered their support and insights all along this process.

I also want to extend my gratitude to the administrators of the six research sites, who helped and supported me with finding the right participants for this study: D. Hazel, R. McConnell, L. De Giorgi, D. Mulvaney, A. Kelly, H. Martin, T. Nugent, and R. McDermott.

And finally, I want to thank my cat for keeping me sane by timely distracting me from the "crazy" number of texts I had to read, and the pages I needed to write. In the end however, it has been an unexpectedly enjoyable, once-in-a-lifetime experience.

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Glossary and Definitions

Actuator	**in the context of this work it refers to physical devices such as DC motors, ventilation fans, water valves. Peripherals of the ACU.**
ACU	**Arduino Control Unit. Consisting of the Arduino controller, and the attached sensors and actuators.**
API key	**unique identifier code, stored on the online web server at https://thingspeak.com/, ensuring that *My Garden EyeDuino* mobile phone app will be granted remote access only to a particular BGAS.**
AppInventor	**online mobile app development platform, developed by MIT Massachusetts, available at https://appinventor.mit.edu/**
Arduino Mega 2560	**programmable microcontroller, with various communication ports allowing for connecting and controlling a range of sensors and actuators. More details are available online at https://store.arduino.cc/products/arduino-mega-2560-rev3**
Artefact	**when used in the context of referring to the installation that has been developed specifically for this research, it indicates the bespoke combination represented by *My Garden EyeDuino* mobile phone app, the online server at https://thingspeak.com/, the Arduino Mega 2560 and all the connected peripherals that ensure the proper functioning of the bespoke gardening automation system.**
BGAS	**Bespoke Gardening Automation System**
Control/Data channels	**specific data channels located on the web server holding critical information for the ACU to operate properly and be able to communicate remotely with *My Garden EyeDuino* mobile phone app.**
CSO	**Central Statistics Office**
DC	**Direct Current**
DCU	**Dublin City University**
EEPROM	**Electrically Erasable Programmable Read-Only Memory, in this context built into the Arduino board, and used for storing data.**

Enclosure	**in the context of this document, it refers to a standing structure with a frame made of wood, plastic, or metal, covered with plastic polythene, aimed at ensuring optimal climate conditions for plants to grow inside. Also referred to as greenhouse or polytunnel.**
My Garden EyeDuino	**bespoke mobile phone application, developed by the researcher using the *AppInventor* online platform, aimed at ensuring the remote communication between the participants and the ACU.**
GT	**Grounded Theory**
ICT	**Information Communication Technologies**
MM-GT	**Mixed Methods - Grounded Theory**
MMR	**Mixed Methods Research**
Polytunnel	**see enclosure.**
PV	**Photovoltaic (solar panel)**
REST	**Renewable Energy Sources Technology**
RTC	**Real Time Clock. In this context, electronic module attached to the Arduino board, providing the current date and time.**
SD	**Secure Digital (card)**
Sensor	**in the context of this work it refers to those electronic components, part of the ACU, in charge of reading and reporting values related to air temperature, air humidity and soil moisture.**
Tiny DB	**database used by *My Garden EyeDuino* mobile phone app to store variable values.**
Vignette	**visual, printed, or audio text offering a possible scenario for a given situation.**
Watchdog	**Arduino predefined timer that monitors if the board is in running or hanging state. If the watchdog is not 'kept alive' at predefined intervals, the Arduino board will be reset.**
Web server	**online server at https://thingspeak.com/ acting as a communication bridge between *My Garden EyeDuino* mobile phone app and the ACU. Also acting as a data repository which can be downloaded and analysed.**

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Abstract

EyeDuino Project: a study of community-engaged automated gardening systems powered by renewable energy, by Viorel Hamilton Niculescu

This study aims to address the digital divide amongst particular communities in Dublin through an innovative assemblage of gardening, renewable energy and bespoke automation systems. Through the combination of gardening (as a social and cultural activity undertaken in specific communities), automation, digital technologies, and networked practices (including a bespoke phone app), this project investigates the social outcomes and attitudes emerging from the gardening system developed for the project and the issues it raises in relation to digital literacy, sustainability and community empowerment.

The number of technologies being embedded into the fabric of our society is ever increasing. However, the exposure level to such innovative solutions is not evenly spread across the population. Various determinants ranging from financial to cultural factors shape the process of engagement and adoption of technology, which in turn shapes the population's attitude towards innovations as Hill (1988) and Winner (1989) observed. This uneven diffusion of technologies uptake may result in a potential decrease in people acquiring new skills and knowledge, leading to an increase of the digital divide(N. Taylor et al., 2018).

To this end, the author designed six automated gardening systems and deployed them at six community gardens located in Dublin, Republic of Ireland with the intention of discovering the actors that influence the stakeholders' adoption of innovative technologies and reveal the 'accidents' (Virilio & Lotringer, 1983) that happened following this engagement process. Moreover, as these experimental installations are powered by renewable energy produced by photovoltaic solar panels, the participants' sustainability awareness and acceptance are imparted and discussed. The niche innovative gardening systems assisted the participants with their tasks around their garden, while trying to fill the 'attitude-behaviour gap' (Claudy et al., 2012; Ozaki, 2011; Peattie, 2001) regarding adoption of renewable energy sources. Apart from aspects of social, financial and education attainment nature, this study confirms that the 'labor illusion' (Buell & Norton, 2011), a concept providing that people expect to see that the technologies are 'working hard', plays a critical role in stakeholders' willingness to learn new skills related to using those technologies.

The participants did not assign a financial value to the gardening automation systems, which were offered to them as a 'gift'. However, they used the systems to advertise their higher affluence within their community, and as an opportunity to show-off their new acquired skills. This played a major role in their engagement with the artefact. Furthermore, the younger participants who are still living with their parents proved that niche innovations may act to breaking the cultural barriers regarding a set of mutually accepted cultural rules within their communities regarding engaging in tasks which are not necessarily perceived as socially acceptable, such as gardening in this instance.

The bespoke artefact designed specifically for this project allows the author to reveal and discuss the factors that influenced the participants' attitude related to renewable energy sources. Also, determinants acting as barriers/incentives towards participants from Dublin, Republic of Ireland in engaging with innovations and the resulting outcomes following this interaction are examined.

1. Chapter 1 - Introduction

'However seductive they may seem, silver bullets [...] do not exist [...] innovation is inherently risky. Failures vastly outnumber successes' (Wilson & Grubler, 2011).

The stark statement from above may lead innovators to consider that there are no reasons to develop original technologies, fearing the high rate of failure. However, the history of technological development confirms that considerable time must pass before early prototypes are gradually transformed into their largely accepted versions, eventually to be implemented on extensive scales in our society. Innovations often rely upon various pre-existing or developing technologies (E. Rogers, 1995; Roger Silverstone, 2005), and successful inventions depend on aspects such as precedence, identity, and market (Silverstone & Haddon, 1996).

To this end, the author proceeded to design an experimental installation which attempts to address issues related to people's attitude in relation to adoption of innovations, as well as their behaviour regarding our planet's natural resources. More specifically, the author's expertise with automation technologies and computer coding was coupled with their passion for gardening. The resulting artefact consists of a unique combination of several pre-existing components, mainly intended to support gardeners with specific tasks related to the growing of vegetables. The custom developed *My Garden EyeDuino* mobile phone app allows individuals to remotely monitor the microclimate conditions inside some enclosures and operate various physical devices. At the other end of the communication line, a bespoke automation system was designed by the researcher, consisting of various electric and electronic components, such as an Arduino microcontroller board with various sensors and actuators acting as peripherals. The system is powered by renewable energy technology systems (REST) in the form of photovoltaic (PV) solar panels, a solar charge controller and a battery pack.

The participants in this study have some previous gardening skills, however they have never been assisted by any automation technologies in their garden. Six automated systems were designed by the researcher with the intention to complement, rather than replace, some basic activities performed by the participants around their garden, such as maintaining optimal air humidity, temperature, and soil moisture values for vegetables' growth cycles. These systems were deployed within community gardens in Dublin, Republic of Ireland, which are located in areas that could be considered to belong to the working-class according to the literature (i.e., Dublin City Council, 2020; Haase & Pratschke, 2017; Seery, 2018).

A similar study that was conducted in Dundee, Scotland (D. Taylor & Packham, 2016) served the author with valuable insights about incentives and barriers influencing people's engagement with innovative technologies. The participants in the present study are actively involved in gardening activities within their communities, thus the author's expectation was that they would have at least some basic sustainability attitude and knowledge about the environment in terms of food and energy production. This aspect was confirmed by the focus group discussions and interviews. Therefore, this study investigates whether there is any correlation between the participants' existing sustainable practices and their willingness to improve their awareness, technical skills, and knowledge on this topic when presented with an innovative sustainable solution. This can arguably inform future similar studies, allowing for improved models to be designed by relying on valuable observations.

1.1. The scope of this research

We are surrounded by innovations, and technological development is embedded in the fabric of our modern society. Individuals' reliance on technologies may improve the quality of their life but could also alienate their social communication and practical skills. For instance, the internet, computers, or telephony allows family members living in different parts of the world to communicate and become better integrated into society. However, in more recent times, some vital public services have been moved partially or entirely to online platforms (DEASP, 2020; Government of Ireland, 2017; Irish Tax and Customs, 2021), resulting in the less technically inclined individuals to be affected by the digital divide, 'commonly described as the gap between those who have access to computers and the internet and those who have not' (Roger Silverstone, 2005, p.24).

The extant literature suggests that the introduction of technical innovations, regardless of scale and length of interaction period, will inevitably disrupt stakeholders' previously existing status quo (W. E. Bijker & Law, 1992; Murphie & Potts, 2003; Orlikowski, 1992). As Orlikowski (1992) points out, this potential duality delegates stakeholders with the power to interpret and make use of technologies in ways that could entirely diverge from the intended use of their inventors. Regardless of whether we adopt a technological deterministic stance in line with Marshall McLuhan's view, or a more social constructivist (or social shaping of technology) position aligned to Raymond Williams' interpretation, there is clear evidence that no technology is 'pure' (W. E. Bijker

& Law, 1992), in the sense that any engagement with artefacts will change people's behaviour and influence their perceived social power within their communities. Virilio & Lotringer (1983) labelled these resulting scenarios as 'accidents', although Rogers (1995) argues that these resulting consequences represent the very purpose of adopting and interacting with innovations.

People's knowledge and previous experience with technology may motivate or prevent them from risking for their lifestyle to be disrupted by the introduction of innovations aiming to replace familiar, long-established players. Bessant (2013) suggests that niche innovations which are intended to complement rather than replace established actors or activities, for instance in the form of the Bespoke Gardening Automation System (BGAS) which was developed for this research, have better chances of being trialled and adopted by their intended stakeholders.

Moreover, the BGAS is powered by photovoltaic panels, and this setup was designed by the researcher with the clear intention to mitigate insights linked to the 'attitude-behaviour gap' (Claudy et al., 2012; Ozaki, 2011; Peattie, 2001), referring to people's desire to be socially relevant and acceptable. Concurrently, factors of financial, educational or cultural nature may override stakeholders' sustainability morals, or even turn them into opponents of renewable sources technologies.

1.1.1. Locating the study

The technical and innovative solution in the form of BGAS played a central role in conducting this research, by way of providing the participants with practical means to care about their garden on a local scale, while at the same time acquiring new technical skills.

Six community gardens in Dublin, provided the required physical space to build the six automated systems. Nineteen participants with some previous gardening skills were purposefully recruited by the researcher. Their remote interaction with the BGAS started in March 2019 and lasted until November 2019, representing the process which provided the quantitative strand. Complementary focus group discussions and qualitative interviews were conducted with the participants between January 2019 – January 2020, allowing for nuance to be added during the interpretation of the quantitative data.

A mixed methods - grounded theory (MM-GT) approach was carefully chosen by the author, being considered the most suitable methodological instrument for this study. Data integration and triangulation were performed to ensure that an accurate descriptive account of the studied phenomenon was produced.

1.1.2. Research questions

This research's objective is to offer valuable insights regarding how the innovative interventions have affected the participants' lifestyle following their engagement with the bespoke gardening automation system, while being compelled to acquire new skills of both technical and practical nature. Individuals' age, social interests, cultural beliefs, education attainment, and financial status shaped the meaning that they have attached to discrete innovative technologies.

The innovative artefact deployed within community gardens intends to fill the technological knowledge gap, as well as to promote sustainable practices and behaviour to society members. The discussion chapter advances improvements that can be made to the current chosen design and approach. Therefore, this study aims to answer the following research questions:

RQ1: What are the outcomes following the engagement of the participants, which were particularly chosen for this study, with the sustainable, innovative gardening automation systems?

RQ2: What are the factors acting as barriers / incentives associated with the participants' adoption of innovative automated gardening systems and acquiring new skills and knowledge about renewable energy solutions?

2. Chapter 2 - Artefact design and approach

This project provided an ideal environment for collaboration, while simultaneously allowing for valuable data to be gathered and disseminated. Larger existing agricultural ventures (Biswas, 2021; Bose et al., 2021; Singapore Food Agency, 2019, 2021; The Earth Observatory, 2021) serve as a pertinent example that shows our society's strive to monitor and reduce the impact on our planet's finite volume of natural resources. The main theme of discussion of this research revolves around the impact that the implementation of specific automation technologies within several community gardens has had on experienced gardeners. While similar gardening automation systems are known to exist for several years, they are generally owned by and located within large enterprises, their purpose is aimed at mass food production, and only provide their users with a fixed, predefined set of functions and settings (e.g., Bharti et al., 2020; Miah et al., 2022; Premier Tech Ltd., 2023). Customisation, repurposing, and scalability do not represent factors of concern in these cases. For comparison, the reduced available growing spaces within community gardens (and potentially private gardens), located in urban or suburban areas, mandates the adoption of a flexible approach, both in terms of its scale and available functionalities. Characteristics of each individual location, as well as individual needs, directly dictate the design and implementation of specific technologies.

Traditionally, practice-based projects result in the production of some form of digital installation that is to be exhibited at specific locations and are to be interpreted from an artistic perspective (Alves Lino et al., 2010; Hawkins, 2010; Heath et al., 2002; Hindmarsh et al., 2005; Medeiros & Wanderley, 2014; Morrison et al., 2011; Odendaal, 2020; Pollock & Paddison, 2014; Sakamoto et al., 2020; Tresset & Fol Leymarie, 2013; Wood et al., 2014). Generally, their intended audience can only interact with them for a limited, generally small, amount of time. The 'participants' are usually not purposely chosen by the author, and their interaction with the artefacts is mainly of digital nature. While many of these installations are intended to introduce innovative ideas to society members, the analysis of the effects of a long-term exposure to such technologies is missing from these contexts. In addition, the intended audience must travel to the artefact's location and willingly introduce themselves to it.

In contrast, the design adopted by this study promotes the introduction of innovations not only to some participants' lifestyle, but also visually to other community garden members. The direct (or indirect), lengthier exposure to some practical innovation is more likely to produce meaningful results related to social and behaviour traits (E. Rogers, 2003; Zhang et al., 2015), concluding with rich details to reveal the effects and consequences of people being exposed to such bespoke installations.

The author was also inspired by Maslow's proposed model of human hierarchy of needs (Figure 2.1) which indicates that while most people strive to achieve the goals positioned at the top, 'Needs lower down in the hierarchy must be satisfied before individuals can attend to needs higher up' (McLeod, 2020, para.3). This resulted in the BGAS to be designed for the purpose of conducting this research, and it represents a symbolic linkage between the two extremes, in which the production of food relies on innovative, creative methods represented by REST.

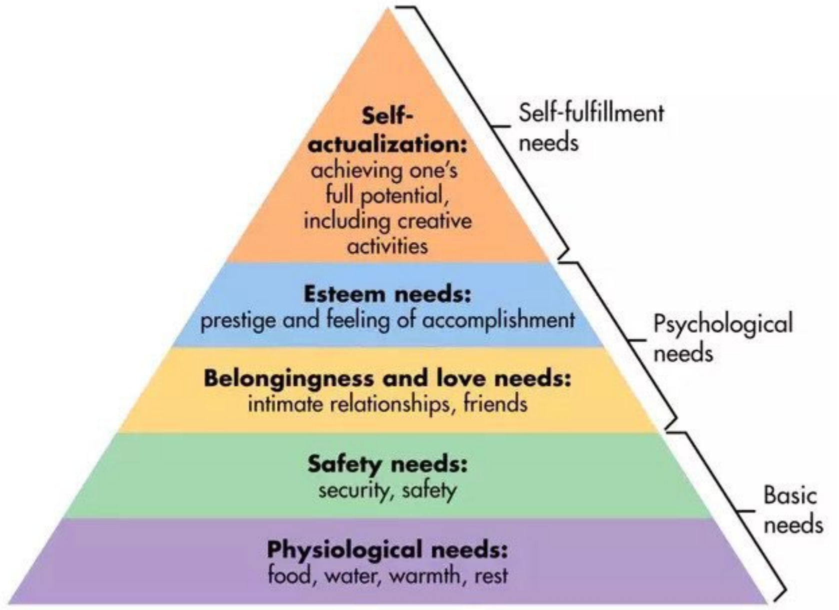

Figure 2.1 - Maslow's hierarchy of needs. Source: (McLeod, 2020)

As a result, the practical aspect of this study required that a bespoke artefact be constructed, which relied on the combination of a few technologies:

- A physical enclosure.
- An automation controlling unit (ACU) and electronic peripherals.
- A custom developed mobile phone app.
- A secure web server which would ensure the remote communication process.

The author's statement of the artefact (Appendix A) offers detailed information about this innovation. Also, the folder titled 'Portfolio' that accompanies this document contains relevant information related to the design and implementation of individual components of the artefact.

2.1. The physical enclosures

To properly be able to conduct this research, and for the purpose of ensuring information rich and consistent gathering of data, a total of six enclosures had to be built and made accessible to the participants. The reasons these enclosures had to be built/retrofitted are:

- Similar existing installations are much more expensive, and at the same time they would not have provided the necessary, customisable, and scalable interface to collect the required quantitative and qualitative data, as per this study's design.

- The already existing solutions for this kind of installation are generally of a larger scale, which would have not suited the purpose of this study looking at urban populations having access to only small areas where they could potentially build similar sustainable systems.

- Larger installations are normally based on electrical power provided by non-sustainable technologies. One of the purposes of this study was to analyse the engagement with, and to promote the use of alternative sustainable energy sources, and therefore a smaller construction scale was needed for the renewable technology system used in this project to be able to provide the required amount of electricity.

Following agreements set in place with local administrators as outlined in section 4.3.1 Participant recruitment process, the enclosures were intended to allow individuals to grow vegetables, aiming to offer optimal climate conditions. Automation features related to basic gardening tasks (irrigation, ventilation, and air temperature control) were added to them. The enclosures were built between September 2018 – March 2019 at six individual sites around Dublin, mainly in what could be described as 'working-class areas' (Dublin City Council, 2020; Haase & Pratschke, 2017; Seery, 2018), as following:

- Three community gardens, with free access for volunteers.

- Two up-skilling centres intended for teenagers coming from disadvantaged backgrounds, with free access (CDETB, 2021).

- One public allotment, with paid-for annual membership (further identified as the 'negative case').

A polytunnel / greenhouse was already in place at three locations, and the researcher retrofitted those with the necessary automation technology, as will be further described. On the other three locations the author proceeded to build brand new enclosures, consisting of timber structures, covered in plastic polythene, measuring 2.4 metres long x 2.4 metres wide x 2.2 metres high (Figure 2.2). The scale of these was chosen for convenience and to reduce the financial investment, entirely supported by the researcher. Any different scale of the enclosures, lower or larger, would have not had any impact on their technical functionality or on the interaction level of the participants. For further details and exact research site locations please refer to Appendix C.

Figure 2.2 – Enclosure located at one of the research sites. Source: Hamilton V. Niculescu

2.2. The BGAS and ACU

A central controlling, processing, and remote communication point at each location was built around an Arduino Mega 2560 programmable board, mounted in a small plastic box, and was positioned inside the enclosure along with the required peripherals and accessories (Appendix D). Apart from reading, monitoring, and controlling critical system values, such as the battery voltage level, air humidity, temperature, and soil moisture values, the ACU facilitated the remote connection with the secure online server through which the communication with participants' mobile phone app took place.

The electricity for the ACU and peripherals at each enclosure was provided by a pair of PV solar panels rated at 100 watts each, connected through a dedicated solar charge controller to a battery pack providing 12 volts direct current (DC). The researcher purposely chose a power rating of 12 volts (or lower) for powering the system, to ensure the participants' electrical safety, and to reduce the risk of electrical fire. The BGAS comprised the ACU and various electronic and mechanical parts connected to it, such as:

Sensors:

- One temperature and humidity sensor (5 volts), used for controlling the two sliding windows and one ventilation fan.
- One soil moisture sensor (5 volts), used for controlling the irrigation (one water valve).
- Four ultrasonic sensors (5 volts)**,** informing on the current position of each two windows (open/closed).

Actuators:

- Two DC motors (12 volts), each operating a sliding polycarbonate window in accordance with air temperature, mounted on the sides of the enclosures.
- One ventilation fan (12 volts), operating in accordance with air humidity.
- One latching water valve (12 volts), operating the irrigation according to soil moisture.

During their three months participation in the study, each participant was able to choose from two modes of interacting with the remote system via *My Garden EyeDuino EyeDuino* mobile phone app:

- Manual mode - all gardening related tasks were controlled entirely by the participant. The participant assumed the role of managing all actions related to gardening. The ACU would still monitor critical values related to the continuous and optimal operativity of the system (e.g., battery voltage, soil moisture, etc.) and override/disable the participant's commands if necessary. The participants have full control over the water valve (to control the irrigation), the sliding windows (to control the temperature), and the ventilation fan (to control the air humidity). These actions would ideally be performed in accordance with the specific values provided in the phone app by the sensors connected to the ACU. Additionally, in this mode the participants can change the specific thresholds values related to different gardening automation features: the optimal temperature, air humidity and soil moisture.

- Automatic mode - all functionalities were controlled entirely by the ACU. The participant only assumed the role of monitoring and overviewing the ACU's actions related to gardening tasks. The ACU would have full control over the actuators, following the readings obtained from the sensors, and in accordance with the threshold values that were previously set by the participants. Thus, readings related to the soil moisture, air humidity and temperature would directly impact on the operation of the water valve (irrigation), the ventilation fan and the sliding windows.

Regardless of the selected working mode, the ACU would continuously monitor specific critical fail-safe parameters to ensure the safe and optimal operation of the BGAS, as described below.

1. Battery low. The battery pack provides electricity (12 volts DC) for the ACU and peripherals. The PV solar panels would charge the battery and provide electricity to the entire system during daytime, while the battery pack alone would provide electricity at night-time. Depending on the location and positioning of each research site in relation to the Sun's path, as well as the season and the amount of available insolation (Sun exposure), the battery pack voltage may vary accordingly. Therefore, two complementary measures were put in place:

- **Software.** When the battery pack charge level drops below 10 volts, the system will automatically switch OFF the ventilation fan and the irrigation (if previously ON) and prevent the user from switching them ON until the battery voltage rises above 10 volts. This is to prevent further excessive battery drainage, as well as to ensure that the enclosure would not get flooded, in the case if the electrical power continues to go down, which would have left the irrigation water valve in the open position.

- **Hardware.** A specific function included in the solar charge controller's menu further prevented the battery discharge, should the voltage continue to drop below 9 volts. The entire system would be disconnected from power until the voltage rises above the 9 volts level, and the system would restart automatically. This is to prevent permanent damage to the battery pack due to excessive discharge.

2. GPRS connection down. The GPRS connectivity facilitates the remote communication between *My Garden EyeDuino* mobile phone app and the ACU, via the online server. Should the connection become unavailable, with the participants being unable to remotely control the system's functionalities, certain routines were programmed to activate in a specific order, aimed at keeping an optimal microclimate inside the enclosure without the participants' input.

- **Software.** Should the GPRS connection become and remain unavailable for more than fifteen minutes, the ACU would restart itself to retry to get a fix on the GPRS signal. The system would automatically switch itself to Automatic mode. A routine programmed within the online server would alert the researcher (via email) of the fact that a specific BGAS is offline, mainly due to a missing GPRS signal. The message contained the research site location name and the timestamp, allowing the researcher to further monitor and investigate the issue.

- **Hardware.** A small electronic circuit containing a timer would automatically restart the ACU every day at 3 am, to refresh the ACU and to prevent situations where the system may have become unresponsive for any reason. Should the ACU be running as normal at the time, this restart procedure would not affect the system's previous working mode, i.e., upon restart the system will return to the last known working mode. Otherwise, should the system be in an unresponsive state at the time of the restart procedure, the new working mode would be automatic.

3. Flood protection. The researcher devised a special procedure inside the code, aimed at preventing any accidental water floods from happening on the research sites. In this sense, after running comprehensive tests on all six research locations, it has been decided that a specific figure of eighty percent in relation to the soil moisture to be set as the highest threshold for this feature. Should the participants set the irrigation ON (while in the manual mode) and subsequently forget to switch it OFF, once the soil moisture reaches the maximum threshold level, the water valve would automatically be switched off by the ACU. The user would be prevented from further switching it on until that value would drop below eighty percent.

The pseudocode, representing the logical functionality of the ACU, is included in Appendix E. All values resulting from system changes happening in either automatic or manual mode have been recorded on the online web server located at https://thingspeak.com for the whole duration of nine months while the data collection was in progress, and to which only the researcher had access to download for analysis purposes.

2.3. The mobile app

The participants' digital communication with the enclosures was supported by the mobile phone app titled *My Garden EyeDuino*, which was entirely developed by the researcher, and provided to the participants free of charge. The app has a user-friendly, 'designed for all' interface and intuitive functionalities, and also aims to ensure the confidentiality and privacy of the participants in the study. The participants were able to receive real-time details in relation to the enclosure's conditions, and act accordingly by changing various built-in functionalities and settings in the app, such as:

- Open/close the sliding windows.
- Start/stop the air ventilation fan.
- Start/stop the irrigation.
- Change the threshold values for the available sensor readings.
- Send a log to the researcher.

When the current microclimate conditions inside the enclosure did not match the optimal values set by the participant, colour-coded bars and in-app notifications were being displayed on the phone's screen, prompting the user to take corrective measures (Figure 2.3).

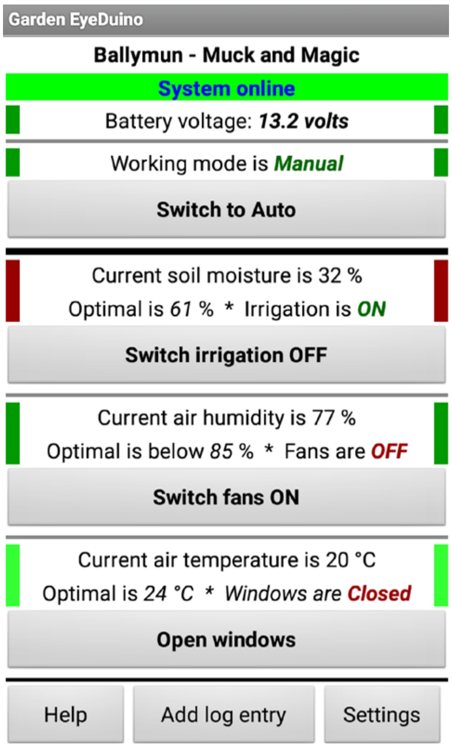

Figure 2.3 – The main screen of My Garden EyeDuino app, allowing for remote monitoring and full control over the enclosure located at a specific research site. Source: Hamilton V. Niculescu

The development process of *My Garden EyeDuino* app started long before a stable version was released for user testing, with early experimental designs being available since April 2018 (Appendix G). While major updates have been performed during the researcher's own trial time frame, some notable tweaks have been further implemented following feedback received from the participants for the duration of data collection and during the second stage of the interviews, as detailed in section 5.6.2 - Proposed improvements of the automation gardening system. Some notable improvements of the mobile app include:

- Early versions of the app were continuously running in the background, instantly alerting the users of any changes related to the remote system. Following tests and feedback received from five initial pilot testers (a separate cohort from the main participants), this feature was removed due to concerns related to the additional power demand from the phone's battery, also acting as a potential annoyance to the user. Moreover, the author considered that the continuous stream of data being exchanged between the app and the online communication server may negatively impact on the user's data plan offered by their mobile service provider.

- The design was improved by increasing the text size and adding colour coded sidebars to allow for quick identification of the current status of the system. These improvements have been suggested by the five initial pilot testers (a separate cohort from the main participants) who were offered access to the app before the actual data collection process had started.

- The 'Add log entry' button was added, allowing participants to submit their feedback directly to the researcher, rather than the participants keeping a written journal. This was suggested during a focus group discussion and was implemented in the app before the first round of participants commenced their remote interaction with the BGAS.

- A checkbox option was added to allow for the start-up screen, including the privacy notification, to be subsequently by-passed when the user restarts the app. This option was added following the feedback received during the second stage of the interviewing process with the first round of participants.

- The flood protection threshold value was adjusted. During the visits to the research locations at various times, the author noted various characteristics of the soil existing at each site. These observations led the researcher to improve the app's built-in measures aimed at preventing accidental water flooding.

Other app improvements which were considered by the author, and also suggested by the participants following their three months test period, were not implemented. These could however be examined while designing similar projects in the future.

- To provide some in-app video feedback. This feature was not implemented due to several reasons such as: the required additional planning, physical equipment, and electronics, which would have gone past the allowed budget; the low quality of the available GPRS signal in the current setup would not support video streaming; running into potential privacy issues with other individuals using the garden.

- For participants to receive SMS messages and/or emails, containing critical alerts based on the system's real-time conditions. The researcher considered these options as being too intrusive, potentially leading to the participants getting annoyed and dismissive. This can be further investigated by collecting specific details covering this aspect, which fell outside the scope of this research.

- The addition of graphs, showing the history of interaction, climate details and actions performed by the BGAS. This suggestion was made by several participants, looking for a richer and more detailed view of the system. The author chose not to implement this feature on the current iteration, aiming to keep the app as simple as possible, with least distracting options, allowing the participants to focus on the actual interaction with the technology and gardening tasks.

By using the *My Garden EyeDuino* custom mobile phone app developed by the researcher, the participants were offered full control over some specific gardening tasks, in accordance with the information provided on screen by the sensors. The secure connection with the online server also required specific settings to be provided within the code that generated the mobile app. The participant's interaction with the remote enclosure via the phone app was therefore recorded, making-up the quantitative data strand of this study. These details were automatically recorded every (approximately) twenty seconds on the online server, and were available only to the researcher, at any time, for monitoring purposes.

Thus, the main reasons for the *My Garden EyeDuino* custom mobile phone app to be developed by the author are:

- Non-existence on the market, either free of charge or paid for, of a mobile phone app that offered the required, custom, and highly specialised functionalities required by the research design. Also, the 'design for all' model implemented during the processes of both the app development, as well as the construction of the enclosures, aimed to address and eliminate potential reasons for their rejection.

- Following feedback received from the participants, the app's interface and functionality was easily amended accordingly, aspects which otherwise could have acted as a deterrent factor in their engagement with the enclosures.

- By having the mobile app developed by the researcher, the required anonymity and privacy of the participants was also guaranteed.

A detailed induction on the functionality and usage of the mobile phone app was offered to each participant, on an individual basis, before starting their trial period. On start-up, the app presented the participants with a screen informing them in plain English on aspects related to privacy, confidentiality, and anonymity, as well as asking for their consent for the data to be transferred to and from the online server, and for the researcher to be able to monitor this in real-time. The app will only proceed upon the user's agreement. The complete navigation workflow is being depicted in Appendix F. The pseudocode illustrating the logical flow of *My Garden EyeDuino* mobile phone app is included in Appendix H.

2.4. The online server

Access to a secure online web server (https://thingspeak.com/) was acquired and set up by the researcher, which ensured the remote connection between the mobile phone app and the controlling unit. The data being exchanged between the phone app, the online server, and the enclosures does not hold any details that could possibly lead to the identification of any of the participants, but only contains an application ID (in the form of a combination of random letters and numbers, known as 'API key'), and related numerical data representing the system's status and settings. For instance, the number '0' represents a feature being in the 'Off/Closed/Manual' mode, while the number '1' represents the 'On/Open/Automatic' mode. Numerical values representing temperature, humidity, and soil moisture for any individual enclosure were also stored in specific data fields. The application ID represents the only detail that would link the generated data to their actual user, and this information is only known to the researcher for analysis purposes and designing of the second stage interviews. Therefore, should the server have been hacked and the data compromised, the stolen data would have not contained any details that could have led to the identification of any person or setting. Reviewing the quantitative online data would require a unique username and password, which were only known to the researcher.

In conclusion, the participants in this study were not just spectators of some generic form of digital art performance, but they became active agents, managing the manner the artefact in this study would perform, while being provided with assistance for specific gardening tasks.

3. Chapter 3 - Conceptual framework

This chapter offers a description of the theoretical concepts acting as framing and support for later developing the discussion section. The concepts of technological determinism and social constructivism are introduced, along with the consequences that follow people's physical and psychological interaction with innovations. The chapter develops to discuss the concept of digital divide, a term used when referring to the level of adoption and usage of technological artefacts, which varies across different society members, being determined by a multitude of factors.

3.1. Technological progress and impact on society

Originating from the Greek terms 'techne' (art, craft or skill) and 'logos' (word or knowledge), the word 'technology' can be interpreted as 'knowledge about skilful practices' (Lister, 2009, p.87). Aristotle's account of the practical aspect involved in the 'techne' expression led Parry (Parry, 2014) to further characterise the notion of technology as 'something involving theoretical understanding' (para. 2). It is therefore argued that both the tools, as well as the required skills and knowledge of using those tools define the concept known as technology (Lister, 2009). Thus, while 'a technology is not a natural object, but one made by humans' (Murphie & Potts, 2003, p.4), the changes being advanced by the necessity of acquiring new sets of skills to fully make use of technology play a significant role in the process of individuals adjusting their attitudes and behaviour.

Marshall McLuhan suggests that technology development is embedded in our society (in Lister, 2009). The sinuous path that followed from the invention of very first tools and up to modern innovations supports the theory that humanity is fond of always 'killing' old technologies and replacing it with new, more appealing tools (Lehtonen, 2003). This technological deterministic approach is characteristic to McLuhan's interpretation of innovations' expansion process, regarded as being a revolutionary phenomenon which acts as a great agent of social change (Lister, 2009). 'You can't stop progress' (Murphie & Potts, 2003, p.11), and to this end, technology must be progressing independently and without influence from any other social actors. McLuhan is not interested in 'why' a technology is being developed but is only concerned with those properties of innovations that indirectly alter society's intrinsic values. His phrase 'the medium is the message' (in Lister, 2009, p.93, emphasis added) suggests that one should look beyond any obvious appearances and discover the less discernible impacts imposed on society following the adoption of innovations.

The complementary approach to the technological innovations and their influence on society is that of Raymond Williams, supporter of the social constructivism concept, considering technology development as a 'business as usual' operation. Also known as the 'social shaping of technology', social constructivism advocates for the idea that innovation and adoption of specific technologies represents the result of the desire, interests and social pressure coming from specific groups of people. For Williams, the development of innovative technologies is sociological, and to this end he is more concerned with the powerful relations and mediation between the ideology of a society and the technical development, arguing that 'any particular technology is then as it were a by-product of a social process that is otherwise determined' (Williams, 2004, p.6). This implies that technology alone is considered as being incapable of fostering the reshaping of society's behaviour and cultural beliefs, with additional several factors being considered as playing their part in the process of change (Lister, 2009).

Setting the technology – behaviour relationship aside, Rogers (1995) argues that 'invention and diffusion are but means to an ultimate end: the consequences that result from adoption of an innovation' (p.394), which may be interpreted as 'the changes that occur to an individual or to a social system because of the adoption or rejection of an innovation' (p.150). History proves however that these changes are not always of a positive nature (i.e., Bessant, 2013; Gobo, 2018; E. Rogers, 1995). These 'unintended consequences' or 'accidents' as Virilio and Lotringer (1983) refer to, are embedded into any technology, no matter how pure it might be perceived as being (W. E. Bijker & Law, 1992). People became desensitised due to the ever-increasing technological bombardment they are subjected to. The technologies, interpreted as 'tools', became natural extensions of their body (Lister, 2009). Orlikowski (1992) adds that the 'technology is created and changed by human action, yet it is also used to accomplish social action' (p.405), implying that technologies present both a duality and a flexibility aspect by allowing users to interpret and reformulate its original purpose so that it fits and suits the needs of specific influential groups.

Technology and society are mutually constitutive, and 'for good or ill, [the technologies] are woven inextricably into the fabric of our lives, from birth to death, at home, in school, in paid work' (D. A. MacKenzie & Wajcman, 1999, p.3). According to Hill (1988), 'technological change... is not, by itself, productive of social change. Instead, the direction of change is a product of the specific alignment between the technological possibilities, and the society and culture that exists' (p.21). Winner (1989) further emphasises that 'what matters is not technology itself, but the social or economic system in which it is embedded' (p.26).

Even though the interaction with innovations may irreversibly, although unintentionally, affect society's wellbeing by radically changing its lifestyle and behaviour (Owen, Bessant, et al., 2013; Owen, Stilgoe, et al., 2013), Bessant (2013) states that 'the challenge is not whether or not to innovate, but how?' (p.1), with voices suggesting that development of more inclusive, 'designed for all', bespoke technologies are needed (Nygård & Kottorp, 2014; Page, 2014; Sochor & Nikitas, 2016; Vines et al., 2015). In other words, technology itself is not intrinsically good or bad, but the meaning that people attach to it will result in obtaining some desired or undesired consequences (Bessant, 2013; Ozaki, 2011; Peluso, 2015; E. Rogers, 1995). This supports previous knowledge suggesting that the society and technology development issues need to be addressed concurrently during the design process, and not in isolation (Callon, 1987), in a co-creation process of 'heterogeneous engineering' represented by different actors that are eventually 'shaped and assimilated into a network' (J. Law, 1987, p.113).

3.2. Digital divide and the technology adoption process

Scholarship suggests that technology penetration is lower in the case of older people (Friemel, 2016; Gilly et al., 2012; OECD, 2001, 2016; Selwyn & Facer, 2007). Studies conducted over the years reveal that similar factors are driving population's (lack of) access and desire to avail of latest innovations (CSO, 2018; Friemel, 2016; Goedhart et al., 2019; Helsper & Reisdorf, 2017; Marler, 2018; OECD, 2001; E. Rogers, 2001; Selwyn & Facer, 2007; Warschauer, 2003). Despite the unpredictable nature and duality of innovations, it is argued that the technologies will ultimately empower people and improve their social status. This is even more prominent with the adoption of Information Communication Technologies (ICT) by senior citizens, in the form of mobile phones or personal computers for instance (M. Bernard & Phillips, 2000; Quan-Haase et al., 2016).

Traditionally, when referring to ICT many think of the internet and computers only. Selwyn & Facer (Selwyn & Facer, 2007, p.3) argue that 'there is a diverse and wide range of technologies which can be considered as ICTs – not just computers and the internet'. For instance, apart from talking to other people, the affordances offered by a mobile phone may include controlling smart home devices, getting driving directions, listening to online music, finding information about tourist locations, or buying online services and products (Batty et al., 2012; Caragliu et al., 2011; Gretzel et al., 2015; Gungor et al., 2013; Güngör et al., 2011; R. Law et al., 2014; Mehmood et al., 2017; Munar & Jacobsen, 2014; Naramski, 2020; Nishiyama et al., 2014; Wang et al., 2007). For people to benefit from all these available services, they may be expected to acquire skills that are specific to the ICT domain. It can be considered that the combination of both the communication technology (hardware), and the knowledge and skills (software) constitute ICT.

While availing of these communication technologies is not absolutely vital, having access to and using innovations could potentially lead to a better social inclusion, as well as to an improved quality of life by helping people stay connected to family members and friends (çarçani & Mörtberg, 2018; Chan & Suarez, 2017; Charmaraman & Delcourt, 2021; Grigoryeva et al., 2016; Guan et al., 2017; Monachesi, 2019; Rassy et al., 2021; Selwyn, 2003; Selwyn & Facer, 2007; Talmage et al., 2021). It is argued that the benefits to be gained from the interactions with these innovations generally surpass the inherent unwanted consequences, resulting in a potential decrease of the digital divide in our society (Aristi, 2018; DiMaggio et al., 2001; Friemel, 2016; Hargittai, 2002; Kongaut & Bohlin, 2016; Lam & Ma, 2019; Lucendo-Monedero et al., 2019; van Dijk, 2005).

Concerns about the creation of a two-tier information society, of 'haves' and 'have-nots', were voiced as early as 1996 (European Commission, 1996). The digital divide has been increasing and it is likely to continue with this trend 'because of the effects of unemployment, poorly functioning digital skilling programmes and socio-cultural norms in some economies' (Chetty et al., 2018, p.1). The literature (Newholm et al., 2008; OECD, 2001; E. Rogers, 2001; Selwyn, 2004; Selwyn & Facer, 2007) suggests that the digital divide is determined by a series of factors including:

- Missing equipment, such as electronic devices and internet services.
- Income and financial status.
- Family size and demographics.
- Education and skills.
- Low credibility of content and safety concerns.
- Ethnic, cultural, and language barriers.

These aspects appear to remain relevant even in our modern society, on the account that as new technologies emerge, the population chooses to remain 'locked-in' with their familiar and obsolete, but once innovative artefacts. The rapid development of new services will only amplify the socio-economic impact associated with their lack of access to these technologies. As the society is continuously being shaped by innovations, new knowledge and skills are therefore necessary to be acquired to prevent a further increase of the digital divide (N. Taylor et al., 2018).

It is therefore assumed that the technological development and adoption of innovations is inherently beneficial for the population's digital literacy and social inclusion. In response, recent decades saw governments and state institutions introducing or supporting many forms of computer training courses, sometimes free of charge (Selwyn & Facer, 2007; SpringboardCourses.ie, 2021; Technology Ireland ICT Skillnet, 2021; Waterford Institute of Technology, 2014) with the intention of including 'everyone in the information society' (Government of Ireland, 2003). Moreover, specific services in Ireland, such as registering for a tax number, paying taxes, or receiving numerous social benefits have been moved partially or entirely to online platforms (DEASP, 2020; Government of Ireland, 2017; Irish Tax and Customs, 2021). Amongst other arguments, one aim was to reduce the 'digital divide' gap between generations.

Yet, it is argued that the individuals' natural behaviour of opposing any potential lifestyle changes needs to be addressed for a decrease of the digital divide level to be achieved. The individuals should be able to make an informed decision on how, if, and when to use communication technologies (Selwyn & Facer, 2007). As such, after finishing their training courses, many individuals did not make use of their newly acquired ICT skills, for they did not 'view engagement in ICTs as a positive force that would transform the quality of their life' (Crump & McIlroy, 2003, p.3), or those skills were incompatible with their workplace environment (Alghamdi & Holland, 2020; Goedhart et al., 2019; Loh & Chib, 2019; Mącik & Mącik, 2014; Prajaknate, 2017; D. Taylor & Packham, 2016a). As those technologies and acquired skills were not adapted to their needs, new domains of exclusions were created, and people became more socially excluded than they were before, with older people having to rely on the younger generation for accessing various online social services (Age Action, 2018, 2020; CARDI, 2013; Citizens Information Centre, 2019; Hardill, 2013; Lloyd et al., 2016; Silverstone, 2003).

Once an innovation has been adopted, a follow-up process known as domestication gets initiated, acting to reshape both the technology and the adopters' behaviour (Berker et al., 2006; Helle-Valle & Slettemes, 2008; Silverstone & Haddon, 1996). A domestication process will be deemed successful if an innovation is perceived by their stakeholders as not being threatening anymore, but as a natural extension of their body. TV sets, telephones, the internet, or mobile phones are only several examples of successful domestication processes (Berker et al., 2006; Silverstone, 2005). During a process of 'translation', people transform and shape technologies to better suit their needs, involving less effort to be put in consequently, eventually resulting in technologies changing and shaping people's behaviour, forming inter-relational 'societies-natures' clusters (Callon, 1987; Cressman, 2009; Latour, 1991, 1992, 1993; Michael, 2000; Nimmo, 2011).

The idea put forward is that social, cultural, and economic factors have a major influence on if and how a technology will be used by the stakeholders, or whether that specific technology will be even further developed or abandoned altogether due to lack of interest.

3.2.1. Technology adoption – barriers / motivations

Many studies found that older people are more likely to reject the adoption of innovations due to aspects such as their perceived relative advantage, relevance, complexity, and compatibility (Damant & Knapp, 2015; Eynon & Helsper, 2011; Friemel, 2016; Lunsford & Burnett, 1992; Sochor & Nikitas, 2016; Sourbati, 2009; Viswanath Venkatesh et al., 2003). It is further claimed that senior citizens are less likely to adopt innovations due to their degrading cognitive functions, lack of perceived usefulness and up-to-date information (Classen et al., 2021; Gilly et al., 2012; S. Kim & Choudhury, 2021; Parasuraman & Colby, 2001; Søraa et al., 2021; Sovacool et al., 2021). However, reasons other than age alone have been documented, such as people's perception of technology (E. J. Lee et al., 2003; OECD, 2016, 2019; Oster & Thornton, 2012); design and installation costs (Faiers & Neame, 2006); image, social status and identity (Ozaki, 2011); visibility, affordance, feedback, and constraints (Guo et al., 2017); cultural and personal beliefs (Arpaci, 2015; Hofstede, 2001; Sorge & Hofstede, 1983); having a disability that prevents usage; privacy and security concerns; gender; lack of literacy or language barriers (K. Arts et al., 2016; Chetty et al., 2018; Friemel, 2016; Helsper & Reisdorf, 2017; Kouadio, 2007; Lucendo-Monedero et al., 2019; Marler, 2018; E. Rogers, 2001; Selwyn & Facer, 2007).

The slow diffusion rates of technological skills within particular social groups or communities are due to a series of factors such as stakeholders' technophobia (fear of technology), personality, knowledge, resources, social aspects, household composition (Selwyn, 2003), as well as having ideological reasons (the so-called 'refuseniks') for rejecting technologies (D. Taylor & Packham, 2016b; Wyatt, 2003). Parasuraman (Parasuraman, 2000) suggests that aspects related to technology discomfort – the 'perceived lack of control over technology and a feeling of being overwhelmed by it' (p.311) – as well as people's insecurity in using innovations – the 'distrust of technology and scepticism about its ability to work properly' (p.311) – play a significant role in individuals' willingness to engage with innovations. If the citizens do not foresee any benefits to be gained following a learning process on how to use a particular gadget, their motivation will drop considerably (Harvey et al., 2019; Waarts et al., 2002).

Functionalities offered by innovations may require some time to pass before users will adjust to it, to be able to judge their usefulness (D. L. Alexander & Lynch, 2008) and to eventually decide whether further engagement with such technology would demand acquiring of new skills and complex knowledge which may interfere with their current lifestyle and needs (J. W. C. Arts et al., 2011; Tornatzky & Klein, 1982). Local and national cultural beliefs, those sets of rules for 'collective programming of the mind that [are] distinguishing the members of a group or category of people from others' (G. Hofstede et al., 2010, p.3), also play an active role in the adoption and diffusion of specific innovations. Localised interests and attitudes greatly influence people's prospect of having their lifestyle and behaviour affected by the introduction of new technologies (D. Taylor & Packham, 2016).

Another aspect to be considered is the 'not in my back yard' (NIMBY) syndrome (C. R. Warren et al., 2005), where individuals or communities prefer not to have innovations installed around their household. This leads to a limited visibility of some innovations, resulting in a lack of information about it and finally to a low adoption rate. People's behaviour is therefore highly influenced by how other members of society act and behave. Exchanging of ideas and opinions will better motivate people to learn and adopt innovations (Bandura, 1986; çarçani & Mörtberg, 2018; Friemel, 2016; Kalkbrenner & Roosen, 2016; D. Kim et al., 2009), possibly avoiding projects to be abandoned due to resistance being encountered from society. Therefore, pressure from society and peers also plays a vital role in the process of adoption of technologies (Banerjee, 1992; Bikhchandani et al., 1992; Conley & Udry, 2010; A. D. Foster & Rosenzweig, 2010).

Lehtonen (Lehtonen, 2003) wrote that 'the movement from one technological solution to another isn't so smooth; and most of this stickiness is cultural' (p.387), hinting at the lock-in process that will develop over time following the adoption of specific technologies. The excessive cost and risks associated with discarding of familiar devices may act toward preventing the society to engage with technological innovations, and remain with the familiar devices which do not require learning new skills and acquiring of fresh knowledge about how to use it (Arthur, 1989; David, 1985; Owen, Bessant, et al., 2013; Perkins, 2003; Press & Arnould, 2009).

Hence, innovations that potentially disrupt the status-quo of already existing technologies may face difficulties when trying to replace long established players (Bessant, 2013; Christensen, 1997; Henderson & Clark, 1990; Perkins, 2003). In these instances, the diffusion, adoption, and domestication processes may be unsuccessful due to failing to develop niche products and services. Rather than trying to entirely replace the existing, already familiar technologies, niche innovations could aim to complement and improve individuals' experience with older devices (Ramirez-Portilla et al., 2014). People may discover that specific innovations and automation solutions, for instance, represent a non-threatening technical alternative which could potentially assist them with conserving their body energy (Murtagh et al., 2015; Richter, 2013). This strategy not only allows people to learn new skills within a familiar environment, but also increases their chances to 'leapfrog from low levels of development to sustainable development' (Sarabhai & Vyas, 2017, p.427).

The innovation acceptance rate also correlates with individuals' skills and education level (Augustenborg et al., 2012), yet a higher level of education does not always guarantee an increased rate of adoption of innovations. Instead, the wealthier part of the population is more likely to become adopters (Amoako & Okpattah, 2018; Borenstein, 2017; Litman, 2014; Namara et al., 2013; M. G. Smith & Urpelainen, 2014a, 2014b; Worthington et al., 2011). Extant studies provide that there is a direct correlation between people's formal education and their financial status: a lower education level results in a lower economic position (B2B marketing, 2019; Eurostat, 2020), while in return a lower family socio-economic status is more likely to further force the younger population to drop out of school early (Videnovic & Lazarevic, 2017). Moreover, individuals' current ambitions and social status will directly affect the way they choose to interpret specific scenarios or vignettes aimed at highlighting the advantages and disadvantages associated with the adoption of a particular innovation or service (Henwood et al., 2018; Murtagh et al., 2014). For instance, the installation of PV panels may be driven by the desire to reduce one's electricity bills in some cases, while for others will be but a means to advertise their more affluent social status or that they care for the environment.

3.3. Affordance, material culture and social symbolism

It has been demonstrated that by involving the future stakeholders in the development process, the uptake of innovations increased considerably (Broman Toft & Thøgersen, 2015; Ozaki, 2011; N. Taylor et al., 2018). Further, modern innovations are designed with multiple affordances in mind, to potentially attract the largest possible number of users. Mobile phones, for instance, were originally designed with the specific purpose of offering remote voice and text communication. As the technology advanced, a range of additional affordances has been added to the basic phone features, such as taking photographs, playing music, browsing the internet, etc. (Kongaut & Bohlin, 2016). While using any technology, the stakeholders can choose to avail of only some specific available services which best suit their needs, potentially ignoring and labelling other features as not being useful (Silverstone, 2005). This led to the development of specialised innovations in fields such as agriculture, medicine, engineering, entertainment, etc. (Aker, 2011; Chikatsu & Takahashi, 2009; Fowler et al., 2005; Humpston, 2009; Jiang & Liu, 2017; G. Kim & Chan, 2007; Klein, 2006; Larsen & Sandbye, 2020; Marshall & Davis, 2021; Muangprathub et al., 2019; Oo & Phyu, 2021; Qasim et al., 2021; Qiu et al., 2006; Reynolds et al., 2020; Watanabe et al., 2003)

Suchman (2007) offers the example of a hammer and its potential multiple uses, for example in carpentry or as a weapon, and explains that any object is given a meaning only the moment its affordances are being interpreted and it is consequently being put into practice. As Leonardi (2010, p.8) maintains, 'although the physical matter of an artifact is common to each person who encounters it, the affordances of that artifact are not. Affordances are unique to the particular ways in which an actor perceives materiality', pointing to the multitude of different uses offered by the same artefact, which are interpreted and filtered through the previous existing experiences, perception of the world, age, motivation, needs and cultural views of the stakeholders (Chemero, 2003, 2009; Gibson, 1986; Harré, 2002; W. H. Warren, 1984). Moreover, Leonardi (2010) maintains that 'people do not interact with an object prior to or without perceiving what the object is good for' (p.8), allowing for a process of negotiation to get initiated first, for such objects to be later included or not into their set of cultural beliefs and behaviour (Woodward, 2007).

Hutchby (2001) takes this idea further and proposes that there must be a connection between people and objects, so that while the materiality of an object remains unchanged, its affordances change according to the 'properties' of people. What is interesting to note is that the author refers here to both physical and digital artefacts, and as such their materiality is characterised by their affordances and restrictive characteristics, rather than by their physical attributes. The 'material' nature of computer software offers their users similar affordances as any other physical artefact.

Displaying ownership of the latest innovations, especially in the form of electronic devices and 'green' technological solutions, represent the norm of advertising one's image and social status (Friedman, 1997; Gartrell & Cartrell, 1979; Hosseini et al., 2018; Kencebay, 2019; Mallett, 2007; Shih, 2014; Sovacool & Axsen, 2018; Taib et al., 2017; White & Sintov, 2017). Woodward (2007) writes that the notion of material culture 'emphasises how apparently inanimate things within the environment act on people, and are acted upon by people, for the purposes of carrying out social functions, regulating social relations and giving symbolic meaning to human activity' (p.3). As semioticians Saussure and Peirce would agree, specific signifiers are used across various cultures to regulate social relations, infer belonging to a particular class, and establish social meanings (A. A. Berger, 2016; Woodward, 2007; Worthington et al., 2011). As Woodward (2007) further remarks, 'The fact that one has exclusive control and ownership of an object is the crucial aspect mediating the boundaries between self (who controls the object) and the other (who doesn't)' (p.135).

Berger (016) adds that the perceived role of artefacts within people's lifestyle also changes according to age and offers as an example the smartphone and its significance, ranging from amusement and play during childhood, and then changing to career and socialising towards adult life. Referring to artefacts and their material culture, Woodward (2007) concludes that they might be interpreted 'as a crucial link between the social and economic structure, and the individual actor' (p.4), helping us to understand the underlying social and economic dimensions of our communities. Therefore, material culture reflects 'the beliefs, customs, traditions, and values of a particular society or group of people' (Nuessel, 2013, p.207), acting as a signifier for individuals' occupation, age, religion, social status, identity, and culture (Eco, 1976).

However, this process does not always reveal an accurate image of other society members, as people can easily adjust and control objects to intentionally promote a distorted image of themselves, with the intention of feeling more empowered and to satisfy their self-esteem (Belk, 1988). This is especially true for urban environments where, due to the existing large population densities, the level of the personal interaction between people is low, and therefore a speedy reading of other's 'properties' is employed in such ways that excludes the need for the exchanging of words (Woodward, 2007). The decision to have PV solar panels installed on top of their house, for instance, may not necessarily be driven by individual's care for the environment, but by the peers' pressure to display their affluence and that they are socially responsible (Mergel & Bretschneider, 2013; Murtagh et al., 2015; Nolan et al., 2008; Oster & Thornton, 2012; Rai et al., 2016).

3.4. Energy flow and sustainable solutions

The world population is predicted to reach 8.5 billion by 2030 (UN, 2015, 2022), with around 4.7 billion people (sixty-eight percent) to reside in urban environments alone (WHO, 2016, 2018). Not only will the global population increase, but also the current urbanisation level will see a significant inflation from the current level at around fifty-six percent (Statista, 2021). As the urban population rely on resources largely 'imported' from outside the cities, this will result in further deepening the 'metabolic rift' that already exists between these two areas. This notion, coined by Karl Marx, refers to the phenomenon of humans becoming physically and psychologically distanced from their resources (J. B. Foster, 1999; Moore, 2011).

Our society became accustomed to consuming more, and for instance an increasing demand for electricity is being forecasted (EirGrid & SONI, 2019; Pasqualetti, 2011). Thus, it is argued that our society needs to become more resilient and find better ways of harvesting more locally produced energy, be it in the form of electricity, heat, or food. Governments play a significant role in promoting large scale REST at local levels by providing knowledge, technical skills, and financial assistance to their citizens (Li et al., 2013). Localised energy production will not only potentially lower the consumption rate, but also offer a positive social context for individuals' actions (Middlemiss, 2008) by involving local communities in the development process of what Walker and Devine-Wright (Walker & Devine-Wright, 2008) call 'community renewable energy' projects. These actions also aim at increasing awareness by bringing energy sources closer to people, turning them into both active producers as well as conscious consumers (Ricci et al., 2010; J. C. Rogers et al., 2012; Shackley & Green, 2007; Walker & Cass, 2007). Meanwhile, niche sustainable innovations may provide opportunities for a more efficient management of energy and natural resources (Bessant, 2013), while trying to best anticipate both positive and negative outcomes in such a manner that communities will benefit from their democratic and sustainable approaches (Owen, Bessant, et al., 2013).

3.4.1. Opposition to green technologies

Despite early interest being expressed, it has been found that people may reconsider their position in relation to adoption and installation of green technologies at the 'back of their garden'. Aspects such as perceived relative advantage of technology; complexity of the innovation; social influence; available capital/knowledge about grants and installation costs (Faiers & Neame, 2006; Vasseur & Kemp, 2015a); poor maintenance and lack of technical know-how of the installers (Saka et al., 2017); lowering their property value; negative impact on fauna; noise and visual impacts; efficiency and reliability; or availability on local markets are few factors that were mentioned (K. Arts et al., 2016; N. Bergman & Eyre, 2011; Enevoldsen & Sovacool, 2016; B. H. Hall, 2004; Pasqualetti, 2011; J. C. Rogers et al., 2012).

Moreover, 'social barriers are blocking our way' (Pasqualetti, 2011, p.202). These alternative energy sources may be regarded as posing a negative impact on the environment by way of visually changing the landscape or generating noise pollution (Mergel & Bretschneider, 2013; Nolan et al., 2008; Oster & Thornton, 2012; Pasqualetti, 2011; Rai et al., 2016). In this sense, Claudy et al. (2013) found that 'by reducing reasons against adoption, thus allowing consumers to act upon their positive attitudes' (p.283) will have a positive effect on the adoption of REST.

Reasons for social opposition for the installation of wind turbines are different from those in the case of PV solar panels or other technologies (Eleftheriadis & Anagnostopoulou, 2015). The 'labor illusion' (Buell & Norton, 2011, American spelling in original) refers to the phenomenon of people's desire to observe the technology working 'hard' to perceive it as being efficient. In this sense, the reduced feedback offered by renewable technologies adds to people's perception that these sources are not functional or reliable. PV solar panels are completely silent, while wind turbines do not need to spin at high speed to produce electricity and be efficient (Painuly, 2001).

People maintain to be informed on existing environment issues, yet reasons such as build quality and price still represent the main drivers of their decisions in acquiring innovations (Faiers & Neame, 2006; Maletic et al., 2010; Peluso, 2015; Yudelson, 2007). Studies support the idea that provision of incentives, and imposing a minimal impact onto their current lifestyle will result in people agreeing for technologies to act on their behalf, meaning that both financial savings as well as promoting environmentally friendly practices would be achieved as a result (Dong Energy Eldistribution A/S, 2012; Ilic et al., 2012; Mah et al., 2012). In general, green products are more expensive than traditional solutions, and of a lower quality. By addressing factors such as social pressure, raising awareness, compatibility, and reliability could act as incentives for people's desire to advertise their status and altruistic behaviour, leading them to switching to newer technologies (Eleftheriadis & Anagnostopoulou, 2015; Griskevicius et al., 2010; Ozaki, 2011; Paliwal, 2012).

3.5. Conceptual framework summary

The existing complementary stances on the evolution of innovations, advanced by supporters of technological determinism and social constructivism, were considered by the researcher during the early design stages of this study, and they further influenced the development process of the artefact. To this end, taking advice from authors such as Bessant (2013) and Ramirez-Portilla et al. (2014), a niche innovation in the form of the BGAS was developed by the researcher, with the clear intention of complementing and assisting people with activities around their garden. People's natural social and cultural stickiness to old but familiar technologies act as an important barrier.

Therefore, a co-creation technological development model was implemented, aiming to reduce participants' unfamiliarity with the artefact, and to increase the chances of its adoption. The social and material values that were associated by the participants with the artefact are investigated. Also, the resulting 'accidents' following participants' interaction with this innovative setup represent another theme to be revealed by this research, prompting the advancement of a nuanced description of the barriers / incentives that can be linked to their engagement level with the artefact.

The 'attitude-behaviour gap' (Claudy et al., 2012; Ozaki, 2011; Peattie, 2001) regarding adoption of renewable energy sources represents the second main topic to be discussed in this paper. The 'reverse NIMBY' behaviour specific to the Irish citizens (C. R. Warren et al., 2005) informed the physical design of the artefact, in the sense that the PV panels and associated peripherals were positioned in such a manner that their visibility would be optimal for the participants and visitors in the community garden where the innovation was located. The initial plan of including an additional small wind turbine was dropped due to opposition from the managers of such gardens.

The next chapter outlines the chosen methodology and evaluates the implications on the data integration process following the multiple stages of data collection. The uniqueness of the artefact represented by the BGAS is detailed, along with the sample of the individuals that were recruited to participate in this study.

4. Chapter 4 - Methodology

Exposing people to innovations will inevitably influence their daily routines, for any technology will 'demand' some attention from their stakeholders (Briguglio & Formosa, 2017; Claudy et al., 2015; Moores, 2000). The researcher determined that to confidently offer an accurate description of 'what' happened with the studied phenomenon in this unique setup, a clear indicator would be needed to explicitly reveal participants' remote communication with the artefact via the *My Garden EyeDuino* mobile app. In addition, an account of 'why' and 'how' was deemed critical to draw a more detailed picture. Therefore, two strands of data were considered as being necessary to achieve this objective: the quantitative to reveal 'what' happened, and the qualitative to explain 'why' and 'how' it happened, relying on focus group discussions, in-depth interviews, and observation of the participants. The qualitative strand would also establish participants' stance in relation to innovations and renewable sources, allowing the researcher to discuss and recommend additional potential ways of reducing the associated 'attitude-behaviour gap'.

4.1. Overview

To mitigate the collection of such rich and meaningful details, this study employed six bespoke automated enclosures which have been constructed by the researcher within six individual community gardens in Dublin. These artefacts offered the participants some assistance with their usual gardening tasks, and a virtual communication channel between technology and people was developed following their remote interaction process.

Therefore, this study aims to

- identify the actors that influence the adoption or rejection of discrete innovations, and to reveal and discuss any 'accidents' that were recorded following participants' interaction with such artefacts in this situated environment.
- investigate factors addressing the 'attitude-behaviour gap' in relation to people's awareness and adoption of renewable energy sources.

Resorting to insights as enumerated in the literature review chapter, the author was able to conceptualise a research approach that would offer an explanatory description of the multiple factors that play a role in the adoption process, ranging from social and financial status to cultural norms and education attainment. Rather than relying on traditional methods for quantitative data collection – such as cross-sectional or longitudinal surveys for instance (Axinn & Pearce, 2006; J. W.

Creswell & Clark, 2010; O'Cathain, 2019; Schrauf, 2016) – an innovative design has been specifically developed for this study by way of relying on six physical enclosures. No ready-made, similar technical solutions are available in Ireland to individuals. This led the researcher to designing and building such installations, which allowed for gathering of a very accurate quantitative account of the participants' interaction with the technology performed via the custom developed *My Garden EyeDuino* mobile phone app.

The researcher was further guided by methods which are characteristic to the constructivist approach developed by Katy Charmaz (2005, 2006) as part of the grounded theory (GT) research. Thus, the qualitative stage was prioritised to offer accurate insights and rich explanations of the quantitative indicators. Axinn and Pearce (2006) and Franck (2002) suggest that empirical studies should establish and consider factors such as attitudes, behaviours, social classes or values before meaningful details are gathered and analysed. Consequently, an additional initial qualitative phase was employed for this research, which represents a slight deviation from traditional mixed methods approaches, aimed at ensuring a more rigorous theoretical underpinning.

This longitudinal study was therefore informed by mixed sequential explanatory design methods, consisting of three distinct phases for data collection: qualitative, followed by quantitative, and finally by qualitative again. Meaningful quantitative details, revealing participants' interaction patterns with the artefact, were further contrasted and discussed during the second interview, offering support as the research progressed. This aims to offer an understanding in relation to the 'accidents' and lifestyle changes that were adopted by the participants following their exposure to the BGAS. Moreover, the explanatory design offers better qualitative insights into the relationships and trends signalled by the quantitative component in relation to their interaction with the artefacts (Creswell & Clark, 2010).

Johnson et al. (R. B. Johnson et al., 2007) stress that those mixed methods studies that are mostly driven by the qualitative data represent 'the type of mixed research in which one relies on a qualitative, constructivist-poststructuralist-critical view of the research process, while concurrently recognizing that the addition of quantitative data and approaches are likely to benefit most research projects' (p.124). This triangulation process effectively reduced the researcher's bias, ensuring better data reliability and validity by combining the strengths of the two complementary methods (Lingard et al., 2008).

4.2. Rationale and application of the chosen data collection methods

Developed in sociology in 1967 by Glaser and Strauss, GT research is based on the interpretation of qualitative data, mainly generated by way of interviews, questionnaires, and observations of participants (Birks & Mills, 2011), and can be employed in both quantitative and qualitative research (Glaser, 2008; Glaser & Strauss, 1967; Holton & Walsh, 2017). Historically, the outcome aims at explaining a phenomenon by generating a theory, or describe the social interaction processes and the perception of people being studied, of which little to nothing was known before, and which is of interest to the researcher (Babchuk, 2011; Birks & Mills, 2011; Brinkmann, 2013; Charmaz, 2005, 2006, 2014; Creswell, 2007, 2014; Glaser & Strauss, 1967, 1999; Kennedy & Thornberg, 2018; Kvale & Brinkmann, 2008; Strauss & Corbin, 1994).

The constructivist GT method which influenced this study was developed by Katy Charmaz (2005, 2006), and is characterised by a less structured approach (Babchuk, 2011, 2015; Charmaz, 2014; Creswell, 2015). As Morse and Niehaus (2009) explain, 'grounded theory is a way of identifying what is *going on* or what *is happening* (or *has happened*) within a setting or around a particular event' (p.94), thus allowing the researcher to build a description of how people interpret and understand a situated environment, and how their behaviour changed following their exposure to such a phenomenon.

Formally conceptualised around the late 1980s (Molina-Azorin, 2016; O'Cathain, 2019), the mixed methods research (MMR) consists of 'the combination of at least one qualitative and at least one quantitative component in a single research project or program' (M. Bergman, 2008, p.1). Methods specific to quantitative designs are integrated with interviews and observations in a concurrent or sequential manner (Axinn & Pearce, 2006; Creswell & Clark, 2011) to better answer the research questions (Plano Clark & Ivankova, 2016).

R. Johnson et al. note that GT 'is a research method that fits remarkably well with MMR' (2010, p.65-66), and that led the academic community to develop the MM-GT typology comprising a research design which is well suited in the fields of education and social sciences (Birks & Mills, 2015; Charmaz, 2014; Guetterman et al., 2019; Holton & Walsh, 2017; R. Johnson et al., 2010; H. Smith et al., 2020; Walsh, 2015). While traditionally GT would seek to generate a theory, it is argued that when used under the MM-GT umbrella, the development of a model or framework could be sought instead (Guetterman et al., 2019), or even to establish analytic categories or themes (Charmaz, 2011; S. B. Merriam & Tisdell, 2016; Wutich et al., 2015). The methodological rigor employed in MM-GT led to a worldwide academic recognition of this approach, with Smith et al.

(2020) declaring that 'mixed methods and grounded theory are particularly complementary' (p.185).

By combining the strengths of both methods, the author was able to eliminate the limitations that are inherently specific to each tool when employed individually (Creswell & Clark, 2011; Teddlie & Tashakkori, 2009; Venkatesh et al., 2013), with arguments pinpointing both divergent and complementary findings (O'Cathain, 2019; Viswanath Venkatesh et al., 2016). This synergistic approach mitigated the building of a more diverse, yet accurate picture than it could have been obtained if the study would have relied on a single method (Bazeley, 2009b; Caracelli & Greene, 1997; Guest, 2012; B. Hall & Howard, 2008; Maxwell & Loomis, 2003; Mertens & Hesse-Biber, 2013). Appendix B presents a list of similar existing studies, supporting the argument that the MM-GT method has organically evolved over the years across various fields of study, serving as an appropriate method in this type of situated scenarios.

Further, a narrative explanatory approach was adopted, with the qualitative expanding the quantitative (Creswell & Clark, 2011; Guetterman et al., 2019) and explaining specific indicators that were 'identified during the first phase of the study' (Catallo et al., 2013, p.3). Guetterman et al. (2019) acknowledge that when mixed with MMR, not all the techniques specific to GT need to be employed and relied upon. Under this social constructivist research model, the phenomenon being studied is considered more important than the methods used in the process. This allowed the researcher to put themself within the reality which they were analysing, and take a reflexive stance in trying to understand it (Charmaz, 2005; Guba & Lincoln, 2004). Thus, while in the middle of the researched subject, the researcher was able to make sense, interpret, and explain the views of the participants through the prism of their own subjectivity, preconceptions, experiences, and values. O'Cathain (2019) maintains that 'Integrating data from various sources enhances validity and minimizes the risk of a partial or inaccurate interpretation' (p.593). Mixing quantitative and qualitative data improves the quality of the study, by providing complementary or contradictory views supporting the theoretical construct (Venkatesh et al., 2016).

The qualitative strand was therefore conducted on a small population sample (nineteen participants), sacrificing the scope to produce more detailed, in-depth insights which are not necessarily meant to be statistically significant. Instead, the resulting knowledge focuses on explaining a localised and specific phenomenon related to the impact that bespoke automated gardening systems had on people, describing the factors that would have acted as barriers or incentives towards their interaction with this innovation, and the 'accidents' that resulted following these interactions. Further, the practical nature of the participants' engagement with the artefacts powered by REST allows the researcher to offer insights regarding their perceived "attitude-behaviour gap".

4.3. Methods operationalisation narrative

The qualitative stage of this study has been guided by the constructivist approach developed by Charmaz (2014; 2006), and an additional qualitative stage was included in the design as depicted in Figure 4.1.

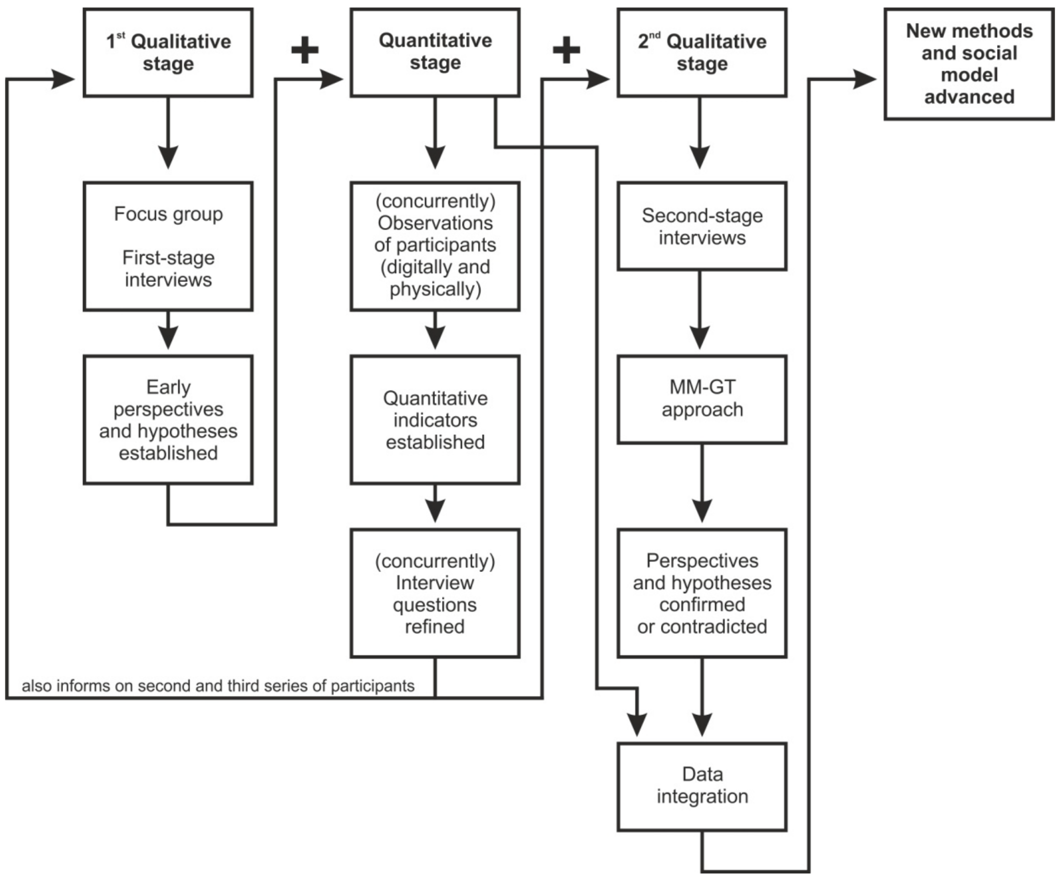

Figure 4.1 – Procedure of MM-GT application. Source: Hamilton V. Niculescu

Two strands of complementary data have been collected for the duration of this MM-GT study for the purpose of answering the proposed research questions:

- Quantitative – resulted following the participants' remote interaction with the BGAS via the custom developed *My Garden EyeDuino* mobile phone app.

- Qualitative – focus group discussions; in-depth semi-structured interviews; observation of the participants; participants' logs; researcher's personal memos and notes.

4.3.1. Participant recruitment process

A purposeful sampling / criterion-based selection was chosen, where specific participants and locations were carefully selected to provide rich, useful insights (LeCompte & Preissle, 1993; Light, R.G. et al., 1990; Patton, 1990). This 'strategic sampling' (Davies, 2007) was deemed as being the most appropriate method to be employed in the present research, to assist with the 'identification and selection of information-rich cases related to the phenomenon of interest' (Palinkas et al., 2015, p.1). Random sampling would not have worked in this case, as this method would not have ensured that the participants have enough knowledge for the study to be properly conducted (Light, R.G. et al., 1990; Morse & Niehaus, 2009; Schreier, 2018; Weiss, 1994).

Forty-seven communal gardening sites in Dublin were initially identified and an email was sent to their contact address, explaining the purpose of the study, and inviting them to participate. Nine replies were received, mentioning certain constraints which prevented them from accepting to host the researcher's proposed project. Those reasons included the lack of available space; restrictions being imposed by the local government; fear of encouraging vandalism due to the addition of electronic equipment on site; and concerns related to the addition of potential noise and visual changes. The latter mainly referred to the original proposed design which included a wind turbine, along with the rest of the automation technologies, to provide the required electricity.

To address some of the above concerns and to reduce the reasons against accepting the proposed project, the researcher proceeded to redesign the setup. Thus, the installation would consist of only PV solar panels mounted at ground level, without the inclusion of an additional wind turbine. The size of the proposed physical enclosure has also been reduced, and the electronic equipment was to be mounted inside a small box, placed within the enclosure to reduce its visibility. However, the same level of the proposed overall functionality has been preserved.

Following further communication by email, seven positive replies have been received as a result, and another extra four locations were identified by the researcher by 'word of mouth'. After visiting and analysing various aspects related to those locations, six sites were finally chosen to participate in the study. A written agreement was signed between the coordinators and the researcher (Appendix I), and the coordinators were informed that some people from within their community will be recruited following focus group discussions to be organised on their sites. Subsequent email and phone communication with the coordinators resulted in organising five focus groups discussions at five locations, which took place during February 2019. The purpose for conducting focus group discussions was to ensure that:

- The chosen participants already have an interest in growing vegetables, and while being involved in the study their attention will not be distracted by such 'new' activities.

- The chosen participants would not feel like strangers to that place, allowing them to act naturally, for they already belong to that local community.

- Being able to interact with other people, which the participants already knew, would allow for specific communication, exchange of ideas and opinions, as well as forming attitudes towards technology in a social and friendly environment.

- The chosen participants being known to the local community would serve as an extra safety and security measure for the enclosures and the embedded technology, as well as an opportunity to spread the information about the innovative and more sustainable way of growing vegetables.

4.3.2. Sponsorship

To get access to potential participants in the study, the researcher contacted the coordinators of various community gardens and allotment plots in Dublin. Furthermore, a booklet containing a full list and contacts of such places, made available to the researcher by the Dublin City Council upon an email request, proved to be an invaluable resource and a starting point for building connections with people already involved in gardening. The physical spaces required to build the automated enclosures, required for conducting this research, were facilitated free of charge by D. Hazel, R. McConnell, L. De Giorgi, D. Mulvaney, A. Kelly, H. Martin, T. Nugent, and R. McDermott, to whom the researcher remains grateful. No exchange of money, or provision of other advantages or facilities has been involved before, after, or for the duration of conducting of this study.

4.3.3. Demographics

Participants' composition

- Eight females, twelve males.

- One participant (male) unavailable for the second interview (P11).

- One participant (female) dropped out before the first interview, not being further identified in this research.

Age groups

- 18-25 six people
- 26-35 two people
- 36-45 five people
- 46-55 two people
- Over 55 four people

Please note that the above age groups classification is only made for the purpose of showing the spread in a clearer manner, and do not imply that these would have any direct correlation with the participant's experience or participation in gardening specific tasks.

Gardening experience

- None two people (further identified as 'negative cases')
- Occasional nine people
- Often eight people

Occupation

- Employed seven people
- Retired three people
- In education nine people

4.3.4. Sample composition and size

Mertens (2018) recommends that researchers should not exclude from the study those people from hard-to-reach groups, such as disabled individuals or those speaking a foreign language. Factors such as heterogeneity, 'age, gender, relevant experience, social class and/or occupational group and ethnic identity' (Davies, 2007, p.147) were considered as much as possible during the participants recruitment process, especially those aspects that could potentially challenge some preconceptions – for instance older adults using technologies. However, choosing the 'right group' of participants for this study that would cover all the suggested aspects was not entirely possible, given the restricted range of the studied environment. Other specific selection criteria have been regarded as being more important during the design of this study, such as people having a previous interest in growing vegetables for instance, which resulted in obtaining more qualitative results.

Accounting for size, 'samples in qualitative research are mostly not representative of a population' (Schreier, 2018, p.85). As already mentioned, by sacrificing the scope for detail, smaller sample sizes allow for better in-depth analysis of social, cultural, and economic factors of each participant, as in some instances the data resulting from just one interview was quite extensive, to be further discussed. The recommended average sample size for qualitative research is anywhere from 1 to 20 participants (Birks & Mills, 2011; Brinkmann, 2013; Davies, 2007; Maxwell, 1996; Schreier, 2018). As a result, the qualitative stage of this study is based on two-stages interviews with nineteen participants, further identified as P1 to P19 (Figure 4.2), resulting from the following process:

- Six automated enclosures were built at six separate locations in Dublin.
- Each enclosure was made available to participants for a total period of nine calendar months (March 2019 – November 2019).
- A period of three calendar months was allocated to each participant, up to a total of three participants per enclosure, and a total of eighteen people for the whole project.
- On one occasion, two participants expressed their desire to share the control of the enclosure during their trial period.

Details about the correlations that have been noted to exist between various indicators (e.g., age or previous gardening experience influencing the engagement with the BGAS) are offered in the findings and the discussion chapters of this document.

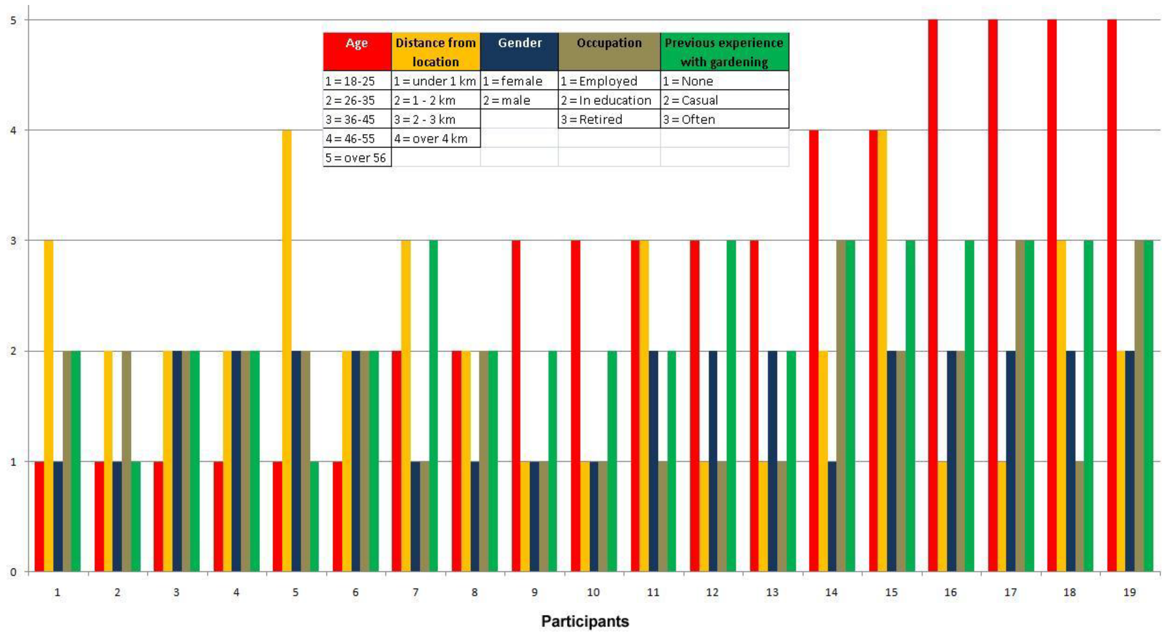

Figure 4.2 – Participants' profile. Numbers in the horizontal axis do not match the participants' number (P1 – P19) as further allocated in this document. Source: Hamilton V. Niculescu

4.3.5. MM-GT data collection

The detailed methods and processes used for gathering the two data sets are explained in the next sections. The research consisted of an initial qualitative step, represented by focus groups discussions and first stage interviews, and continued with the traditional MM approach, namely the quantitative followed by the qualitative (second stage interviews) data collection phases.

The BGAS involved in the conducting of this research played two critical roles:

- The quantitative details, representing the participants' engagement level with technology, were collected in an innovative and more accurate way, rather than relying on established, traditional methods (e.g., surveys or telephone calls).
- It encouraged the participants to remotely communicate with the remote enclosure via the custom-made *My Garden EyeDuino* mobile phone app, thus prompting the rich qualitative details to be captured during the in-depth, second stage interviews.

4.3.6. Quantitative strand

The quantitative data for this study were automatically captured following the participants' remote interaction with the six gardening automated systems via *My Garden EyeDuino* mobile phone app, as described in detail in 'The mobile app' section. For the duration of nine consecutive calendar months which have been allocated for the data collection process, time-stamped detailed blocks were recorded on the secure online server (https://thingspeak.com) as Figure 4.3 shows, and they provided the researcher with useful information indicating the past and current details in relation to the participants' interaction level, as well as the system's status, as following:

- System working mode (automatic/manual).
- Soil moisture (percentage).
- Air humidity (percentage).
- Air temperature (Centigrade).
- Irrigation status (on/off).
- Fans status (on/off).
- Windows status (open/closed).

The 'system working mode' could have two possible values, number '0' indicating the system performing in manual mode, and number '1' indicating the automatic mode. The transition between these two working modes could be initiated by the participants via *My Garden EyeDuino* mobile phone app (indicating their interaction level with the remote system), or by the ACU under specific system conditions, as detailed in 'The BGAS and ACU' section. In correlation with other relevant quantitative and qualitative details, this indicator served as the guidelines for refining the structure of the second stage interviews.

The rest of the quantitative details served as a reinforcement for the discussion around the invaluable assistance with specific tasks that the BGAS has offered to the participants, which therefore not only had an impact on their lifestyle, but also on the vegetables' growth cycle, as examined in the discussion chapter.

Figure 4.3 – Online server acting as data depository, as well as the communication link between the mobile phone app and the automated system. Source: Hamilton V. Niculescu via https://thingspeak.com

At the end of the data collection process, the researcher downloaded all the available details from the online server, in the .CSV (comma separated values) file format. The data were imported in Microsoft Excel, which enabled the quick identification of the actions that have been performed at any individual research location, date, and time for the whole previous nine months. *Figure 4.4* offers some insights into the modelled quantitative data that were used to support the analysis and discussion chapters (please refer to Appendix J for further details).

1	Created at	Working mode
623	2019-06-28 15:48:52 UTC	1
624	2019-06-29 02:27:51 UTC	1
625	2019-06-29 09:12:58 UTC	0
626	2019-06-29 09:13:02 UTC	0
627	2019-06-29 09:13:04 UTC	0

1	Created at	Battery voltage	Soil moisture	Irrigation	Air humidity	Fan	Temperature (centigrade)	Windows
352702	2019-06-22 15:19:57 UTC	13.9	62	0	48	0	32	1
352703	2019-06-22 15:20:23 UTC	13.8	62	0	47	0	31	1
352704	2019-06-22 15:20:46 UTC	13.7	62	0	47	0	32	1
352705	2019-06-22 15:21:10 UTC	13.8	62	0	46	0	32	1
352706	2019-06-22 15:21:30 UTC	13.7	62	0	46	0	32	1

Figure 4.4 – Sample date/time stamped data showing system's working mode and microclimate conditions inside the enclosures. Source: Hamilton V. Niculescu via https://thingspeak.com

4.3.6.1. Challenges concerning the quantitative data collection

The practical aspect involved in the quantitative data collection implied that potential risks were present. Specific preventive steps have been prepared in advance by the researcher, covering scenarios that could have posed a negative impact on the quantitative data collection process:

- Technical malfunction or system break down – as is the case with any equipment, break downs or malfunctions are common, both mechanically and/or electronically. The researcher continuously monitored the six enclosures for the duration of data collection, with spare parts being available immediately and being replaced as required.

- Broadband (GPRS) connection down – these time frames varied between a couple of hours up to a maximum of one day. Should extreme cases have occurred, switching to another GPRS provider could have been performed in a matter of hours if necessary.

- Bad to extreme weather conditions – high winds or other extreme weather conditions could have affected the proper physical functionality of the enclosures. In those cases, a delay/interruption of up to two weeks in the data collection process has been scheduled, to allow for repairs. However, this was not a case of concern for the whole duration of data collection.

- Antisocial behaviour or vandalism – although caution was taken to choose locations in safe or protected areas, there might have been cases of intentional vandalism or theft of equipment. In those cases, a delay/interruption of up to two weeks in the data collection process has been scheduled, to allow for repairs and subsequent replacement of the missing equipment. However, this was not a case of concern for the whole duration of data collection.

4.3.7. Qualitative strand

The early extra qualitative stage of this study, comprising of five focus group discussions and first stage qualitative interviews, aimed to offer the researcher a better picture of the early behaviour, attitudes and values of the participants in relation to automation and innovations, as well as details about their engagement with generic technologies (Franck, 2002). This further honed the literature review process when searching for supporting and divergent findings.

The focus group discussions further allowed the author to resort to a theoretical sampling method of strategically choosing who to interview and what situations to analyse, to be able to collect meaningful, rich, and high-quality data (Birks & Mills, 2011; Charmaz, 2006). These qualitative data gathering methods have been completed by observation of the participants, allowing the researcher to form a more informed opinion, while at the same time taking care that during these encounters not to influence their behaviour (Axinn & Pearce, 2006; Creswell, 2007).

4.3.7.1. Interviewing as a data collection method

Along with focus group discussions and observation of participants, semi-structured interviews represented the main method that the author adopted for gathering qualitative data for this study. Kvale & Brinkmann (2008) state that semi-structured can be 'defined as an interview with the purpose of obtaining descriptions of the life world of the interviewee to interpret the meaning of the described phenomena' (p.3). This approach also ensured that the researcher did not become a simple passive spectator and was able to better relate to the interviewee and data, as Birks & Mills (2011) suggest.

Another mechanism that the author has used was funnelling. This involved the adoption of an interview flow that started with some general, open questions, and as the discussion progressed gradually changing to more specific themes, which led to developing of a much deeper understanding of specific ideas (Corbin & Strauss, 2008; Maxwell, 1996; Morgan & Hoffman, 2018; Roulston & Choi, 2018). Flip-flopping on the other hand attempted to 'resolve' situations where allusive answers did not properly provide the looked-after explanation for distinct cases. For example, participants mentioning that 'the weather was not great' would have not provided enough details to fully understand the actions they took in such cases. A reversed follow-up question such as 'what if the weather was good' prompted them to describe potential actions they may have performed in that instance. The design process of this research was also informed by Kvales' (2007) suggested 7-stage model, namely thematising, designing, interviewing, transcribing, analysing, verifying, and reporting, as further explained.

4.3.7.2. Informal to pilot to final interviews

To ensure that the interviews are of high quality and that they fit within the research context, the interview questions were drafted, and one pilot test was conducted, as suggested by Roulston & Choi (2018). The original interview questions were drafted in September 2018 and presented to a series of people for testing purposes. Following the feedback that the researcher received, some of the questions were reformulated. It was decided that additional vignettes be also used for the duration of the actual interviewing and focus group discussions process, to elicit better details on specific aspects. For instance, when the participants expressed their desire to switch, entirely or partially, to renewable electricity sources, the researcher mentioned that regular tasks, such as doing laundry or cooking, might need to be rescheduled at other times for the technology to become profitable.

The people that were selected for the pilot interview were not further involved in the study, to avoid any bias in terms of their future answers, approach, actions, interaction, engagement with, or attitude towards the technology. Figure 4.5 depicts the indicative schedule that was created for conducting the preparation and interviewing processes, with colour coding indicating the milestone phases during the data collection process. The focus group discussions, as well as individual interviews were conducted at the location of each individual enclosure.

2018 - 2020		
September - February	Building the 6 automated enclosures and testing Pilot runs of the enclosures Pilot interviews and redrafting questions	
January	Focus group discussion (participants recruitment)	Qualitative data collection starts
February	Focus group discussion (participants recruitment) Interview with 6 people in first trial round	Data analysis starts
March		Quantitative data collection starts First three month round starts
April		Data analysis + interview adjustments
May	Interview with 6 people in second trial round	Data analysis + interview adjustments
June	Interview with 6 people from first trial round	Second three month round starts
July		Data analysis + interview adjustments
August	Interview with 6 people in third trial round	Data analysis + interview adjustments
September	Interview with 6 people from second trial round	Third three month round starts
October		Data analysis
November		Last round ends Quantitative data collection ends
December	Interview with 6 people from third trial round	Data analysis
January		Qualitative data collection ends
February - May		Corroboration of quantitative and qualitative data Analysis and interpretation
June - October		Writing / finishing up of PhD thesis

Figure 4.5 – Schedule for period 2018 – 2020. Source: Hamilton V. Niculescu

4.3.7.3. Types of questions

Considering the relatively small sample of participants represented by nineteen individuals, Davies' (Davies, 2007) suggestion has been considered, with mostly open-ended questions having been used for conducting the interviews. The GT guidelines allow for the qualitative data collection to be fluid, and as a result the questions that were presented to early participants were not identical to those advanced to subsequent participants. This approach allowed for achieving more specificity as themes and concepts started to emerge, following Morse's (2018) advice.

The interviews started with general, open-ended questions, and more focused, targeted questions were included as the interview progressed, following Corbin and Strauss (2008) suggestions, to ensure a logical flow for the discussion, emphasising the 'what' and 'how much' topics (Brinkmann, 2013; Creswell, 2007). As Creswell (John W. Creswell, 2007) also suggests, after initially exposing processes such as 'What was the process of your engagement?' and 'How did you interact with the system?', the researcher returned for more detailed answers related to:

- The core phenomenon, i.e. 'What was central to your engagement with the enclosure?'
- Causal conditions, i.e. 'What influenced, caused, or prevented your interaction?'
- Strategies, i.e. 'What was your plan for engaging with the system?'
- Consequences, i.e. 'What has happened upon your interaction, or lack thereof?'

Appendix K contains additional detailed information on the main questions advanced during the two-stage interview sessions.

4.3.7.4. Details about the structure of qualitative data setup

The qualitative data were therefore collected as following:

- Five focus group discussions (conducted in English), each group comprising five to nine people.
- Thirty-six semi-structured qualitative interviews (thirty-four conducted in English; two conducted in Romanian and translated into English by the researcher).
- Observations of participants' physical interaction with the automation system; logging their interaction and the meanings they attached to it.

Focus groups discussions, consisting of five to nine people as suggested by Morse & Niehaus (2009), took place during February 2019, providing an overview and insights in relation to the general knowledge, attitude towards technology, and technical skills of people already involved in growing vegetables. These discussions took place before the first batch of participants commenced their interaction with the enclosures and assisted with the participants' recruitment process. Early themes and concepts were identified at this stage, which later proved helpful for a better understanding of the phenomenon being studied.

Individual interviews with each participant were conducted before starting, as well as at the end of their three-month involvement stage in the study. The two-stage interviews, conducted approximately three months apart, allowed for the identification and discussion of:

- Participants' change of attitude and interaction with technologies, more specifically with automation technologies aimed at assisting with gardening and food production.
- Reinforcement or contradictions in participants' statements, in combination with the available quantitative details.
- Potential unexpected consequences of introducing innovations into this unique context.

The first stage of the interviews with the participants took place as follows:

- Late February 2019 - early March 2019
- Late May 2019 - early June 2019
- Late August 2019 – early September 2019

All interviews were audio recorded, and they were intended to reveal the participants' stance in relation to themes such as available recycling facilities and behaviour; attitude towards sustainable practices; and upgrading to innovative technologies.

The second stage of the interviews investigated technical aspects and the participants' attitude towards technology, having been conducted as follows:

- During June 2019
- During September 2019
- During December 2019

Observation of the participants took place for the whole duration of each participant's involvement in the study, in the form of monitoring the real-time quantitative data available online, as well as by the researcher being present physically on each of the six sites where the automated enclosures were located. This represents a customary practice in grounded theory research, also serving the purpose of collecting 'grounded' information about the physical systems' functionality and status, as well as prompting any required maintenance of the systems. Useful insights were gathered, acting as critical details during the writing of memos, such as the participants reporting something for instance, while the situation at the actual research location indicated otherwise.

4.3.7.5. Technicalities - focus groups and interviews

To facilitate an accurate identification by the researcher – during participants' recruitment process, memo writing, and data analysis/interpretation – both video and audio recording were being used during the five focus group sessions. Researcher's own equipment was used, with a camcorder positioned on a tripod and a shotgun microphone connected to it being used for audio/video recording. The material has been recorded onto Secure Digital (SD) cards, and later safely transferred onto the researcher's private Google Drive account provided by Dublin City University (DCU).

Only audio recording was subsequently used for individual interviews. Researchers' own recording equipment was used for this task; the audio material has been recorded onto SD cards, and later safely transferred onto the researcher's private Google Drive account provided by DCU.

The recorded video and audio materials have been subsequently safely deleted from the SD cards.

4.3.7.6. Interview challenges

As it is the case with any method of data collection, interviewing implies preparation for any foreseeable problems that may arise prior or during the actual process. Potential issues were identified by the researcher, and relevant steps have been taken to prevent or address it, should they occur:

▪ Not being able to locate or contact people that were already interviewed, after discovering that there are contradictions between the qualitative and quantitative data. The solution was to analyse and interpret available quantitative data before conducting the second interview, as suggested by Morse & Niehaus (Morse & Niehaus, 2009);

▪ People not interpreting the questions the way they were intended, and as such their answers do not match the context of the interview. The solution was to run at least one pilot interview with other people, and redraft the questions based on their feedback (Maxwell, 2018);

▪ Interviews can only offer in-vivo information, not a direct understanding of participants' views, actions, perspective, body language, etc. The solution was to employ multiple methods for generating data, such as quantitative, observations, and memos (Joseph A. Maxwell, 2018);

- When saturation in one section has been reached, the interview needs to move on to another direction. The solution was to analyse and interpret the available data as soon as it became available, so that a 'draft' image about what is needed and what is not can be drawn. This allowed for effective use of follow-up questions (Creswell, 2007; Roulston & Choi, 2018);

- Equipment malfunctions. The solution was to have back-up equipment already available (Pickering, 2008);

- People not being available for the interviews, either before or after their testing phase. The solution was that during the focus groups discussions to properly inform them about their availability requirements for the duration of the study. The second interview could have been rescheduled for a later time, if necessary.

4.4. Data analysis process

Miles & Huberman (1994b) note that the data analysis refers to the process of reviewing 'a set of field notes, transcribed or synthesized and to dissect them meaningfully while keeping the relations between the parts intact' (p.56). Thus, after all the 'partial data' (Davies, 2007) has been gathered, the researcher proceeded to integrating, coding, analysing, and interpreting it. Details about behaviour and contexts have been offered by answering 'what' and 'how' questions. Early themes and patterns were developed following initial data coding, assisting with the further data collection, and ensuring that meaningful and rich details have been aggregated. The qualitative details that were gathered during the two-stage interview process have been associated and contrasted against indicators found in the quantitative data. With the help of memos and observations data, new insights have emerged during the more in-depth, inductive data analysis.

Employing inductive and reflexive methods, by way of experimentation, introspection, and observation of the behaviour of the participants, narrative descriptions of the properties, causes and consequences of the phenomenon that has been studied were advanced (Axinn & Pearce, 2006; Franck, 2002).

4.4.1. Data coding

The GT literature presents qualitative data coding as process which involves breaking the data into multiple parts, identifying five to seven themes following a classification process, and recombining the data into categories that will finally assist with the development of a new theory or concept (Alemu et al., 2015; Charmaz, 2012; N. K. Denzin & Strauss, 2003; Gibbs, 2012b, 2012a; Ryan & Bernard, 2003). To allow for flexibility, the author initiated this process immediately as the qualitative data collection started and continued all along this stage. This allowed for the quick identification of areas that needed more data to fill the gaps.

The major coding steps that have been involved in this study are associated to and largely accepted in the constructivist GT qualitative research (Charmaz, 2006; Creswell, 2007; Glaser & Strauss, 1967; Maxwell, 1996; Morgan & Hoffman, 2018):

- Initial coding, also known as open coding – data was fragmented, generating a detailed line-by-line series of codes. This allowed for the analysis of individual fragments to identify properties or subcategories.

- Selective coding, also known as intermediate coding – the fractured data was reconnected, forming conceptual, more abstract categories; relationships were predicted or hypothesised.

- Axial coding – a feature of the work of Strauss and Corbin, which aims to identify a central phenomenon, and its causal conditions; strategies and consequences have been delineated, arriving at a compact summary in relation to existing data.

The data-driven type of coding was adopted, which saw the structural codes emerging from the raw data (Brinkmann, 2013). The code development process is iterative, meaning that the raw data has been repeatedly examined, the researcher linking the codes to chunks of data (such as sentences or paragraphs), which ensured the emergence of meaningful labels (Miles & Huberman, 1994b; H. Smith et al., 2020). The data collection and analysis took place simultaneously, and for open coding purposes, gerund verbs were being used in the NVivo software, implying action which later turned into topics (Charmaz, 2006, 2012). A combination of line-by-line and incident-to-incident methods has been used at this stage.

Alongside with reviewing of extensive analytical memos, the analysis naturally moved on to the next stage, focused coding, following a process of differentiation, combining and reflection on data (Charmaz, 2006; Miles & Huberman, 1994a). The qualitative data resulting from focus group discussions, interviews, and observations of the participants have also been integrated with the quantitative data collected following the participants' interaction with the BGAS. The open coding process resulted in the development of 138 individual topics, which during the focused coding stage have been subsequently grouped under four main themes of interest: Education, Finance, Behaviour, and Technology (Appendix L).

Axial coding was the final stage of data analysis to be performed, to answer questions such as 'when, where, why, who, how, and with what consequences' (Kathy Charmaz, 2006, p.60). Specific literature, addressing the four main themes previously developed in NVivo, has been consulted with by the researcher (e.g., W. E. Bijker & Law, 1992; Blok & Gremmen, 2016; Bucci et al., 2019; Colgan, 2019; CSO, 2018; EPA, 2019; Guo et al., 2017; Harvey et al., 2019; Murtagh et al., 2015; E. Rogers, 1995; N. Taylor et al., 2018; Vasseur & Kemp, 2015b; Walker et al., 2010). This aimed to establish a better understanding and to be able to create meaningful connections between the terms and concepts that have been discovered. The Education and Finance categories help establish the participants' background, and distinctive elements that are characteristic to the Irish society have been examined, to place and discuss the newly acquired knowledge within the local context (CDETB, 2021; Claudy et al., 2011; CSO, 2014, 2016, 2017, 2019a, 2019b; EPA, 2016; Farries, 2019; Finnerty, 2016; Met Éireann, 2020). In some instances, reverting to the original interview data was required to re-evaluate the meaning and context of specific situations.

4.4.2. The quantitative-qualitative integration process

The concurrent processes of data collection and analysis relied on triangulating the available details with indicators from the quantitative data. In what could be described as a partially mixed-methods design (Teddlie & Tashakkori, 2009), the qualitative and quantitative data have been mixed only at specific stages during the research, namely the data collection and inference. Serving as a validation method, this model facilitates the construction of a nuanced and accurate account of the engagement of the participants with the bespoke gardening automated systems and the mobile phone app.

The quantitative and qualitative details were produced ensuing different traditions of data collection, and as a result they have been mixed iteratively, with the first set informing the latter and assisting with the on-going systematic refinement of the interview questions. Specific strategies have been employed, such as converting the quantitative details into narrative form, and delimiting the negative cases for the forthcoming special analysis, as suggested by the literature (Bazeley, 2009b; Caracelli & Greene, 1997; Creswell & Clark, 2011; Miles & Huberman, 1994b; Teddlie & Tashakkori, 2009). Further, this 'qualitizing' technique (Sandelowski, 2000) ensured that the incoming qualitative details subsequently offered narrative support or contradicted the signals arising from the quantitative, following a process of negotiation that took place between the two sets (Patricia Bazeley, 2009; Fetters et al., 2013; Greene, 2007; Guetterman et al., 2015; Lingard et al., 2008; O'Cathain, 2019; Viswanath Venkatesh et al., 2016), in what could be characterised as 'an interactive level of interaction' (J. W. Creswell & Clark, 2010, p.65).

The high quality second type of data that emerged was therefore mitigated by the precision of the early quantitative data, improving the protocols, and fine tuning the interview questions following the author's reliance on a 'strategy of connecting [...] the results of one strand build to the collection of the other type of data' (J. W. Creswell & Clark, 2010, p.67). The lack of 'why' and 'how' details in the quantitative have been complemented by rich details in the (sometimes) speculative and theorised qualitative (J. W. Creswell & Clark, 2010; O'Cathain, 2019). The author was compelled to go back and forth between the quantitative and qualitative, to make sure that the narrative form accurately describes the quantitative figures, and that the emerging profiles offers a realistic representation of the phenomenon (Creswell, 2007; Glaser & Strauss, 1967; Kennedy & Thornberg, 2018; Sandelowski, 2000). This deductive reasoning allows the author to project the findings on a specific population to a more generalised, theoretical sample (Tashakkori & Teddlie, 2003).

4.4.3. Data validation procedures

Coding what people have said is open to interpretation, and depends on the experience of the researcher, as opposed to instances of quantitative research. The results of qualitative research, and of GT in particular, only represent the views of the researcher in relation to a 'snapshot' in time of a phenomenon happening under specific conditions, which may not be consistent with the views of other researchers using the exact same settings (Charmaz, 2005; Corbin & Strauss, 2008; Flick, 2011; Roulston & Choi, 2018).

The immediate effect caused by the researcher being located right in the middle of their data is what it was termed as 'reflexivity', recognising that this relationship is expected to take place in studies influenced by GT (Hammersley & Atkinson, 1983; Maxwell, 2018). Strauss and Corbin (1994) confirm that 'the interplay between researcher and the actors studied [...] is likely to result in some degree of reciprocal shaping' (p.147), by 'interplay' the authors referring to the 'acting on' and 'reacting to' data during the collection stage, a fact acknowledged by the author of this study.

The adoption of the MM-GT method for this study ensured that 'a potential bias coming from one particular approach is not replicated in alternative approaches' (Axinn & Pearce, 2006, p.1), acting to increase the confidence that the data to be presented closely reflects the reality, and not the researcher's views and preconceptions (Axinn & Pearce, 2006; Rosenbaum, 2001). Further, as the triangulation 'can check the accuracy of what your respondents tell you about other observations' (Davies, 2007, p.154), the MM-GT approach played a pivotal role eliminating the social desirability aspect, described by Phillips & Clancy (Phillips & Clancy, 1972) as 'the tendency of people to deny socially undesirable traits or qualities and to admit socially desirable ones' (p.923).

Some form of a triangulation process is usually adopted to fill the gaps, and to minimise researchers' bias and personal views of the world (Bazeley, 2009a; Charmaz, 2006; N. K. Denzin & Strauss, 2003; Flick, 2018; Kaplan, 2004). Long before the concept was officially introduced in social sciences around the 1970s by Norman Denzin, the concept of triangulation was used implicitly by researchers who used to combine qualitative and quantitative methods to achieve more grounding for their studies. By using multiple approaches for studying the same phenomenon, researchers were able to cross-check the interpretations of various sources and increase validity of their data (Corbin & Strauss, 2008; Davies, 2007; Flick, 2018).

The participants were asked to send 'logs' via the built-in feature in *My Garden EyeDuino* mobile phone app (please refer to 'The mobile app' section for additional details), consisting of short narrative texts expressing their ideas, concerns, opinions, thoughts, etc. This ensured that the participants said not what they believe or 'remember' they did, but what they really did (Barbour, 2018; Drew & Heritage, 1992; Gilbert & Mulkay, 1983; Hodkin & Radstone, 2003; Webb & Stimson, 1976), acting towards an increase of the data reliability.

However, this MM-GT study relies not only on what people said, but also on what people did. This triangulation process was done by integrating the qualitative details with observations of the participants and the quantitative data, as people sometimes forget or purposely omit to mention certain facts and aspects (Davies, 2007; O'Leary, 2004). These multiple views and perspectives led to the 'crystallization' (Richardson & St. Pierre, 2005) of the proposed conceptual model, which added transparency to the study (Birks & Mills, 2011; Richardson & St. Pierre, 2005). Meanwhile, by activating the 'episodic memory' (Flick, 2011) during the interviewing process, the resulting additional details complemented aspects which might have been missed during the analysis of data obtained from observations and/or quantitative sources. This represented a good opportunity for follow-up questions to validate what has been previously said (Maxwell, 2018; Roulston & Choi, 2018).

4.4.3.1. The process of triangulation

Taking inspiration from previous existing works (J. W. Creswell & Miller, 2000; J. W. Creswell & Poth, 2018; H. Smith et al., 2020), the author ensured that the details that have been gathered are described as accurately as possible. Theoretical, data and methodological triangulation, as well as feedback provided following member checking, have been used to support the findings and discussion of this study. In this sense, the researcher started the process of data collection with no intention to prove that the BGAS involved in this project would resolve to a positive or negative experience for the participants, but rather this was to be revealed following their participation in the study and during the inductive data analysis. The possibility that multiple early perspectives on the collected data could be advanced has been considered. The integration of data coming from various sources by relying on different methods filtered the various hypotheses, allowing the researcher to build an accurate conceptual model.

Semi-structured interviews, observation of the participants, as well as consulting with the logs and personal notes ensured that the qualitative data did not rely on a single stream, but it has been informed by complementary sources. The observational data, collected following a series of visits to the research sites for the duration of the study, provided the researcher with a confirmation that the existing and future data are properly 'grounded' and aptly support the conclusion. Also, the feedback and support provided by Dr Declan Tuite, acting as supervisor, who constantly suggested new possible inquest areas, represented an invaluable validation for the on-going process.

By observing relevant indicators in the quantitative stream, specific qualitative details have been supported or rejected, assisting with building of a more accurate conceptual model. A truthful representation of data is therefore delivered following the integration of all available data about the same phenomenon, gathered through the employment of different methods (Birks & Mills, 2011; Davies, 2007; Ely et al., 1991; Erlandson et al., 1993; Glesne & Peshkin, 1992; Lincoln & Guba, 1985; S. Merriam, 1988; Miles & Huberman, 1994a; Patton, 1990).

4.4.3.2. Member checks and audit trail

The author presented the participants with a summary of the findings, as well as early insights into the studied phenomenon. This way, they had the chance of identifying any misinterpretations for the data by the researcher and providing further feedback on those. Additionally, the two-stage interview process employed by this study offered the researcher the opportunity to rephrase certain questions which did not originally result in meaningful explanations, resulting in clarifications being brought into specific areas.

The data analysis commenced immediately as the interview with the first participant was transcribed. Using the NVivo software, early codes and themes started to emerge, shaping the course and context of the upcoming interviews. There have been occasions however when the researcher realised that the existing structure of codes did not considerably allow for data flexibility and the new incoming data did not fit with it. As is the case with any fluid research, some codes became less important, while the addition of more relevant codes rendered the existing NVivo data structure obsolete. On two occasions, the researcher proceeded to reinitiate the process of data fracturing and recombining, to allow for new concepts to make more sense within the overall picture. During these processes, the researcher created detailed notes and memos which have been preserved, as the existing literature recommends (Bazeley, 2009a; Morrow & Smith, 1995; Tranfield et al., 2003), details which later proved to be particularly useful in the conceptualising of the findings.

4.4.3.3. Peer debriefing

Early findings have been presented by the author during national, as well as international academic conferences, such as ECAH 2019, ECSEE 2019, ICICTES 2020 and ICICTSD 2020. For the full list of conferences please refer to Appendix M. While earlier presentations assisted the researcher with better establishing the grounds for better framing of the upcoming study and data collection process, the later conferences played a key role in dissemination of early findings and establishing strategies for developing the initial drafts of the discussion and conclusion chapters.

The feedback gathered from the audience at these academic events, as well as the networking opportunities that followed, acted as guidelines for adding further nuances towards the development of this thesis. For instance, contacts that were established with industry professionals offered useful insights in terms of better situating automation technologies within the context of food and energy production. Some participants' previous experience with similar social projects located in community spaces provided additional knowledge about the importance of consulting with future stakeholders before introducing innovations into their life. Also, innovative ideas about recycling of materials and energy have surfaced, as for instance the possible use of heat produced by large enterprises' computer server farms for maintaining a proper climate inside nearby greenhouses, thus prolonging the growing cycles of vegetables. Some of these ideas could potentially be further developed and analysed in future research projects.

4.5. Ethical considerations

According to Weber (1904), 'the very recognition of the existence of a scientific problem coincides, personally, with the possession of specifically oriented motives and values' (p.15). To produce a responsible and ethical result, the researcher acknowledges their more powerful, influential position within the study, and endeavoured to reduce its effects on the outcome of the research (Mertens, 2018; O'Leary, 2004). A series of ethical guidelines have been followed for the duration of conducting this research, as suggested by Mertens (2018): virtue, consequentialism, and deontological. Additionally, aspects related to participants' privacy, confidentiality, and anonymity were strictly observed by the author.

The researcher contacted the Research Ethics Committee (REC) in DCU and sought formal ethical consent to be given to conduct this study. Ethical approval was consequently granted on 28th January 2019 (REC Reference: DCUREC/2018_258), prior to commencing the data collection, and the study was classified as posing a minimal risk to the participants from an ethical perspective – please refer to Appendix N for a copy of the approval.

4.5.1. Privacy

The researcher was aware that, especially during the interviews, people might choose not to mention certain aspects related to their private lives. When they inadvertently mentioned such details however, the researcher took the necessary steps to protect their privacy. All sensitive data was removed during the transcription of the interviews using the NVivo software, to prevent the possible identification of any specific person, event or location.

4.5.2. Confidentiality and anonymity

The participants were assured that all the details provided will be kept confidential on the researcher's private and secured Google Drive provided by DCU, and that only the researcher will be able to access it. Also, during the writing stages, a high level of care was taken not to mention names, places, or settings that may lead to a confidentiality breach. During focus group discussions, great care was taken to avoid situations where confidential data is publicly mentioned on topics that may present discomfort to participants (Corbin & Strauss, 2008; Lofland et al., 2006; Morgan & Hoffman, 2018; Tiidenberg, 2018).

Unique numbers (P1 – P19) were randomly assigned to participants, and these numbers represent the only method of identifying them in the study. The connection between these numbers, the actual locations and participants' names is only known by the researcher. Should, at any stage and for any reason, any participant has requested removal of the data linked to their person, the researcher would have proceeded to do so, as recommended by Tiidenberg (2018).

4.5.3. Informed consent

All participants have been informed about the methods used, benefits of the study to them, and were made aware that they can withdraw from the study at any time, as well as personal details to be changed or removed altogether from any records upon request. Member checks were applied in this study, in the sense that the respondents had the chance of reviewing the notes and reports following their interaction with the study, to ensure that the details are accurate and complete (Mertens, 2018; Roulston & Choi, 2018; Tiidenberg, 2018). A Plain Language Statement (Appendix O) was presented for all potential participants before agreeing to any terms in relation to their involvement in the study.

4.5.4. Data access and location

All qualitative and quantitative data generated for the duration of this study was securely stored on the researcher's private Google Drive account provided by DCU. The researcher used the NVivo software for the transcription of the focus group discussions and interviews, as well as for the subsequent data coding and analysis. The associated data files, along with all memos and notes generated during the research process, were saved onto the researcher's personal home PC hard drive and backed-up on the researcher's Google Drive account provided by DCU. All this data will be permanently and securely removed from all storage locations, three months after the examination takes place.

4.6. Declaration of conflicting interests

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this research.

4.7. Funding

Apart from the stipend provided by DCU, the author received no other financial support, nor have any privileges been advanced during the research, authorship, and/or publication of this study.

5. **Chapter 5 - Discussion of findings and strategies**

This chapter focuses on revealing and offering a rich description of the social implications and behaviour change resulting from the process of exposing several gardening enthusiasts to a foreign, custom-made gardening automation system. Reasons for adoption or rejection of REST are also discussed.

'The system allows me to do more stuff in other parts of the garden in a more efficient way […] I would have never had the amount of plants I have now, if it hadn't been for the fact that I knew I wouldn't have the time and I would neglect them [...] So I'm delighted to have the opportunity to grow stuff in absence, and not worrying about the tech' P4 asserted, while P12 stated the valuable assistance that BGAS offered to them: 'During the summer there was nobody around here. I mean I did come in once a week and check out the place, and everything was fine. Without the windows opening, the irrigation... everything would have died without these. If I did not have this automation in place and everything would have died, I would have felt very disappointed, as everybody else'. Not only people have benefited from the assistance that was offered by the automation system, but also the vegetables grew under better indoor climate conditions, according to indicators in the quantitative stream. Data recorded by Met Éireann (Figure 5.1) reveal the fluctuation of the outdoor temperature in Dublin over a time frame similar to that of the data collection phase that was employed in this research. For comparison, Figure 5.2 shows the data that have been generated following the deployment of the automation gardening system. There is unambiguous evidence that, from a practical perspective, the implementation of the bespoke technology represented a considerable addition by way of promoting less fluctuating climate conditions for the plants, which in turn resulted in an increased yield overall. This aspect was remarked upon and acknowledged by all the participants.

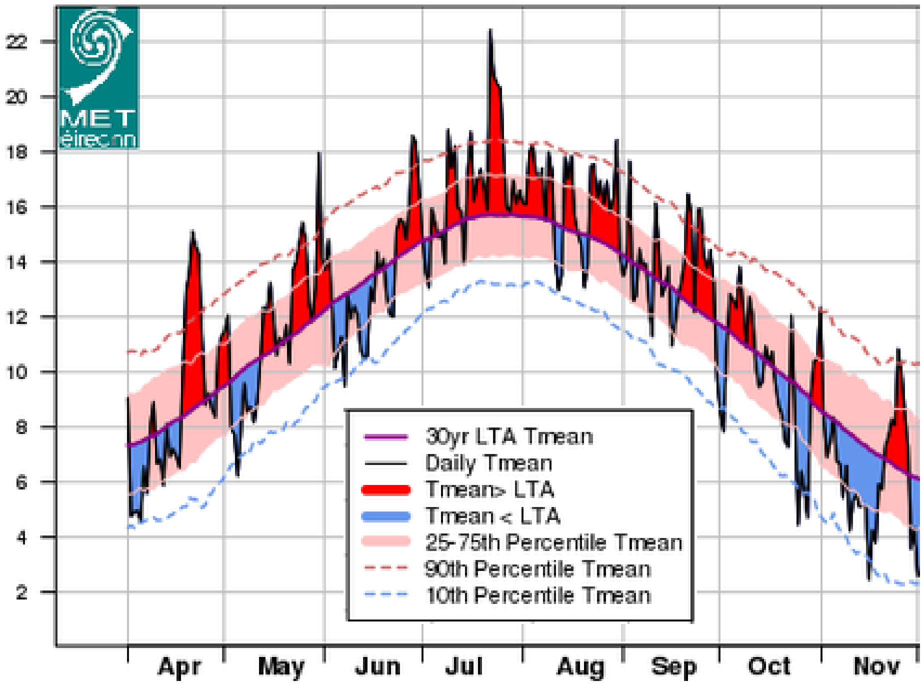

Figure 5.1 – Outside temperature data (Centigrade) recorded by Met Éireann in Phoenix Park, Dublin during the period between April 2019 and November 2019. Source: (MET ÉIREANN, 2020)

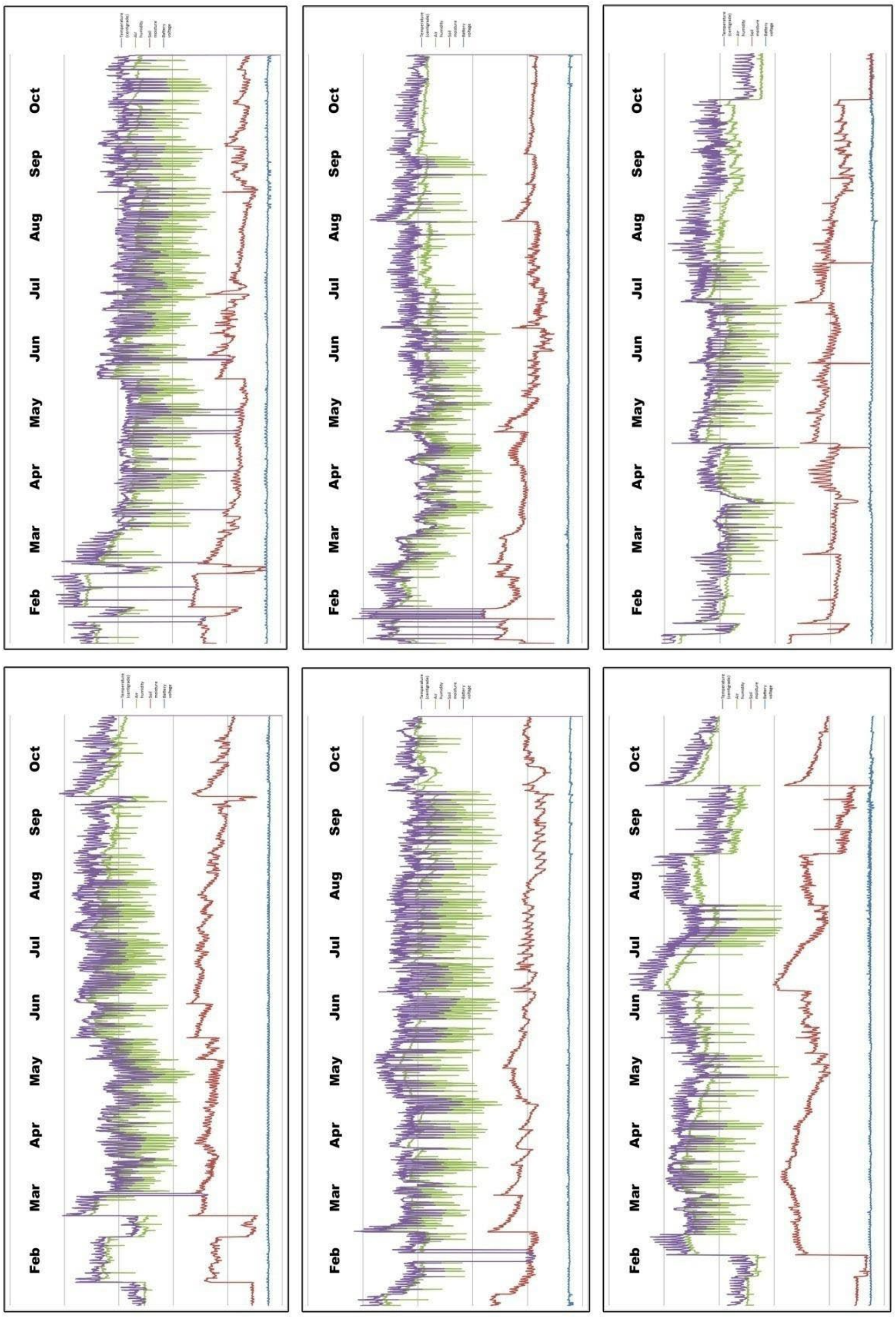

Figure 5.2 – The overall conditions inside the six enclosures for the whole duration of the quantitative data collection period. Air temperature is represented in violet colour. Source: Hamilton V. Niculescu, via https://thingspeak.com

By analysing the quantitative data that was gathered during the whole duration of nine months (Appendix P) it was possible to draw a picture of the participants' level of engagement and interaction with the remote systems (as illustrated in Figure 5.3), and also useful details related to the systems' functionality were also revealed, some of which have had an influence on the uptake of their stakeholders, as voiced during the interviews. For instance, the uptime of the systems varied across the six locations due to several factors:

- The low insolation factor in Ireland (please refer to Appendix Q for detailed information), combined with the particular positioning of each research location meant that on occasions, the available voltage provided by the battery pack reached lower than usual levels, leading to the systems being temporarily switched off automatically.

- As the communication with the online server was dependent on a GPRS connection, it meant that at times, some locations experienced low or lack of signal, with the participants not being able to interact with those individual automated gardening systems. Logs that have been sent by the participants were checked against the quantitative data to confirm (or otherwise disprove) this fact, allowing the researcher to take corrective measures when these were required.

- Due to various equipment faults that developed at some research locations, it meant that some systems were switched off at times, until the faults were addressed by the researcher. These intervals are clearly identified in the quantitative data and these aspects were considered during the follow-up interviews.

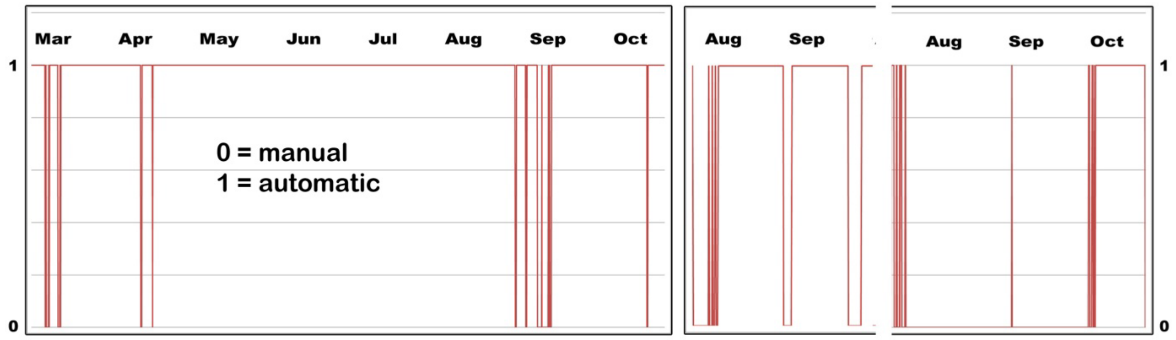

Figure 5.3 – Participants' interaction patterns as revealed by quantitative data. Source: Hamilton V. Niculescu via https://thingspeak.com

5.1. Education and skills

Before analysing the participants' reasons for acceptance or rejection of BGAS and REST, their generic profile will be constructed based on the available observations and interview data. This aims to assist with more accurately placing their actions in the context of their own cultural, social, and financial status.

In addition to lack of access to equipment (computer, smartphone, etc.) as well as the reduced amount of information held about innovations, individuals' education level and income play a key role in enlarging the digital divide gap. By remaining locked-in with obsolete devices, people are at risk of becoming socially isolated due to their lack of access to communication technologies, which in recent years witnessed a gradual translation to online platforms. The ever-growing digital divide gap (Chetty et al., 2018) mitigates the exchange of knowledge between generations mainly in a one-way direction: from the younger towards the older population (Age Action, 2018, 2020; CARDI, 2013; Citizens Information Centre, 2019; Hardill, 2013; Lloyd et al., 2016; Silverstone, 2003).

Some participants did not identify themselves as being on the leading-edge regarding technology, with P2 expressing: 'This smartphone I got for Christmas, this is new technology for me [...] I don't have other devices, I am an old-timer, I'm a bit of a dinosaur when it comes to technology'. Reinforcing the idea that not every new feature built into innovations are necessarily perceived as useful, while speaking about their mobile phone P8 declared that 'this one I got last year. It's adequate for my needs. I still don't know all the functions, so I don't keep up to date, I don't feel the need to keep up to date'. Familiarity with older technologies and the fear that innovations may change people's lifestyle patterns, acting as an excuse and a deterrent factor for upgrading. P2 expressed their 'loyalty' to already owned devices by stating that 'unless I have an absolute necessity for it, no, I'm not into buying new tech'. In addition, participants over fifty-six years of age (four individuals) reported that complex functionalities were a hindrance to adopting innovative technologies, often viewing the addition of extra features as either useless or confusing. P4 complained that 'they rely on too many sensors, too many electronics. Now we don't even know how they work'.

One possible approach aimed at encouraging people into engaging and ultimately adopting innovative technologies would be getting them involved in the co-creation process for such innovations. This method has been employed by the researcher in the present study, and the potential participants have been consulted with in terms of future development of the bespoke gardening system. Feedback and suggestions gathered during the initial contact, focus group discussions and qualitative interviews were considered during the process of updating and refining the functionality of both *My Garden EyeDuino* app, as well as the features offered by the physical enclosures. 'Every time you start the app you have to press "Agree", and that was tiresome. I thought that I agreed once and that would be it, why is it asking me again? So that was annoying', P3 signalled during the second interview. Further, P12 hinted that 'if you showed them the app, it's just words and numbers. What gets people is the moving windows, it's visual', referring to the fact that the app's interface could be improved. The development of specific, highly targeted technologies, with an appropriate complexity level, may trigger the future stakeholders to perceive their real relative advantage more accurately, and to eventually include them into their lifestyle, as the literature also provides (e.g., Jensen et al., 2007; Tate et al., 2012; Tranter et al., 2011; Vasseur & Kemp, 2015b; Willis et al., 2011). Consequently, the findings reveal that this co-creation approach proved to be beneficial, ensuring an increased interest and engagement with the discrete, bespoke technology employed in this research, by both the young and older participants. The validity of this approach is further reinforced by findings of studies where people's interaction with off-the-shelf, less targeted technologies has been investigated, in which case the engagement level of the participants was notably lower (e.g., Guo et al., 2017; Harvey et al., 2019; D. Taylor & Packham, 2016b).

Further, people's views and interpretation of technologies can be directly linked to their cultural background and education attainment. Lack of accurate information and low education levels, as well as barriers represented by technological and computer literacy skills, play a significant role in adoption of innovations, as it has also been noticed by previous authors (e.g., Bucci et al., 2019; Claudy et al., 2013; Kruse et al., 2016; Saka et al., 2017; Tranter et al., 2011). For example, P4 mentioned about their fear that 'sometimes, when you're trying to get your head around, making a mistake by, let's say installing something, or that you might delete something, or upset something else on the computer...'. Furthermore, P9 added that 'if something goes wrong with the computer and I have to do something outside of my ordinary things to fix it, I'd be really frustrated, I don't want to do it ', and P12 declared that 'I'm not a technical savvy person, I can barely use a computer, I never trust technology, I get frustrated when I try using my phone to order something online'.

According to the census data collected by the Central Statistics Office (CSO) in 2016, the education level in Ireland could be averaged between 'lower secondary' and 'third level non degree' (CSO, 2016), and the summary based on the age of population is represented in Figure 5.4. Follow-up data released in 2019 reported similar findings (CSO, 2019a). The interviews and observations data made the researcher conclude that, except for several people, the education level of the participants that were involved in this study would closely follow the above findings.

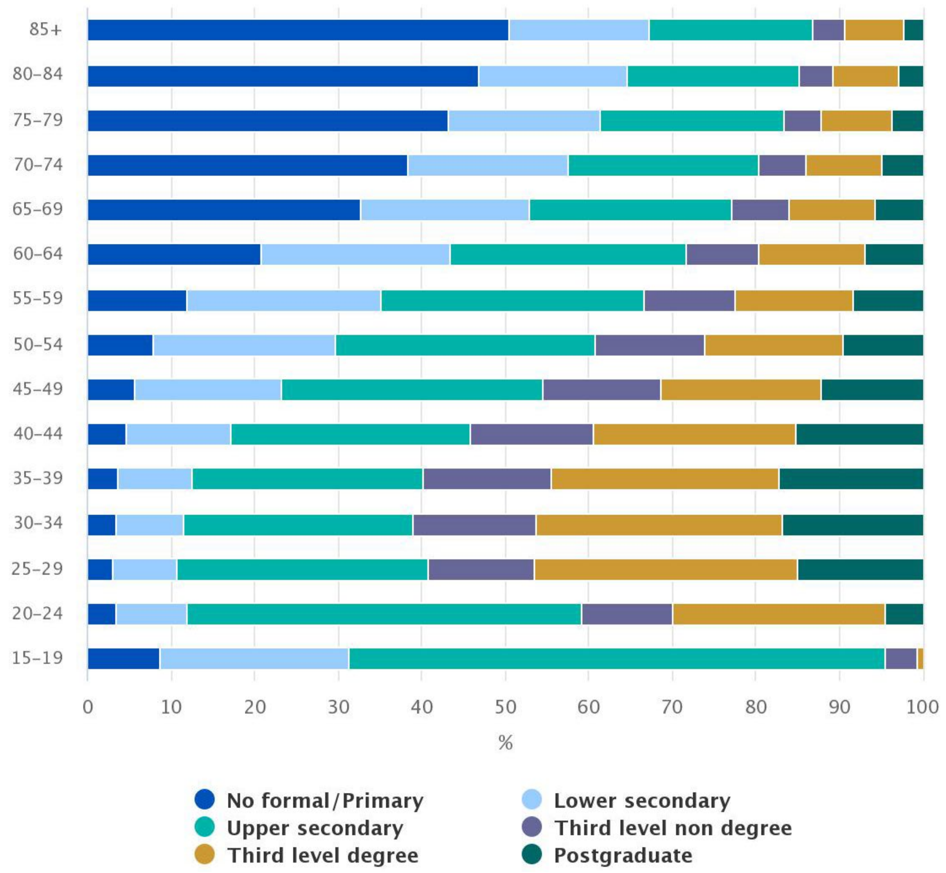

Figure 5.4 – Highest level of education by five-year age groups, 2016. Source: (CSO, 2016)

Moreover, beyond formal educational attainment, some participants acknowledged that they hold limited information and skills related to technology. P2 confessed that 'my education isn't the best, so... I wish I had the knowledge to do that. Using wind turbines, or solar panels... my brain isn't quick enough. I'm an old person', while P11 admitted to not possessing enough knowledge about different energy source types: 'I know some sources are renewable, and others are not, but I don't really know'. Terms that generally imply broader themes have been associated by many participants with only a limited range of objects or actions. For instance, energy is mainly identified as 'electricity to power things' (P5), while technology largely relates to mobile phones. Data released by CSO in 2018 reveal that the younger Irish population is generally more active in terms of interacting with their mobile devices and are more technologically inclined, when compared to older adults (CSO, 2018). The author is aware that due to the Covid19 pandemic, with more people moving their general activities to online platforms, the latest figures may present significant changes; however, statistics used here from 2018 closer match the figures that are more relevant to the data collection phase of this study. To this end, it is argued that the relationship between education and age represents another main determinant for people understanding and being able to acquire the abilities to operate new devices. This was observed during this study, with older adults being less informed about existing innovations and alternative options in terms of energy production and consumption when compared to the younger population. A report published by OECD (2019) claiming that the 'take up of new technologies, particularly digital technologies, depends on the educational levels of the population' (p.60) supports these findings.

5.2. Financial status and misinformation about REST

The penetration of technologies into societies is directly influenced by people's financial status (OECD, 2019). Participants in this study come from the Irish working-class, and a few clearly indicated their financial instability. Following the interviews, the researcher deducted that in addition to other barriers, the lack of available capital is influencing major decisions related to repairing, replacing, and acquiring of technology within their household, confirming findings of previous similar studies (e.g., Claudy et al., 2013, 2015; Eltawil & Zhao, 2010; G, Akinboro F., 2012; M. A. Khan & Latif, 2010; Mirza et al., 2009; Pasqualetti, 2011). 'There is always a second life to something else, anything can be reused, modified... instead of throwing it away', P10 stated, while P1 indicated that 'we eat everything we put on the table. We do not throw anything, because that food costs money and time'.

Lack of clear policies and official information provided by the State in relation to innovations and emerging technologies may act as a mediating factor for the exchange of information amongst population (Darko & Chan, 2017; Powell & Colin, 2008; Selwyn, 2004). While this communication model proved to be efficient with exchanging useful information about the BGAS, as it will be discussed shortly, in this particular scenario it appears to not have been the best approach. Non-official sources, such as word of mouth from friends and relatives, and sometimes resorting to social media networks, meant that in some cases the participants have formed an inaccurate picture related to specific topics, such as the cost or performance of renewable energy sources. This aspect contrasts with propositions advanced by Sauter and Watson (2007) who advise that information acquired from peers and social media may prove to be in fact more reliable than that obtained from official sources.

As a result, PV solar panels and REST are considered by the participants as being too expensive, although during the interviews only a few of them have been able to produce some approximate figures related to their installation and maintenance costs. It can be noted that those participants who own their house (five out of nineteen) proved to have done more informed research on REST in the previous five to ten years and concluded that they are too expensive for them to afford to avail of it. 'I'd love to have solar panels, but I think it's too expensive too. How long it would take for the system to repay the investment, it takes over ten years to get your money back. That was the case a while back when we looked at it', P10 mentioned. However, no follow-up research was done in the more recent times, in an apparent disregard of the fast pace at which technologies progress.

Other reasons for not considering the available sustainable sources are based on more or less accurate accounts. For instance, some participants expressed their disappointment that due to their house location (e.g., flat located in the city centre), or the fact that they are renting, prevents them from even considering the installation of REST. 'There's a block of flats not far from this way, they've put solar panels up onto the roofs, and I'd love if they could do that into our own flats' P3 said, demonstrating their willingness to trial alternative technologies, while P5 expressed their doubts due to location constraints: 'sometimes you can't have them because of the angle of the house'. However, other participants mentioned less accurate facts: 'I don't know enough about solar panels, but I imagine that in Ireland it would be hard. I could be wrong, but I have this idea that a wind turbine would be a better option in Ireland', P9 stated, while P1 concluded that 'Another problem is that batteries emit radiation from which you can get sick quickly, and they need to be improved'.

The researcher remarked that for the duration of the interviews those participants who proved to be more knowledgeable about REST mentioned 'lack of support' and 'return of the investment' more often, while the rest of the participants commonly made references to 'efficiency', 'reliability', and 'available power'. By 'lack of support' participants mainly referred to the financial burden that installation of REST would pose on their household income, arguing that it may take a long time for these innovations to level out from a financial perspective, rendering their acquisition as not profitable. Participants live 'day-by-day', and thus their social and financial status would be incompatible with the acquiring of this kind of innovations without proper external financial support. This confirms previous findings that the wealthier are more likely to adopt innovations (M. G. Smith & Urpelainen, 2014a), and the more expensive (switching to) some specific technology is perceived as being, the more chances of it being rejected or disregarded (Enevoldsen & Sovacool, 2016; Salmela & Varho, 2006).

Notwithstanding participants' lack of accurate details of the price or the way REST produce energy, they proved to possess enough information allowing them to question their efficiency, such as house location and orientation, or the reduced insolation factor in Ireland. This diverges from findings of studies claiming that in general people are missing this sort of knowledge (Hopf et al., 2017; Paravantis et al., 2018). The participants, therefore, proved to hold a mix of accurate and less accurate details, which allowed them to form opinions which may not always reflect the reality, a situation also observed by Akinboro (2012) and Saka et al. 2017).

5.3. Intent and behaviour in resources sustainability

The initial and further minimal maintenance costs represent therefore the main factors that drive the participants' intention to acquire innovative technologies, in this case renewable solutions in the form of PV solar panels. All of those involved in this study demonstrated a high level of awareness of the finite amount of the natural resources that our planet can provide, and mentioned their sustained efforts aimed at tackling it, in accordance with the facilities and low resources that they have at their disposal. However, as Maslow's hierarchy suggests, the needs located at lower levels are prioritised, represented in this case by their working-class status, financial instability, and self-sustaining instincts. In most cases, these factors override individuals' environmental beliefs, morals and attitudes, as also previous studies have remarked (e.g., W. Berger, 2001; Palm & Tengvard, 2011; Qureshi et al., 2017; Vasseur & Kemp, 2015b).

Ozaki (2011) remarked that 'People are capable of being contradictory or hypocritical' (p.13), and this statement is supported by the contrast displayed by a participant during a heated focus group discussion on the topic of sustainability, and the signed agreement form which was returned at the end of the section indicating different thoughts – please refer to Appendix R for details. The researcher found that even those participants claiming to be very pro-environmentally inclined, hinted that without receiving substantial incentives and certainty, they would be reluctant to switch to an alternative lifestyle that would put less pressure on natural resources. P13 has stressed that 'I suppose I would switch, if it saves money. I'd have to find more information about what those changes would imply'. Further, P4 mentioned that 'we just live day to day [...] even with the available grants... unless you have the money to get the grant...', referring to their initial desire to switch to more sustainable energy sources, only to be forced to abandon the idea due to the fact they were unable to produce the required initial investment. On occasions, the participants demonstrated to not have a faithful representation of the implications and consequences that adopting more sustainable lifestyles would pose on their current agenda and activities, such as the need to reschedule their regular activities. For instance, doing laundry or cooking at other times would be required to fully benefit from the technology. The participants agreed that it may not be a straightforward process, but that it would be something they would still be inclined to do 'as long as there are little changes and they are not hard to do, and if they're becoming your habit' (P5).

'The challenge for those wishing to promote green electricity [...] is how to fill the gap between intentions and actual behaviour' (Ozaki, 2011, p.13). Therefore, the deployment of the BGAS, powered by 'green' electricity, represented a new experimental method intended to expose participants to both familiar and innovative technologies. Their already existing gardening practices have been complemented by assistive technologies which are not only innovative, but also relevant to their routines and lifestyle. The artefact that was specifically built for this research consisted of the garden automation system, while the REST in form of PV solar panels and accessories represented the ubiquitous technology that was being subtly introduced along with it. The intention was to build trust with the automation technology around the garden, which people may find as being useful, along with the introduction of some 'foreign' technology that they would eventually accept as being part of the system and potentially becoming interested in finding more information about it. In many instances, REST are 'quiet' technologies and do not always provide feedback to prove that they are 'working hard', resulting in their dismissal, with people labelling them as not functioning and unreliable. By displaying dynamic figures within *My Garden EyeDuino* mobile app – such as battery voltage, climate conditions and automatic shutdown options – the researcher aimed at fulfilling the participants' desire for feedback, proving that the system is continuously performing some relevant tasks, offering them with the 'labor illusion', as Buell & Norton (2011) suggest. The 'attitude-behaviour gap' could be reduced in this specific scenario by promoting REST in settings that are relevant, discrete, and make sense to the participants.

During preliminary stages of this research, some coordinators and members of community gardens suggested other potential research locations that may fit the purpose of the project and be interested in having similar systems installed on their property. This reinforces the knowledge about the existence of the 'reverse NIMBY' behaviour in the Republic of Ireland as noted by Warren et al. (2005), and can be directly linked to observations made by the author of this study in relation to participants' inclination to show-off their material and social status to other members of society.

In addition to earlier observations of the participants' financial status driving their intentions to acquire REST, there is also compelling evidence that (non-)adoption of innovations was also largely influenced and accelerated by the personal experience and attitude towards it displayed by their peers, also remarked in the literature (e.g., Mergel & Bretschneider, 2013; Murtagh et al., 2015; Nolan et al., 2008; Oster & Thornton, 2012; Rai et al., 2016). As P12 stated, 'I see the windmills, and people complaining about it. They don't like them because they are not pretty. In parts of the country they have campaigns and posters against it. I think it's ridiculous. They're missing the bigger picture'. In contrast, P4 voiced their concern about the environmental impact of REST 'cause basically they don't last, they take huge resources, and cost a fortune [...] Wind turbines also use heavy metals that environmentally are a disaster. Yeah, the average life of a wind turbine is just thirty years, and then it gets put into the landfill'. Instead, P9 mentioned that 'it's something I'd love to have: a house that was solar powered. I would be asking how it works with the Irish weather, I'd be curious'. These statements support Nolan's et al. (2008) theory of normative influence, which provides that social influence and pressure from peers may result in people changing or adjusting their behaviour no longer simply based on moral intentions such as 'protecting the environment, being socially responsible, or even saving money' (p.921), but also on personal circumstances and information acquired from peers.

5.4. Inter-generational exchange of information

Being a long-time gardener does not always guarantee having solid knowledge in terms of optimal figures related to temperature, humidity, soil moisture or other indicators required for the plants to thrive. This prompted the participants to engage and communicate not with the researcher alone, but also with other community gardens members. Despite *My Garden EyeDuino* mobile phone app employing a minimalistic design, the participants mentioned their need for additional support that they required from friends and family in relation to using its features. As Taylor et al. (2018) suggest, people are motivated to work together to find a practical solution to achieving some common goal. This was clearly evidenced for the whole duration of the data collection for this study, with participants and other members of the community gardens exchanging ideas and helping each other.

In contrast, a different behaviour took place at the research location where people pay an annual membership fee. Those 'negative cases', as they would be described in the GT literature (e.g., Brinkmann, 2013; N. K. Denzin & Strauss, 2003; Glaser & Strauss, 1967, 1999; Harper, 2013), provided a good foil for the main direction of the findings. The participants at this location lacked the motivation which has been demonstrated on the other research sites, resulting not only in a low engagement with the BGAS, but also in a low communication level with other fellow gardeners. Furthermore, attempts at organising a focus group discussion to take place at the negative location proved to be an impossible task, as those members rarely know and communicate with each other.

Another possible interpretation is that community gardens are created with the intention to provide the somehow more 'disadvantaged' people with access to various tasks on a voluntary basis, while private, paid for membership locations are intended for more affluent members of society. 'Man is a social animal' (Mcfadden, 2013, p.29) and therefore, communicating and exchanging ideas and opinions play a significant role in our society. Non-competitive environments, such as the 'negative' research location in this study, indicate to have led more affluent people to disregard or reject performing any activities or tasks that could potentially disrupt their lifestyle and status-quo.

While all participants showed a high interest in the automation and technology provided in this study, the researcher noted that older people required a more extensive initial training period, a fact also provided by Marcelino at al. (2015). The extra support needed from the researcher mainly related to offering detailed explanations in relation to their expected interaction with *My Garden EyeDuino* app, to properly understand how its functionality relates to the physical devices of the enclosure. The older participants confessed that they initially feared that using the mobile phone to control the automation system would be too complex to them 'because you are relying on technology, and you're hoping that technology is going to do what is doing to you [...] That I won't be able to use it, that it's going to be too complicated […] and then I find it was unnecessary' (P2).

The quantitative data indicates a higher level of early interaction with the BGAS in the case of the younger participants. However, once the logical connection between the mobile app and the physical devices was comprehended, the researcher noted that the overall level of interaction with *My Garden EyeDuino* app changed, in the sense that the older participants became more engaged and active. As P17 noted: 'Very simple. You can go into the settings and change anything you want if you want to'. In effect, as another participant added, this resulted in them learning new skills and acquiring new knowledge about both technologies, as well as about growing vegetables: 'I could have never grown vegetables without help from these technologies, not a chance. The app does everything for you [...] It was brilliant, totally different, and understood better the solar technology, and just how to grow vegetables, for I've never done that before' (P7).

While the younger participants in this study demonstrated to have a higher education attainment level and better skilled at using their smartphone, which is in line with observations made by the CSO (2019a), they lacked the specific required practical gardening skills involved in the setting of this research. Peer support provided by the older adults to the younger participants addressed these gaps in knowledge regarding gardening, more specifically those figures related to the soil moisture, air humidity and temperature. If this support were missing, the younger participants' engagement with the gardening automation system would have potentially been lower, due to their lack of understanding of how their ICT knowledge translates to some practical skills.

This confirms findings from previous studies arguing that higher education levels do not always guarantee a higher adoption rate for new technologies (Abrahams, 2010; M. G. Smith & Urpelainen, 2014a), with missing pieces of information representing barriers against experiencing the full potential of innovations in case of both the young and older stakeholders. This study therefore upholds that while the population's education level plays an important part, it is also the creation of proper inter-generational communication channels that would have a noticeable effect on the increase of the levels of engagement and adoption of bespoke innovations by the larger population, and not only by some specific age ranges. The two-way flow of information and inter-generational learning employed in this research ensured that essential information was passed between generations, addressing knowledge gaps for the younger as well as for the older generations. This approach not only considers the digital divide, particularly specific to older generations, by creating a traditional one-way communication channel as evidenced by the literature (e.g., Age Action, 2018, 2020; CARDI, 2013; Citizens Information Centre, 2019; Hardill, 2013; Lloyd et al., 2016; Roger Silverstone, 2003), but also mitigates the transfer of relevant information towards younger individuals that might be more technically savvy, yet are lacking practical skills. This fact has proved to be especially relevant to the setting of this study, encompassing both technology and wider areas of knowledge, such as gardening and horticulture. Extant knowledge confirms that to advance engagement and access to innovations is not just a matter of simply designing with specific age groups in mind, but rather to facilitate the transfer of skills and knowledge between these generations of people (e.g., V. S. Katz et al., 2018; OECD, 2016; Roberts, 2010; Sourbati, 2009; Dan Taylor & Packham, 2016).

Depending on the participants' previous gardening experience and knowledge, different behaviours were recorded on each individual location, arguably confirming Hill's (1988) and Winner's (1989) assertions that it is not the technology that matters most, but the social system that it is deployed into plays a key role. It was not the technology itself that constituted the main subject for the participants' social interactions, but how to properly avail of the available automation features to better care for the plants growing inside the enclosures. However, all participants admitted that they would not find it easy to describe to other people how the BGAS works overall. Also, should anything stop working as intended, they would have no knowledge on how to address and fix any arising technical issues. As P12 explains, 'you know we have had the problem with the irrigation, which has happened three or four times [...] you've fixed it, but for the future when you'll be gone, I basically don't know what I'm doing'. Most participants admitted to having no knowledge about how the electricity is produced and used to power the automated system, even though they noticed the presence of the PV solar panels on site. Even those participants, who previously proved to be more informed than the others in terms of technology, somehow indicated lacking practical skills in this regard.

5.5. Ownership of technology

The BGAS was offered as a 'gift' to participants, and the researcher noticed that they quickly became familiar with it, although not necessarily completely understanding the intricacies of their built-in functionalities. They proudly assumed the role of 'owners' of such innovations by demonstrating and explaining to other people how the technology performed. Ownership was therefore revealed as playing another significant role in people engaging and adopting innovations, as also revealed by similar previous studies (Enevoldsen & Sovacool, 2016; Koch & Christ, 2017; N. Taylor et al., 2018). This desire might be fuelled by the participants' socio-economic background, whose objective is to eventually reduce their costs and save money, while keeping with their current lifestyles if possible. The financial risk was missing from this context, and many participants agreed that they liked being in control of the BGAS, with P12 declaring that 'you have control over it, telling it what to do and when', while P6 reinforced this statement: 'It's like having your own personal remote, nobody has that app, and you can control the system'.

The researcher noted, however, that the participants did not assign a monetary value to the automated systems, but the practical assistance that it offered to them was emphasised during the discussions. P3 declared that 'I enjoyed having thinking when I'm actually at home or at work, and I can still do things in the garden. That was a brilliant feeling', and P8 admitted that they appreciated 'the way I feel empowered that I can grow some of my own food, the same I would feel empowered that I can produce some of my energy'.

In contrast with the rest of the participants, one negative case (P1) openly admitted that since they have been aware of the situation where they would only be in control of the technology for a limited period (three months), and not actually owning that technology, acted as a barrier towards their interaction with the system. It is worth noting however that this participant eventually requested to have a similar system installed in their own allotment, which has been recently acquired. The subsequent available quantitative data, gathered with the participant's consent, indicate the adoption of a different behaviour and engagement, comparable to data collected from the other five research locations. During the second interview, P1 declared that 'with my greenhouse... it's not like yours. With yours I had no... That is mine. This is what motivates me. There should have been something to motivate me. By not being a location where you can stay for longer, which you would own, to be in control of'.

Therefore, the limited time frame had a detrimental effect on the participants' engagement with the BGAS. Knowing that they will eventually have to relinquish the control over it to the next participant, their initial excitement and interest in the system slowly faded away with time. This confirms Woodward's (2007) stance in relation to material culture, maintaining that people attach personal meaning to objects to better identify with it, and as such mediating the process of building up their personality and self-esteem. When the control over that specific object is taken away from them, people experience it as losing part of their identity, rather than objecting to the monetary loss. P2 joked about this scenario, stating that 'I missed the best part of it, because [*next participant's name*] is getting the next three months, and they'll be watching the fruits grow... they are not getting the keys [*laughing*]. I have troubles with handing power over to [*next participant's name*], there might be a small fight over the key [*laughing*]'.

A further reinforcement of this idea is participants' mention of their personal enjoyment of demonstrating their ownership of technology to their friends and family, by remotely controlling the system's automation via *My Garden EyeDuino* mobile phone app. 'I showed it to my brother. And he didn't believe I could open the windows from my phone. And when he actually saw it working, he was surprised', P6 declared, and also P4 confessed that 'checking the phone app was to show people in the Botanics that this was going on. It was for showing-off that we were chosen, and also that it was a very clever thing to have'.

Most participants indicated that they were constantly waiting for someone else to overview and approve their actions while interacting with the automation gardening system. This need for acknowledgement and instant gratification was more evidently demonstrated by the six younger participants, belonging to a disadvantaged background, and enrolled in some special training programmes developed by the Irish Government aimed at unemployed and unqualified early school leavers (CDETB, 2021). Their experience of interacting with the system has been different from that of the rest of the participants, in the sense that they reported missing the support and feedback from their family and friends regarding their recent activity. While their interaction with the mobile phone was socially acceptable, new activities such as gardening related tasks or remotely controlling technical devices were regarded as affecting the status quo of their community. As Rogers (1995) notes, 'an innovation's compatibility with cultural values can block its adoption [...] Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters' (p.241, 254). However, despite these unfavourable circumstances, the quantitative data revealed a higher-than-average remote interaction with the automation system in the cases of the younger participants, as Figure 5.5 illustrates. It can be concluded that those participants' desire to show-off with their recent activity and skills superseded the lack of support and social pressure which they have experienced.

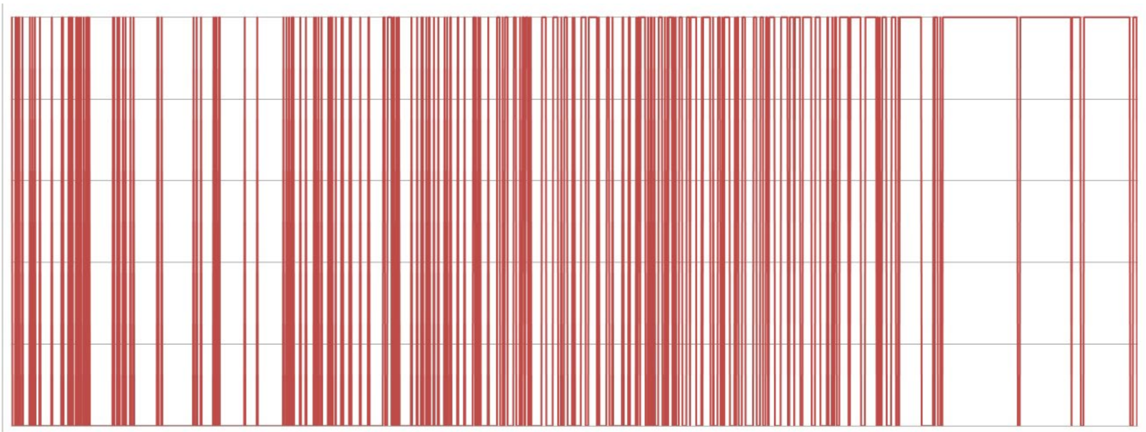

Figure 5.5 – High level of communication with the remote system, indicated by the number of vertical lines indicating the system being switched between the two working modes, automatic and manual. Source: Hamilton V. Niculescu via https://thingspeak.com

Even though not socially accepted, the younger participants interpreted this bespoke automation gardening system as a way of technically detaching from the other peers, demonstrating their superiority, and having access to technologies that are largely not available to other users. Thus, it can be concluded that adoption of innovations may sometimes be dictated solely by their social acceptance of local communities, with niche and highly targeted innovations having a higher chance of motivating people to adopt it and break any mutually accepted cultural rules. Slow but steady exposure of other community members to meaningful innovations may prevent them from remaining 'locked-in' with old and sometimes incompatible technologies, avoiding any innovation inertia (The Government Office for Science, 2008).

5.6. Interaction with the BGAS and mobile app

During the first set of interviews, it was learned that, in general, the participants have a dismissive attitude towards household smart technologies. As a result, they prefer to manually control the built-in features rather than allowing them to perform in the automatic mode. P3 revealed that 'we would set them manually, because setting them on auto is actually costing money', suggesting that smart devices' built-in programmes and functionalities are not always found to be suited for their users' expectations. It can also be argued that people's lack of proper understanding of how these technologies work, combined with their fear of potential monetary loss, result in a lack of trust in innovations. As previously discussed, the participants' behaviour may be influenced by their moral desire of becoming more sustainable, but it is ultimately mainly driven by their financial insecurity.

This insight is further reinforced by the behaviour exhibited by the participants during their interaction with the bespoke gardening system, in the sense that they chose to allow it to perform in automatic mode for extended periods of time, especially during periods of time when adverse weather conditions meant that there was no urgency to interact with the BGAS (Figure 5.6). As the participants did not discern any potential monetary loss in this case, they preferred to save time and conserve their body energy instead as Richter (2013) suggests, by not assuming manual control of the automation system as they would normally do in their household. A higher trust in technology has been therefore mitigated by the fact that their action (or indeed, inaction) would have not resulted in any negative consequences with immediate effect on their financial stability.

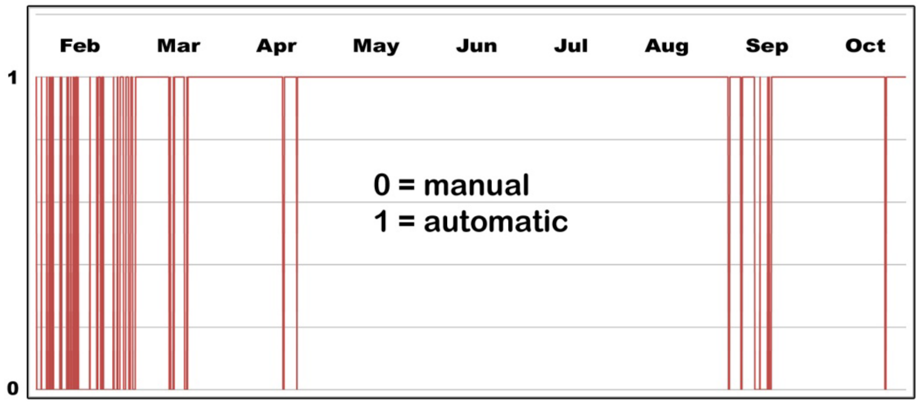

Figure 5.6 – Long periods of time when the BGAS was left to operate in the automatic mode. Source: Hamilton V. Niculescu via https://thingspeak.com

On occasions, when the participants sent logs via the mobile phone app reporting some events, sometimes the observations made by the researcher on the grounds of the associated research sites revealed contradicting situations. For instance, P2 reported that 'Big tomatoes doing well', yet the same day the researcher arrived at that specific location and noticed a completely different picture, as seen in Figure 5.7. When asked about this during the second stage interview, the participant maintained that in fact the tomato plants were doing well at their own house, ready to be transplanted inside the enclosure later.

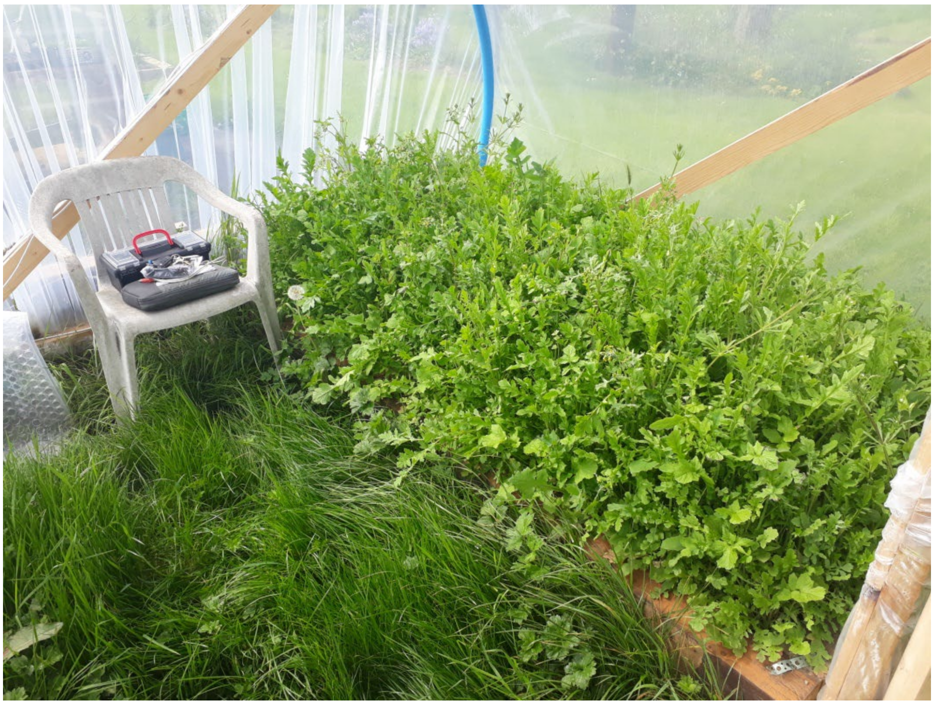

Figure 5.7 – 'Big tomatoes doing well' (P2). Image captured the same day on that particular research location. Source: Hamilton V. Niculescu

Both the qualitative and quantitative data reveal that those more informed participants have performed more consistent adjustments using the settings implemented in *My Garden EyeDuino* mobile app, thus demonstrating a better understanding of what those features were intended for. In contrast, the data for the other participants indicate that adjustments have been done following a process resembling more of a 'trial and error' approach. One reasonable account would be to assume that, as previously mentioned, being a gardener does not necessarily imply having solid knowledge about various figures related to the optimal growing conditions for vegetables. These situations reveal the fact that making use of even apparently minimalistic technology solutions could prove a challenging task if there are missing pieces of information regarding their intended application. The quantitative data clearly indicates that most of the interactions with the remote systems consisted of merely starting the app, without taking any further meaningful actions, or sometimes simply changing the system's working mode from automatic to manual and back (Figure 5.8).

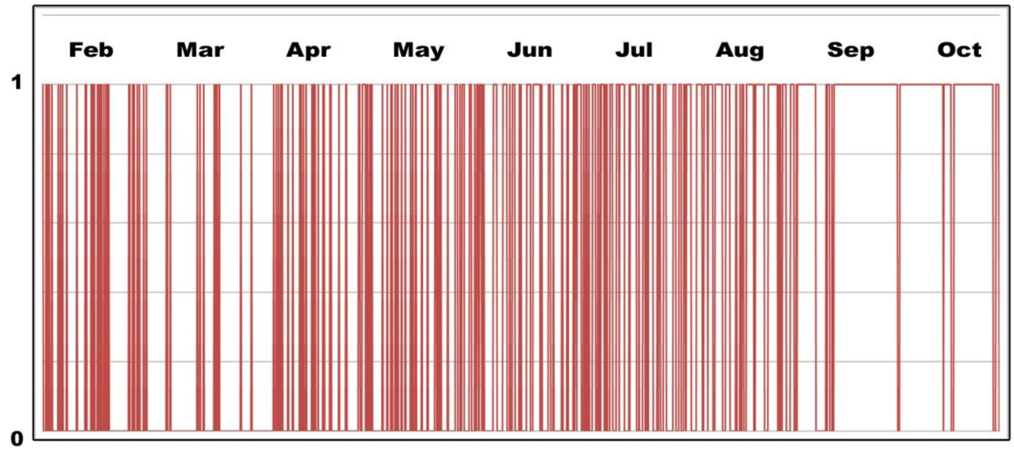

Figure 5.8 – Higher than average interaction with the BGAS. Source: Hamilton V. Niculescu via https://thingspeak.com

This supports earlier suggestions that, after the initial excitement and interest wore out, the participants were either showing-off their ownership to others, or simply checking the systems' status and climate conditions, without performing any other meaningful manual gardening tasks, allowing the system to do so (Figure 5.9 and Figure 5.10).

Control channel

created_at	entry_id	field1	field2	field3	field4	field5	field6
2019-06-01 11:00:55 UTC	4563	56	80	25	5301035	635	1
2019-06-01 13:24:21 UTC	4564	56	80	25	6011423	635	0
2019-06-01 13:28:33 UTC	4565	56	80	25	6011555	635	1

Field 6 in the Control channel indicates the system working mode changing between automatic (1) and manual (0), as triggered by the participant via the *Garden EyeDuino* mobile app.

Fields 5, 6, and 8 in the Data channel indicate the current status for the irrigation, ventilation fan, and windows - off/closed (0) and on/open (1).

For the entire duration of the system being under manual working mode (as indicated by the Control channel), there are no changes in the corresponding figures in the Data channel.

Data channel

created_at	entry_id	field1	field2	field3	field4	field5	field6	field7	field8
2019-06-01 13:24:18 UTC	501699	13.1	6011422	65	0	74	0	23	0
2019-06-01 13:24:50 UTC	501700	13.1	6011424	65	0	74	0	23	0
2019-06-01 13:25:09 UTC	501701	13	6011425	65	0	72	0	23	0
2019-06-01 13:25:37 UTC	501702	13.2	6011425	65	0	73	0	23	0
2019-06-01 13:25:57 UTC	501703	13.1	6011425	65	0	74	0	23	0
2019-06-01 13:26:17 UTC	501704	13.1	6011426	65	0	76	0	23	0
2019-06-01 13:26:38 UTC	501705	13.1	6011426	65	0	75	0	23	0
2019-06-01 13:27:05 UTC	501706	13.1	6011427	65	0	76	0	23	0
2019-06-01 13:27:33 UTC	501707	13.1	6011427	65	0	76	0	23	0
2019-06-01 13:27:51 UTC	501708	13.1	6011427	65	0	75	0	23	0
2019-06-01 13:28:12 UTC	501709	13.1	6011428	65	0	77	0	23	0
2019-06-01 13:28:47 UTC	501710	13.2	6011428	65	0	76	0	23	0

(The quantitative Control and Data channel were downloaded as .CSV files from https://thingspeak.com/)

2019-09-13 22:01:48 UTC	5070	46	80	26	9131702	590	1
2019-09-14 10:54:56 UTC	5071	46	80	26	9141154	590	0
2019-09-14 10:55:36 UTC	5072	46	80	26	9141155	590	1

2019-09-14 10:54:39 UTC	816344	13	9141154	41	0	99	1	21	0
2019-09-14 10:55:03 UTC	816345	12.8	9141155	40	0	99	1	21	0
2019-09-14 10:55:28 UTC	816346	12.6	9141155	40	0	99	1	21	0
2019-09-14 10:55:54 UTC	816347	13	9141155	40	0	99	1	21	0

Figure 5.9 – System being changed from automatic to manual mode via My Garden EyeDuino mobile app, with no further actions being performed by the participant while in manual working mode. Source: Hamilton V. Niculescu. Data downloaded from https://thingspeak.com/ and processed in Microsoft Excel

Data channel									
created_at	entry_id	field1	field2	field3	field4	field5	field6	field7	field8
2019-09-12 19:26:31 UTC	578787	12.1	9122024	34	1	99	0	13	0
2019-09-12 19:26:32 UTC	578788	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:26:33 UTC	578789	12.1	9122024	34	0	99	1	13	0
2019-09-12 19:26:42 UTC	578797	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:27:01 UTC	578814	12.1	9122024	34	0	99	1	13	0
2019-09-12 19:27:16 UTC	578827	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:27:30 UTC	578838	12.1	9122024	34	1	99	0	13	0
2019-09-12 19:27:52 UTC	578853	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:28:07 UTC	578866	12.1	9122024	34	1	99	1	13	0
2019-09-12 19:28:19 UTC	578877	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:28:40 UTC	578894	12.1	9122024	34	1	99	1	13	0
2019-09-12 19:29:01 UTC	578911	12.1	9122024	34	1	99	1	13	1
2019-09-12 19:29:08 UTC	578917	12.1	9122024	34	1	99	0	13	0
Field3 - soil moisture	Field4 - irrigation valve, open(1), closed(0)								
Field5 - air humidity	Field6 - ventilation fan, on(1), off (0)								
Field7 - air temperature	Field8 - windows, open(1), closed(0)								

Figure 5.10 – The irrigation valve, the ventilation fan and the windows being operated in a random manner via My Garden EyeDuino mobile app by the participants within a short period of time. Source: Hamilton V. Niculescu. Data downloaded from https://thingspeak.com/ and processed in Microsoft Excel

5.6.1. Benefits of co-creation and development of the artefact

The participants reported that at the start of their interaction with the automation system they felt overwhelmed by the technical information communicated by the app. This fact may have affected their perception of the level of interaction with the phone app and the remote installation, which in many cases was lower than what they have reported during the interviews. The researcher concluded that the quantitative data indicating stakeholder's interaction with the remote enclosure was in fact related to the participants' learning process: they were trying to apprehend the connection between the numbers presented by the app and the climate conditions inside the enclosure being controlled by the physical devices. This premise is supported by some of the participants' assertion that they lack practical skills. The technology, therefore, acted in these cases as a knowledge bridge where, in some cases, people have learned about optimal growing climate conditions for vegetables, by remotely controlling physical devices and making their own in-situ observations.

There have been times when the researcher had to be physically present on each research site for the purpose of monitoring and maintaining the physical equipment. On such occasions, the researcher would sometimes meet with the participants, who hinted that they enjoy having full control over technology, so that in return the technology would have full control over the plants growing inside the enclosures. These statements were further supported during the second stage interview: 'It's a positive experience, there's so little work to be done, it's just everything at the tip of your hand, so little to be physically done... maybe go in and weed every so often, but... everything else is just amazing. So little work and so little to be done, it does it itself', P2 mentioned. This effectively confirms previous findings, acknowledging situations where people would only be willing to acquire new skills if there would be some benefits to be gained following their 'sustained efforts' (Harvey et al., 2019; Waarts et al., 2002). Rather than assuming control over the available functionalities, some other participants chose to transfer responsibilities over to the system's automatic mode, simply because this way they did not need to learn how to use features which they perceived as not being useful to them. P10 declared that 'I think it's a different mind altogether. It's maybe not right for me, that's what I'm saying [...] 'cause I'm in front of my computer all day, and I come here to be away from that kind of equipment'. With the addition of the assistance offered by the gardening automation, the participants therefore have been able to focus on performing other tasks and activities, traits that have also been remarked by Guo et al. (2017).

The participants voiced their concerns that, due to their lack of either technical skills or gardening knowledge, potentially negative situations could arise. This arguably acted as a barrier towards their engagement with the automation system. A few incidents have been recorded where, due to incorrect figures being set through the mobile app by the users, some research locations got flooded or plants got damaged by lack of water. The participants expressed that they got frustrated and disappointed as a result, as it has been acknowledged during the interviews. Upon contacting the researcher, the situation was explained to them, and additional training was provided regarding the use of *My Garden EyeDuino* mobile app, and the associated actions being performed as a response by the system. It was surprising to learn that older participants proved to be less intimidated by their early failures and continued exploring the settings and functionalities offered by the app.

In another scenario, one participant admitted to removing the soil moisture probes from the ground, with the clear intention to 'manually' start the irrigation in an alternative way. As the automation gardening system was operating in automatic mode at the time, the new low soil moisture readings would have prompted the water valve to open and the irrigation to start, as

Figure 5.11 illustrates. This aspect reinforces suggestions that people may search for innovative ways of making use of any available technology, as well as striving to manage their finance and conserve body energy (e.g., Callon, 1987; Cressman, 2009; Latour, 1991, 1992, 1993; Michael, 2000; Nimmo, 2011). It also strengthens Bessant's (2013) observation that when people become frustrated by lack of discrete features, 'sometimes that frustration drives them to create their own alternative solutions' (p.14).

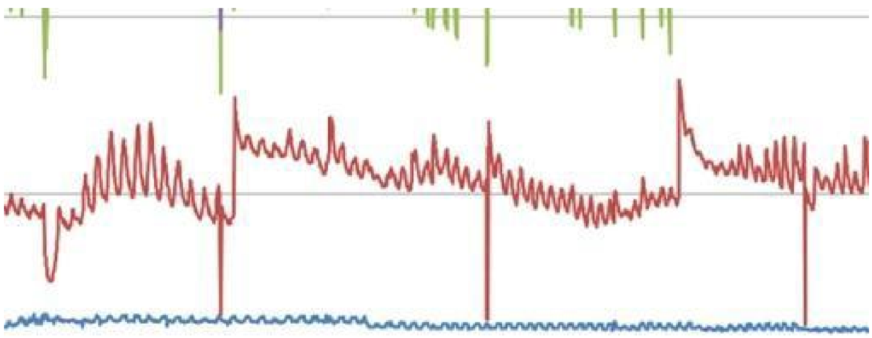

Figure 5.11 – 'Down' spikes (in red) indicating abnormally sudden low soil moisture values. Source: Hamilton V. Niculescu via https://thingspeak.com

At the start of their interaction with the BGAS, each participant was introduced to *My Garden EyeDuino* mobile app, as well as to the whole functionalities of the system, including the REST in form of the PV solar panels, the solar charge controller, and the battery pack. The subsequent interview data, as well as details gathered following the occasional meetings and observations of the participants by the researcher, do not offer support for a conclusive explanation of whether the participants took further notice or remained aware of the existence of the REST or not. Thus, it appears that the presence of REST within this chosen design did have no influence on the participants' engagement level with the BGAS, as these details were never brought back into discussion, and may have not represented an important aspect for them to remember out of the overall functionality. Upon request, the researcher continued to be involved with the maintenance of the automated systems at four former research sites, even after the data collection concluded. Following additional interactions with former participants, it became evident that gaining an understanding of the purpose and functionality of the embedded REST does not represent a priority to them at this stage. Rather than describing these stakeholders as belonging to the innovations 'refuseniks' crowd, it may have been a case where the cultural and social signifiers were missing from this context, as well as being influenced by their relatively low technical skills. This suggests that an alternative method of promoting renewable solutions may need to be adopted in future similar projects.

According to the participants, as they got more familiar and confident with using the app and the automation features, they preferred to allocate more time to performing other activities and gradually forgot about the BGAS, 'probably because it was so consistent and I didn't have to check it, there were no problems', P7 confirmed. If initially the community gardens were regarded more as a way for the participants to socialise with other fellow gardeners, with growing vegetables representing a secondary activity, in the end the BGAS has apparently affected this status quo. Thus, the participants chose to remotely care for the plants, and replace their previous socialising activities taking place within the community garden with other tasks, mainly around their household. As in the case of ninety percent of the participants the distance between their houses and the garden is less than four kilometres, it can be maintained that this aspect did not notably contribute to their decision to remotely care for the plants, with the qualitative data supporting this argument. However, when this study concluded it was noted that most participants returned to their previous schedule, including activities around their garden. As P3 remarked, 'there's things that I've learned that... if you are not checking plants, things can go wrong. If it's completely automated, it makes people lazy'.

5.6.2. Proposed improvements of the automation gardening system

Following the participants' interaction with the BGAS and mobile app, a range of proposed improvements and additions has been suggested. Some features mentioned by the participants have even been considered by the author before the start of the quantitative data collection. However, after a careful analysis of the objective and scope of this research, it has been decided not to implement them at this stage, but possibly on later iterations, as they would not have had any effect on the data collection process or the outcome of this study. Additionally, some of the proposed changes would have been better suited for more commercial systems, whereas the scope of this research was limited to address smaller and more personal setups.

- The addition of an electrical water pump, options to add plant fertilisers, and using better water filters would improve the irrigation system, allowing for better control of the amount of water being supplied to various parts of the vegetable growing areas. A combination of overhead and at ground level sprinklers has been suggested as representing a better solution for specific plants.

- A heating system would allow for plants to be sowed earlier in the year, increasing the overall amount of yield. This is specifically relevant to the Irish climate and its shorter than average growing seasons (S. Alexander, 2017; Met Éireann, 2021).

- Having *My Garden EyeDuino* mobile app continuously run in the background and notify the user when corrective actions are needed could have had a positive impact on their engagement with the remote automated system, preventing them from completely forgetting about it. This option has been considered, but subsequently dismissed, by the researcher in preliminary stages of the app development, on the basis that it could potentially become too intrusive and compete for 'attention' with other existing apps in the users' phone. This in turn might have led to an early dismissal due to recording of increased annoyance and fatigue levels, as extant studies suggest (M. M. Khan, 2008; A. R. Lee et al., 2016; Sert et al., 2019).

- A live video feed was built into the mobile phone app, showing the plants growing in the enclosure, was another suggested addition. This addition could have augmented the 'showing-off' behaviour already demonstrated by some of the participants, and potentially further promoting the engagement and diffusion of knowledge about the automated gardening systems. It would have also offered some extra initial enjoyment, acting as a reward for the participants' proven need for instant gratification. Yet, the minimalist design of the app was aimed at offering intuitive and simple details regarding the microclimate conditions inside the enclosures, without the need to navigate through a multitude of menus and screens which could have caused further confusion. Thus, this feature has not been considered during the initial mobile app development stages. Additionally, the low data transfer speed provided by the available mobile GPRS connection would have not supported the required amount of data to be exchanged reliably with a streaming server.

6. Chapter 6 - Summary and conclusions

Six individual artefacts, each consisting of a bespoke gardening automation system, powered by renewable energy sources technology in form of photovoltaic solar panels, and being remotely controlled from the *My Garden EyeDuino* mobile app via the https://thingspeak.com/ web server, were deployed across six community gardens located in working-class areas in Dublin, Republic of Ireland. These artefacts played a critical role in facilitating the generation of qualitative and quantitative details. Data analysis allowed for the construction of rich discussions regarding the reasons that prevented or limited the participants' interaction with the artefact, and the effects that such time-limited interaction with an innovative technology posed on their awareness, lifestyle, and behaviour. These findings can arguably be applied in other similar settings involving niche innovations.

6.1. Interaction with the BGAS – benefits and opportunities

Tax increases, free ICT training courses, or even incentives of financial nature may not represent optimal methods of trying to reduce the digital divide and promote sustainable consumption. Taking inspiration from Maslow's model of human hierarchy of needs, individuals' basic needs must be addressed first, before pressure from society will 'persuade' them to fulfil their moral aspirations towards the environment, while learning and communicating about innovative technologies. Knowledge provides that as people's economic status improves, which allows them to advance from the working-class to the middle-class status, their moral aspirations and sustainable behaviour are given a higher importance (Beasy, 2020; Earl, 2020; Krishna, 2015; Shi et al., 2011; J. Smith et al., 2015). This research demonstrated that the provision of highly targeted innovations, offering features in accordance with stakeholders' financial level, education attainment, and technical skills, have higher chances of being accurately 'read' by people and given an opportunity to be trialled-out.

The co-created BGAS was offered as a gift and posed no financial risks to the participants. This allowed them to focus on aspects such as learning and interacting with the system at their own pace, and without any pressure that their activities may have any critical consequences. The meaningful, non-threatening context that was attached to it, and the increased backward compatibility with more familiar technologies acted as an incentive towards adoption of this discrete innovation. A lower disruption level on people's income and status quo drove an increase of the chances for innovative technologies to be tested by their intended stakeholders. Closely monitoring the relationship between their education and age resulted in the production of an artefact which they were able to understand and operate, while acquiring new skills and knowledge of both technical and practical nature. This allowed some participants to repurpose and find innovative ways of using the available automation technology.

Thus, the information to be passed between people, of different ages and education, will be relevant, better informed, and more accurate, resulting in a decrease of the digital divide. The knowledge gaps in relation to emerging technologies, to which the government generally fails to promptly react and address by using their official channels, may be filled with valid and up-to-date details, which may allow the population to make better decisions in relation to acquiring and adopting innovative technologies. Knowing their own financial power, people may also better evaluate the available options, rather than assuming that they cannot afford specific innovations only based on casually acquired, and sometimes inaccurate, facts.

Rather than trying to develop a 'designed for all' innovation, a different strategy was adopted by this research. This model could be replicated by future community projects by embedding a more 'fluid design', adapted to the needs, skills, and experiences of their intended stakeholders. By complementing, instead of trying to completely replace existing technologies, innovations will potentially testify to a higher adoption rate, slowly changing people's perspective and attitude towards them. The affordances, rather than the innovations themselves, may act as an agent of change, shaping both the stakeholders and the technology, allowing devices to become natural digital extensions of their body, and thus reducing the inherent 'accidents'.

The artefacts in this study acted therefore as communication bridges that were built between the younger and the older generations, promoting both practical and theoretical information to be exchanged both ways. Moreover, a group of innovators, represented by the participants involved in this study who interacted with the BGAS, may act as a further inspiration and motivation for other individuals to trial and engage with this specific innovation or similar solutions, ultimately leading to their diffusion and domestication.

6.2. Addressing the 'attitude-behaviour' gap

The embedded available signals pointing to the presence of REST providing electricity to the BGAS have largely remained unnoticed by the participants. Their lack of accurate previous technical information, and their familiarity with the ever readily available electricity, resulted in them remaining unaware of the self-sustaining features of the innovations that they have been presented with. This suggests that even though people present themselves as being 'green', they may not necessarily fully comprehend the meaning of this concept, and accordingly, they are not automatically ready to switch to alternative, renewable energy sources.

Participants' relatively low technical skills, the missing cultural and social signifiers, and sometimes potentially inaccurate information received from peers may have skewed their attitude towards REST, and simply ignoring or rejecting it. Without foreseeing any personal benefit to be gained in the setting of this research, the participants chose not to acquire any new knowledge on this topic. The initial plan of including an additional small wind turbine was dropped due to opposition from the managers of such gardens. Undoubtedly, this aspect would have increased both the visibility and the 'labor illusion' (Buell & Norton, 2011) of REST, potentially resulting in recording of slightly different results in terms of awareness and acceptance. This suggests that an alternative method of promoting renewable solutions may need to be adopted in future similar projects, and launching of information and education campaigns would therefore be recommended, before large sustainable projects are planned to be rolled out by enterprises.

6.3. The outcomes following the engagement of the participants, which were particularly chosen for this study, with the sustainable, innovative gardening automation systems

This research revealed that highly targeted innovations may lead to recording of long-lasting or temporary 'accidents' affecting people's behaviour. Pattern changes in relation to their social communication and gardening tasks were noticed for the duration of the study. While the BGAS was acclaimed to be particularly useful, particularly by allowing the participants to grow more vegetables, at the same time they acknowledged that less time than usual was allocated for the care of those plants. Moreover, their reduced physical presence in the community garden, due to being able to operate the system remotely via the mobile app, disrupted their previously existing social interactions with peer gardeners, preventing the exchange of relevant gardening information. Previous gardening activities and tasks that were usually performed by humans have been disrupted, which may result in lower levels of knowledge and communication skills of the population in the long term. Moreover, it was suggested that the reliance on automation systems may impair people's sustainability behaviour, leading to an increase of the dependence on technology and de-skilling of future generations (Barlex et al., 2013; Murtagh et al., 2015).

Stakeholders' drive to avail of features which have been specifically developed to assist with their gardening activities meant that they were more likely to overcome early failures and pursue new ways of better 'exploiting' the technology. Therefore, the pace of interaction with the BGAS was being set by the stakeholders and not by the technology, and this ultimately made them feel empowered and owners of this innovation. As people felt part of the entire development process, they were more likely to learn and discover innovative ways of making use of it and assume ownership and display their affluence to their peers and family members. This aspect is reinforced by the 'negative' cases, where the users' interest and engagement with the BGAS was remarkably lower as opportunities for socialising and showing-off were missing.

It is, therefore, not necessarily the technology itself that drives people's engagement with it, but the opportunity for the stakeholders to show-off their skills and prove their ownership and social status to other members of society. On occasions, this desire may supersede local, mutually accepted cultural rules, as demonstrated by some younger participants.

6.4. Barriers / incentives associated with the participants' adoption of innovative automated gardening systems and acquiring of new skills and knowledge about renewable energy solutions

Findings of this study support arguments maintaining that the financial status alone does not necessarily represent the main driver that prompts people's green behaviour, but their level of education and existing information about this concept – including that of any required sacrifices to be made regarding their current lifestyle habits – will conclude to adjusting their attitude and behaviour accordingly.

Specific innovations, like the one employed in this study, are not available off-the-shelves. This aspect directly influences people's knowledge and skills of operating such innovations, and this is supported by the participants' inaccurate information on how the PV solar panels work for instance. As a result, innovative technologies need to be sourced from international online locations, which subsequently drive their price range in an upward direction, due to import taxes and delivery charges being applied. Thus, people's access to those modern technologies is further prevented by the fact that the budget allocated for such upgrades is in many cases non-existent, as the participants in this study suggested.

Some propositions can be advanced, augmenting and reinforcing findings of previous studies (e.g., J. W. C. Arts et al., 2011; Bell et al., 2005; Damant & Knapp, 2015; Hirsh & Sovacool, 2013; Sochor & Nikitas, 2016; N. Taylor et al., 2018; Walker, 1995; C. R. Warren et al., 2005):

- Less informed people are more likely to oppose REST, perceive it as being inefficient, and overestimate their price.

- Opposition to innovations will be reduced by offering a rationale or vignette, explaining their advantages, and raising awareness of potential negative consequences.

- People belonging to various community groups or from distinct socio-cultural backgrounds will perceive discrete innovations' characteristics as being either useful or irrelevant, based on their embedded accepted rules.

- Visual feedback and instant gratification play a significant role in people engaging with technology, especially when it involves remote communication with it, and some reaction is expected as a response from the equipment.

- Perceived compatibility, personal relevance, as well as involving people in the development and improvement of niche innovations will increase the acceptance rate, avoiding future potential issues related to affordance and lack of knowledge in using specific technologies.

- Trialability and complexity may offer individuals the chance of discovering additional benefits that could have not been foreseen during the design process. Simultaneously, innovations may be 'translated' to better meet users' goals, with some functionalities being perceived as useless and possibly being disregarded.

- Socio-demographic factors can impact the acceptance of innovations. Provision of initial financial support will significantly increase interest in technology and encourage the acceptance of innovations, especially within less financially stable, more disadvantaged communities.

- Being able to attach a meaning to an innovation will increase the chances of its intended users to familiarise with it, assume ownership, and display it as a social badge indicating their social relevance and higher affluence in their community.

These aspects are closely connected one to the other, acting as a 'knowledge spaghetti' (Bessant & Venables, 2008) informing and guiding the process of future responsible innovation and technological development. This process would ideally align stakeholders' needs and expectations with the affordances and symbolic value that the enabling innovations offer. Academia, practitioners, and policy makers are therefore being provided with valuable knowledge to assist with the designing of more efficient development strategies, and with advancing of better-informed socio-economic models. This will gradually act towards reducing the digital divide, encouraging literacy, education, and social participation in the development of sustainable local community projects.

6.5. The contribution to knowledge of this study

Home automation and smart monitoring devices are known to exist for many years, with individuals being able to acquire and install them into their households. However, despite being readily available online and on the shelves in the Irish shops, it could be argued that they failed to diffuse at larger scales into all social and community groups, with an adoption rate of only 15 percent around the time this research concluded (CSO, 2019b, 2020). The participants in this study live in working-class areas in Dublin (Dublin City Council, 2020; Haase & Pratschke, 2017; Seery, 2018), and it is argued that their economic status and lower educational attainment prevents them from accessing relevant and accurate information, and also from keeping up-to-date with technology. This results in a reduced access to innovations and community services, increasing the digital divide between 'haves' and 'have-nots'. Existing knowledge outlines that simply offering people access to equipment and training is not enough, as these may not meet the expectations or may not be aligned with the needs of their recipients (Alghamdi & Holland, 2020; Goedhart et al., 2019; Loh & Chib, 2019; Mącik & Mącik, 2014; Prajaknate, 2017; D. Taylor & Packham, 2016).

To this end, the researcher envisioned an innovative way intended to address the technological knowledge gap, as well as promoting sustainable practices and behaviour to society members. Moreover, this study reveals the social and cultural implications of the introduction of a gardening automation solution on a localised scale, within community gardens. To address participant's potential fear of technology, both familiar and unfamiliar technologies were combined to create a gardening automation system. The BGAS went beyond the status of an art installation, having also acted as a data collection interface, indicating the participants' engagement patterns with the artefact.

6.5.1. BGAS shifted participants' behaviour

This technological setup allowed for the identification of changes that have occurred in relation to social and communication behaviours of those involved. The significance and material value assigned by the participants to the BGAS shifted from that of spectators to self-proclaimed owners of technology, openly showing-off their newly acquired skills and affluence, being able to control and set the pace of the technology. Traditionally accepted social and cultural behaviour within specific communities were overridden by individuals' desire to demonstrate their relevance and superiority within their group, by way of proving their elevated level of knowledge and skills in interacting with meaningful niche artefacts.

Participants' previous attendance patterns to their garden also changed, and this allowed for a new inter-generational communication channel to be initiated, with details of both practical and technical nature being exchanged both ways. In turn, this niche innovation in the form of BGAS encouraged the participants to plant more vegetables to which they were able to allocate less time than before.

6.5.2. The 'attitude-behaviour gap'

The BGAS responded physically to the participants' commands that were being sent remotely from their smartphones. Even though participants were not always physically present on the research location and any visual feedback was lacking, they were made aware of the response to their actions via the *My Garden EyeDuino* mobile phone app. This triggered participants' interest in learning how to use the mobile app and show-off in front of their peers.

On the other hand, the REST components that accompanied the system, although fully operational, were completely silent and unintrusive, which resulted for them to remain largely unnoticed. Despite participants' sustainability traits demonstrated for the duration of this study, it can be argued that lack of feedback from technology, but also participants' socio-economic status played an important role in them not taking further steps in improving their knowledge on this topic.

6.5.3. The co-creation process

The artefact employed for this study plays a vital instrumental role for the methodology practice and data collection process, by facilitating participants' involvement in the study. The co-creation process mitigated reflection on both the researcher and participants' part, as well as inciting the participants to engage in creative thinking and learn about innovative ways to complement their everyday gardening activities. For the duration of the data collection and beyond, the artefact gradually evolved from being regarded by the participants as an innovative prototype to that of a reliable, more familiar gardening assistive technology.

6.5.4. Key insights and contribution points

- It was revealed that those participants with lower or missing support and communication from their family and peers manifested a lack of interest in learning and engaging with the BGAS. This upholds arguments that attempts at introducing society members to new skills and knowledge may result in different outcomes, depending on stakeholders' needs, as well as their embedded socially accepted behaviour and beliefs. In practice, customised and more relevant models need to be devised to incentivise people to engage with potentially disruptive activities.
- Participants' central objective while they were involved in this study was caring for vegetables by relying on innovative automation technologies. This prompted the creation of a communication channel which allowed existing knowledge gaps to be filled across both the younger and older generation. In this scenario, findings of Parasuraman and Colby (2001) are therefore contradicted, in the sense that the older generation, having more informed practical gardening skills, were not intimidated by the innovation, and were compelled to learn new technical terminology that would allow them to better understand how the artefact works. On the other hand, the younger generation also benefited by acquiring valid and relevant gardening related to theoretical knowledge. This aspect can prove very useful to those policy makers looking at discourses around uses and adoption of assistive apps in everyday life.
- The visual impact and instant gratification play an important role in people's drive to interact with innovations. In addition, as it is the case with those involved in this research, their basic needs override their moral and sustainability aspirations. Moreover, participants' relatively low educational attainment, and sometimes less than accurate understanding of REST, also played a critical role in acting as a barrier towards availing of modern innovations. People may oppose the diffusion of alternative energy sources based on their perceived unreliability and high price. Better ways of motivating specific Irish individuals to change their attitude towards REST must therefore be identified.

Further, this thesis offers useful guidance to those decision makers and advocates involved in projects that analyse individuals' engagement and adoption of REST. Also, sustainable food sourcing and greater food independence represent essential topics of interest to those looking to promote the development of social intervention plans and policies, as well as identifying opportunities for establishing future local civic participation projects.

6.6. The future of the BGAS

A longer exposure to the BGAS may eventually result in the stakeholders opening the metaphorical 'black box' which ensures the system's functionality (Fara & Azad, 2013). This aspect will not only facilitate the acquiring of additional technical knowledge, but also potentially discover innovative ways of making use of embedded features aimed at ensuring optimal climate conditions. The materiality of both the physical system and the mobile phone app would gradually become part of their users' daily routines. As it is the case with any work of art, automated gardening systems like the BGAS may initially be analysed by their future owners as a commodity, through the spectrum of their market value. Once they are integrated into people's life however, they will become 'de-commodified', and personal meanings will be attached to them.

After the research phase has concluded, the author proceeded to adjust some features of the BGAS on request, to reduce the running costs. Manual controls for irrigation, ventilation, and windows movement were implemented in one place, while another location witnessed a transition from the solar panels and mobile GPRS connection to the national electricity grid, and a plug-in broadband connection. These behaviours could be directly linked with earlier claims related to the participants' financial status, and them having regarded the automation systems as a gift.

The stakeholders' initial excitement was eventually replaced by convenience and reliance on having some assistive technologies around their gardens. In other words, while the BGAS still demands some attention from its users, it ultimately became part of their 'order of things' as Langdon Winner suggests (in Murphie & Potts, 2003). It was therefore not the technology alone that resulted in individuals' behaviour to adapt, but also the specific context within the technology was deployed, as well as the participants' social, cultural, and economic system.

6.7. Limitations of this study and further research

The multitude of perspectives and choices that can be made during the analysis makes it impossible to capture the 'reality' (Charmaz, 2006; Corbin & Strauss, 2008; Markham, 2018). The resulting analysis should therefore not be regarded as telling the 'absolute truth' about the studied phenomenon, but it represents a 'still' impression only valid for the unique setup and time of the study. The data are therefore interpreted and only meaningfully accurate for the particular, narrow setting that has been used to gather it from, following the BGAS employed for this project's design. It does not attempt to explain the full picture, but only to make sense of the specific context and set of conditions of this study. Hence, the proposed explanation of the social model that has been studied is likely to reveal more 'how' a particular phenomenon (inter)acted under some specific conditions.

The inductive and reflexive methods used for data interpretation, and by using a small sample of nineteen people living in an urban, working-class Irish environment, means that this study's findings may not always apply for larger populations, and/or under different settings or locations, and/or under the influence of different social, economic, or cultural factors. While the findings can potentially be generalised and applied to similar urban settlements, the objective of this research has been to capture traits specific to Irish culture, in a particular context, and by relying on custom designed methods and technologies. Future research may employ different approaches, relying on different participant samples and environments, to produce knowledge that may complement or contradict the findings of this study.

Implementation of similar designs within rural environments and at larger scales may conclude with divergent findings, unveiling behaviours which could not have been traced by the present research. This may be due to the recruitment of individuals from different socio-economic backgrounds, with varied levels of access to smartphones, data plans, and available online connectivity. Additionally, the artefact that was specifically developed for the purpose of conducting this study does not represent a blueprint solution for an assembly-line production, and the deployment of similar gardening automated systems may require some design adaptations to suit the characteristics of other locations.

Aspects such as social cohesion and communication skills within local communities may be impacted in these cases and need to be acknowledged as constituting potential unwanted consequences due to exposing people to bespoke innovations. Nevertheless, the addition of 'supporting' technologies like REST, for instance, may prove to be more relevant to the participants and result in an increased awareness, a phenomenon which could be explored from a distinct perspective.

During early development stages, prototypes and innovations may not be perfectly aligned to their stakeholders' needs and expectations, but accounting to communication and feedback, they can be adapted accordingly. Further similar research may be needed, employing tweaked variables making-up the design of the data collection setup, e.g., lengthier interaction with innovations.

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Appendix A **Author's statement of the artefact**

Innovations in the artefact design and deployment

The artefact which was developed by the researcher and accompanies this thesis, on which the collection of data relies, is made up of individual fragments operating as an entire system:

– The custom-developed *My Garden EyeDuino* mobile phone app.

– The Arduino Control Unit (ACU), represented by a microcontroller and a collection of attached peripherals (sensors and actuators).

– The enclosure/greenhouse/polytunnel housing the ACU, and where plants can be grown.

– The custom-written computer code ensuring the proper functioning of the above.

– The renewable energy source technologies (REST), represented by photovoltaic (PV) panels, a solar charge controller and battery pack.

– The online web server (https://thingspeak.com/) ensuring remote communication between the mobile app and the ACU.

This bespoke gardening automation system (BGAS) combines familiar devices in the form of smartphones, with less familiar technologies represented by the sensors and actuators attached to an Arduino board (Figure 7.1). The remote communication taking place between such technologies offers the participants enhanced control and assistance in relation to growing their vegetables inside special enclosures, known as greenhouses or polytunnels (Figure 7.2).

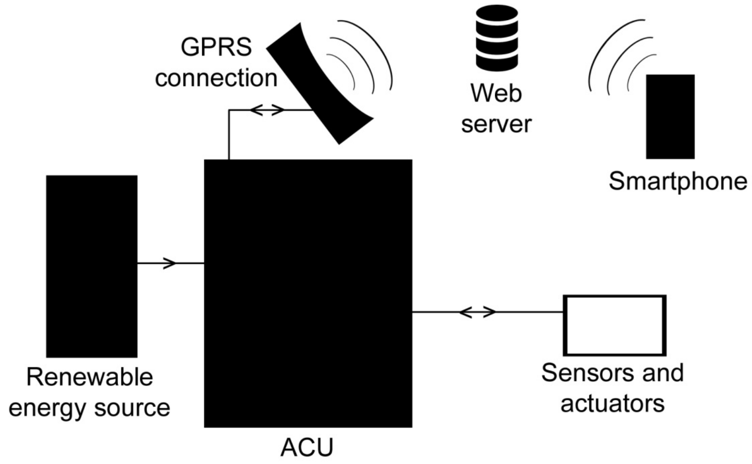


Figure 7.1 – Simplified illustration of the BGAS. Six identical systems were developed by the researcher for the purpose of mitigating data collection. Source: Hamilton V. Niculescu

Author's statement of the artefact (contd.)

Figure 7.2 – Enclosures which housed the BGAS. Some structures were constructed by the researcher, others were already existing on site and were retrofitted. Source: Hamilton V. Niculescu

This artefact was specifically deployed around community gardens in Dublin with the intention of assisting gardeners with their activities. No ready-available, off-the-shelf version of a similar automation system that would offer comparable customisable controls and access to rich data is known to exist. As a result, this experimental artefact had to be specifically designed to assist the participants with the proposed gardening tasks, but more crucially with the generation of quantitative details, offering support for an increased data reliability and interpretation. This allows the researcher to monitor the influence that the introduction of highly targeted innovations poses onto the participants' lifestyle, their social interactions and communication in this particular scenario. The researcher documented the technical development process, and information reflecting some of the work involved in advancing the knowledge related to social and technology engagement is available online at https://eyeduinoproject.online/.

The artefact consists of an association between smartphones – a technology familiar to most individuals – and an innovative automation setup intended to assist with specific gardening tasks. As the smallest interaction with any device will invariably change people's perspective and attitude towards technology, new inter-generational communication channels may potentially be developed, while prior existing social interactions may be disrupted.

The extant literature suggests that those innovations aiming to complement rather than replace the stakeholders' regular activities have an increased adoption rate (DiMaggio et al., 2001; Latzer, 2009; Lazard, 2016; Marshall & Davis, 2021; Munar & Jacobsen, 2014; The Government Office for Science, 2008). As is the case with the gardening automation system developed for this project, the author reflects on the extent of the new tools being accepted as representing extensions of participants' bodies (Lister, 2009) after a period of three-month interaction.

Appendix B Comparable studies adopting similar methods

In support of their decision for the adoption of the MM-GT methodology, the author interrogated the Scopus database, looking for previous similar studies. No restriction in terms of the publishing year was imposed, with the clear intention of being able to identify other researchers' increasingly reliance on MM-GT over the years. Figure 7.3 depicts a selection of such studies. This backs-up the argument that the integration of mixed methods and grounded theory has organically evolved over the years not only as a flexible approach for data gathering, but also to provide richer and accurate insights into the phenomenon under study, which is even more valuable for explaining behaviour and social contexts.

Name of the study	Authors	Year	Methodology
Union Democracy: The Internal Politics of the International Typographical Union	Seymour Martin Lipset Martin A. Trow James S. Coleman	1956	Mixed methods
Labeling the Mentally Retarded: Clinical and Social System Perspectives on Mental Retardation	Mercer, Jane R.	1973	Mixed methods
College physics students' epistemological self-reflection and its relationship to conceptual learning	David B. May Eugenia Etkina	2002	Mixed methods
Utilizing mixed methods to assess parasocial interaction of an entertainment–education program audience	Kawamura, Yoko Ivankova, Nataliya V. Kohler, Connie L. Perumean-Chaney, Suzanne	2009	Concurrent triangulation mixed methods
Utilizing mixed methods to assess parasocial interaction of an entertainment–education program audience	Yoko Kawamura Nataliya V Ivankova Connie L Kohler Suzanne Perumean-Chaney	2009	MM-GT
A Mixed Methods Evaluation of a 12-Week Insurance-Sponsored Weight Management Program Incorporating Cognitive-Behavioral Counseling	Abildso C. Zizzi S. Gilleland D. Thomas J. Bonner D.	2010	Sequential mixed methods
Rebranding exercise: Closing the gap between values and behavior	Segar, M. L. Eccles, J. S. Richardson, C. R.	2011	Convergent MM-GT
Mixing a Grounded Theory Approach with a Randomized Controlled Trial Related to Intimate Partner Violence: What Challenges Arise for Mixed Methods Research?	Catallo, Cristina Jack, Susan M. Ciliska, Donna MacMillan, Harriet L.	2013	Two-phase sequential explanatory mixed methods
Content-driven analysis of an online community for smoking cessation: Integration of qualitative techniques, automated text analysis, and affiliation network	Myneni, S. Fujimoto, K. Cobb, N. Cohen, T.	2015	MM-GT
More than winning: A mixed methods grounded theory investigation of the career development event preparation process	Bowling, Amanda M. Ball, Anna L.	2020	MM-GT

Figure 7.3 – Sample studies involving MM and GT for data collection and interpretation, ordered by the publishing year. Source: Hamilton V. Niculescu

Combinations of specific keywords, such as 'grounded theory', 'mixed methods', 'qualitative and quantitative' and 'explanatory' were used, and various amounts of results were returned, e.g., 407,377 documents for 'mixed methods', with 33,650 belonging to the social sciences category. Further refinements of the search criteria to only scan the abstract or the keywords section of the published studies resulted in a more manageable list, e.g., 5,484 documents in the social sciences field contained 'mixed methods' amongst their keywords.

Comparable studies adopting similar methods (contd.)

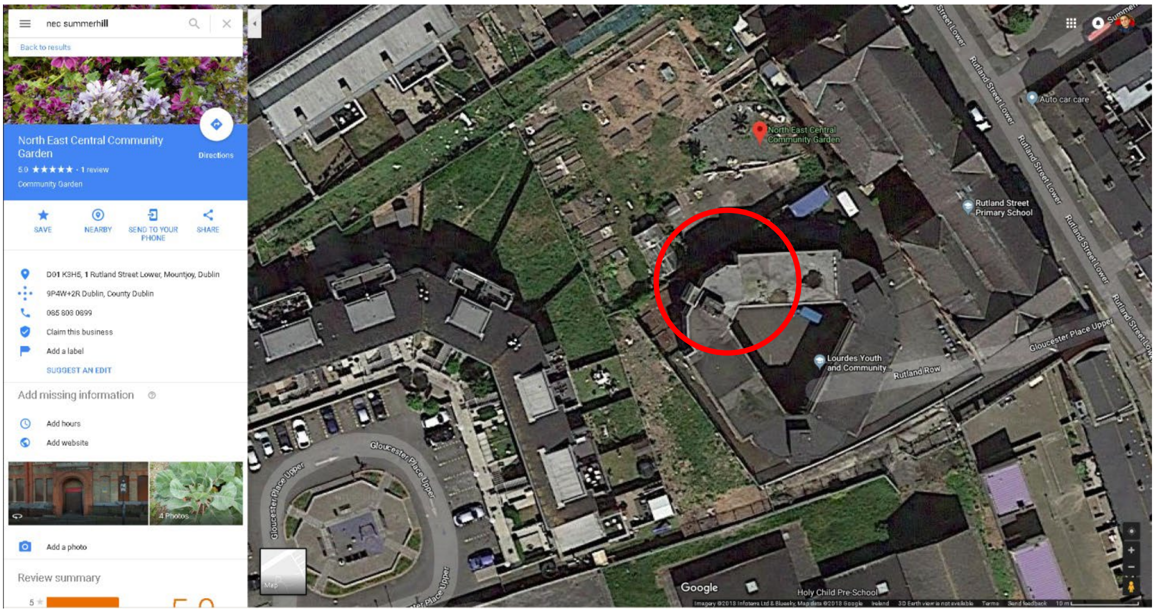
The author further interrogated the Scopus database using terms related to social and practicality aspects, such as 'social', 'adoption', 'barriers', 'sustainability', 'renewables', 'energy'. The collection of the returned results reinforced the author's early decision of choosing a MM-GT approach, by confirming that extant knowledge was produced following similar methods.

Two streams of research analysing the adoption and diffusion of innovations were identified: one that focuses on factors that encourage the adoption of innovations, largely based on Rogers' (E. Rogers, 1982, 1995) 'Diffusion of Innovations' theory; and the second one, which looks at aspects acting as adoption barriers (N. Bergman & Eyre, 2011; Olawuyi, 2017; Painuly, 2001; Ram & Sheth, 1989; Reinhardt et al., 2017).

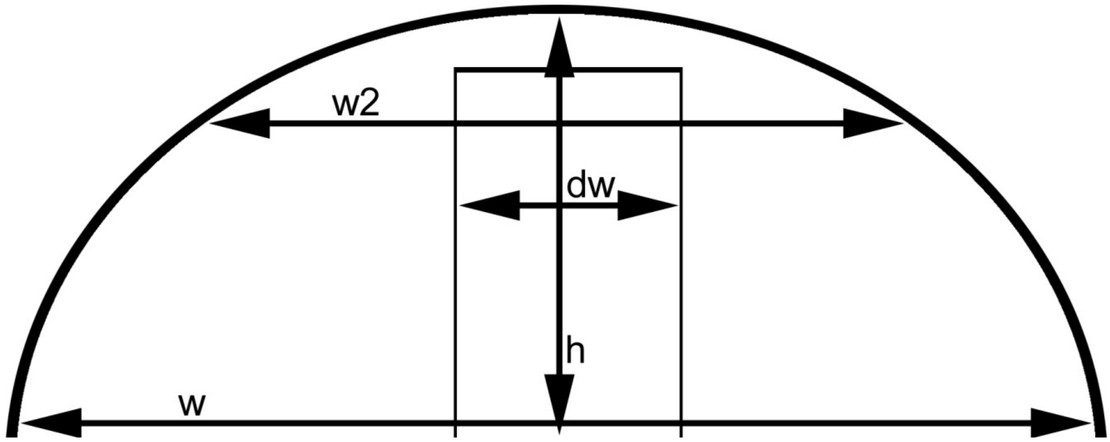
Appendix C **Research Locations and Enclosure Specifications**

The six enclosures (greenhouses) housing the ACU and the required automation peripherals were located at six separate locations in Dublin. Enclosures already existed at three sites, and these only had to be retrofitted with the automation technology. At the other three locations, an enclosure had to be entirely built by the researcher. The amount of yield to be grown inside these enclosures was considered irrelevant in the context of this study, as the BGAS can be easily scaled up or down according to each particular design and location, while its functionality remains virtually unaffected by this process. Therefore, the researcher consulted with a professional builder who advised on the proposed size for the three enclosures to be built, based on the characteristics of each location. Below are the agreed details for each research location, including the irrigation and the mechanical system, as well as the additional required materials and quantities. Additional details from the construction phase are included in the folder titled 'Portfolio' that accompanies this submission.

Summerhill - North-East Central Community Garden (retrofit)



Research Locations and Enclosure Specifications (contd.)



w = 4200mm

h = 2700mm

dw = 1200mm

Back door (1900x1200mm) to be covered with polythene

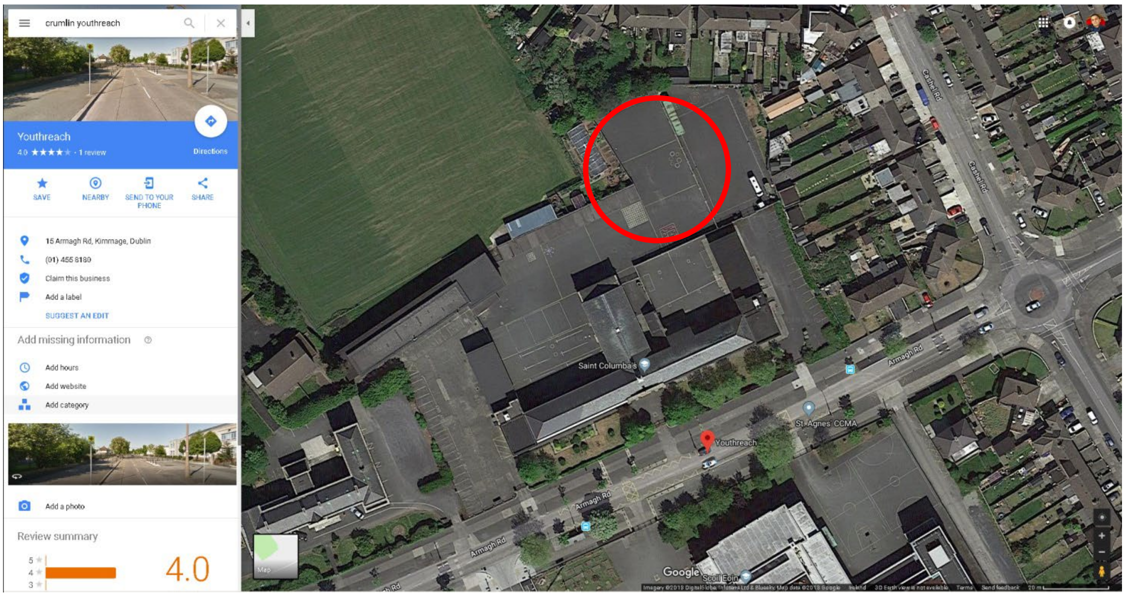
Electric wire needed – 10.5m

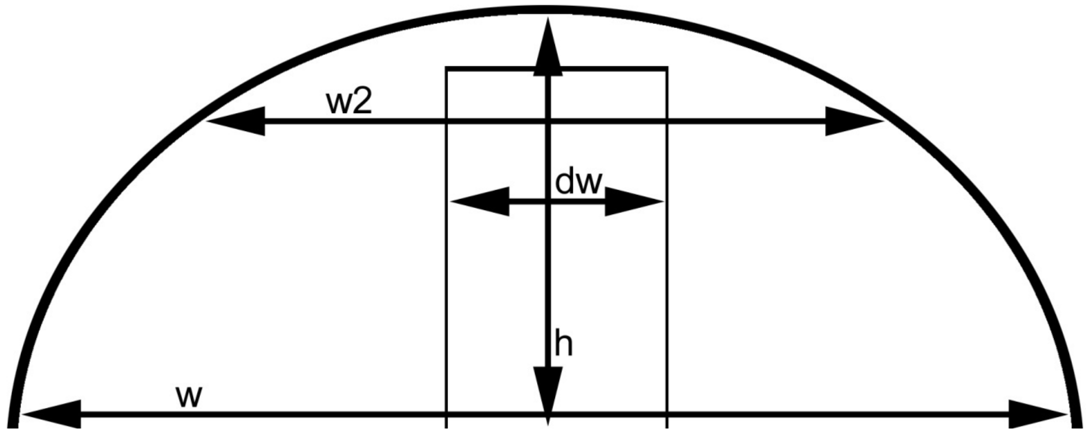
Water pipe along south side wall

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

Crumlin – Youthreach (retrofit)





w = 5400mm

h = 2600mm

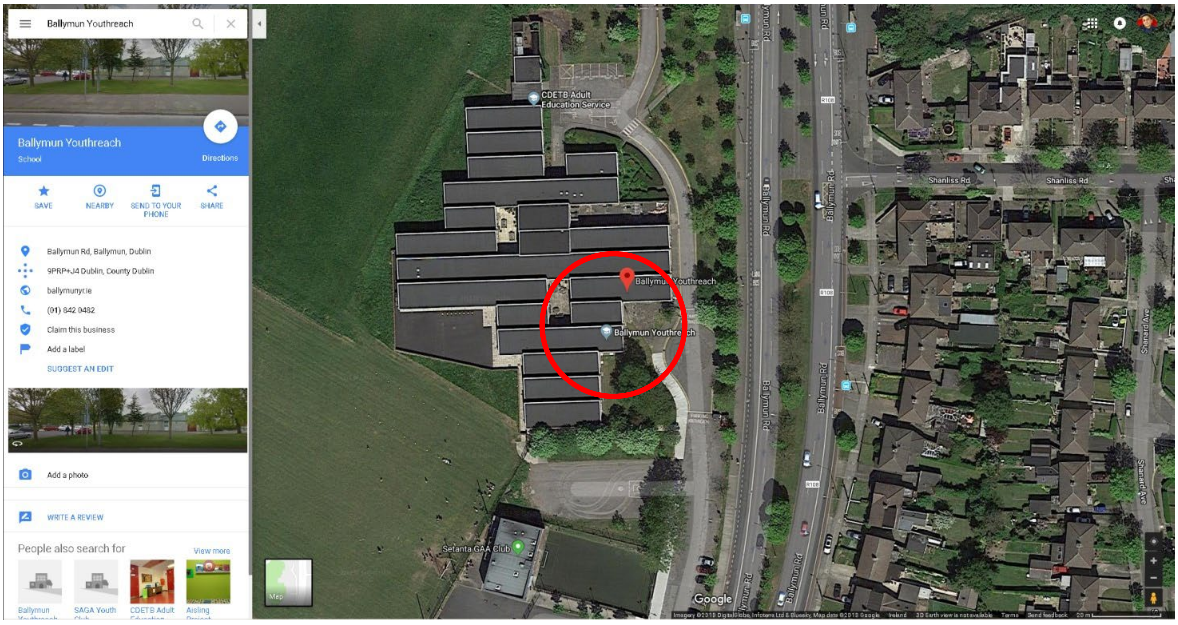
w2 = 4000mm

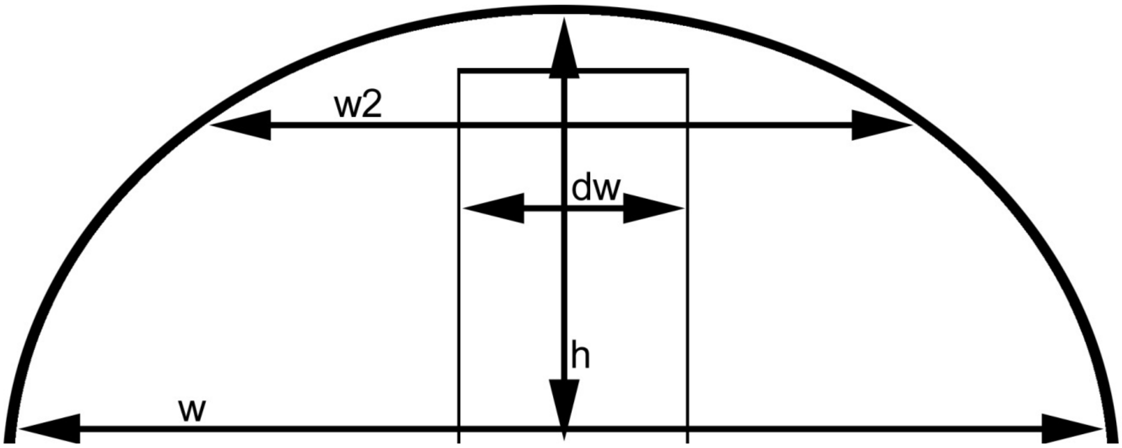
water hose 17.5m

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

Ballymun – Youthreach (retrofit)





w = 3900mm

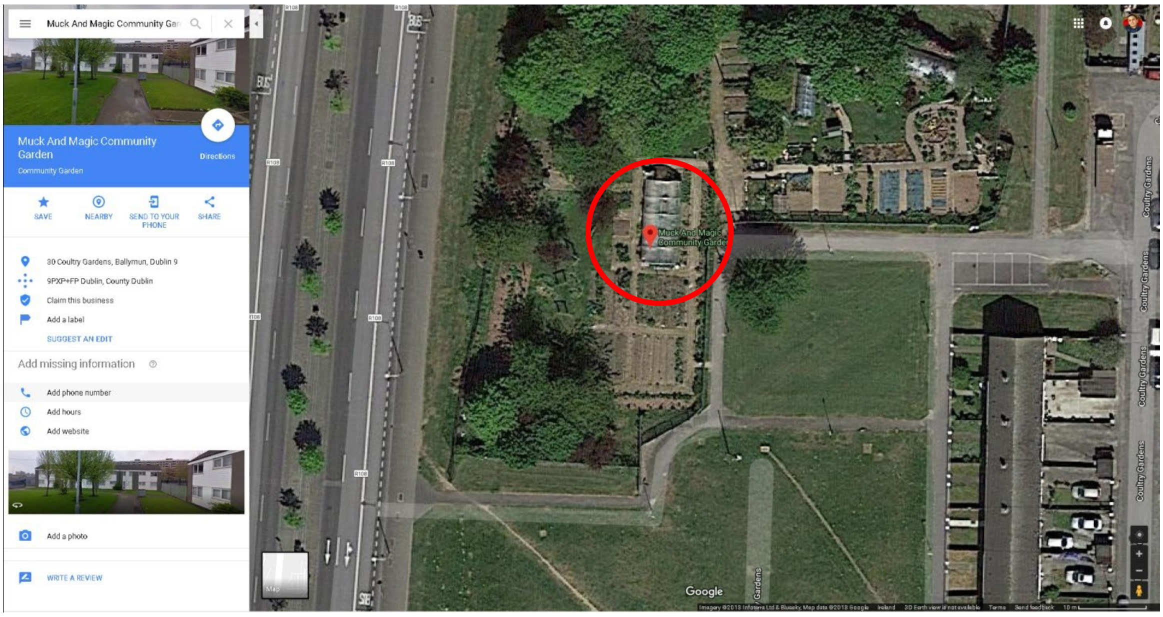
h = 2400mm

dw = 800mm

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

Ballymun - Muck and Magic (new build)



w = 2900mm

l = 2500mm

h = 2400mm

water pipe 20m

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

Rialto - Flanagan's Fields (new build)

w = 2400mm

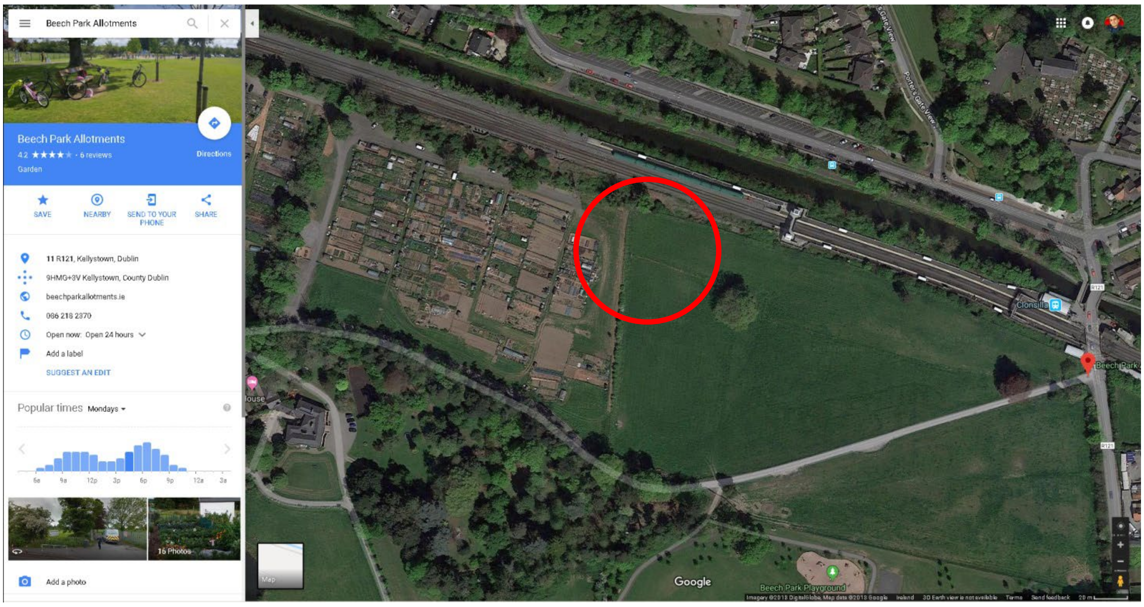
l = 2400mm

h = 2200mm

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

Clonsilla – Beech Park Allotments (new build)



w = 2400mm

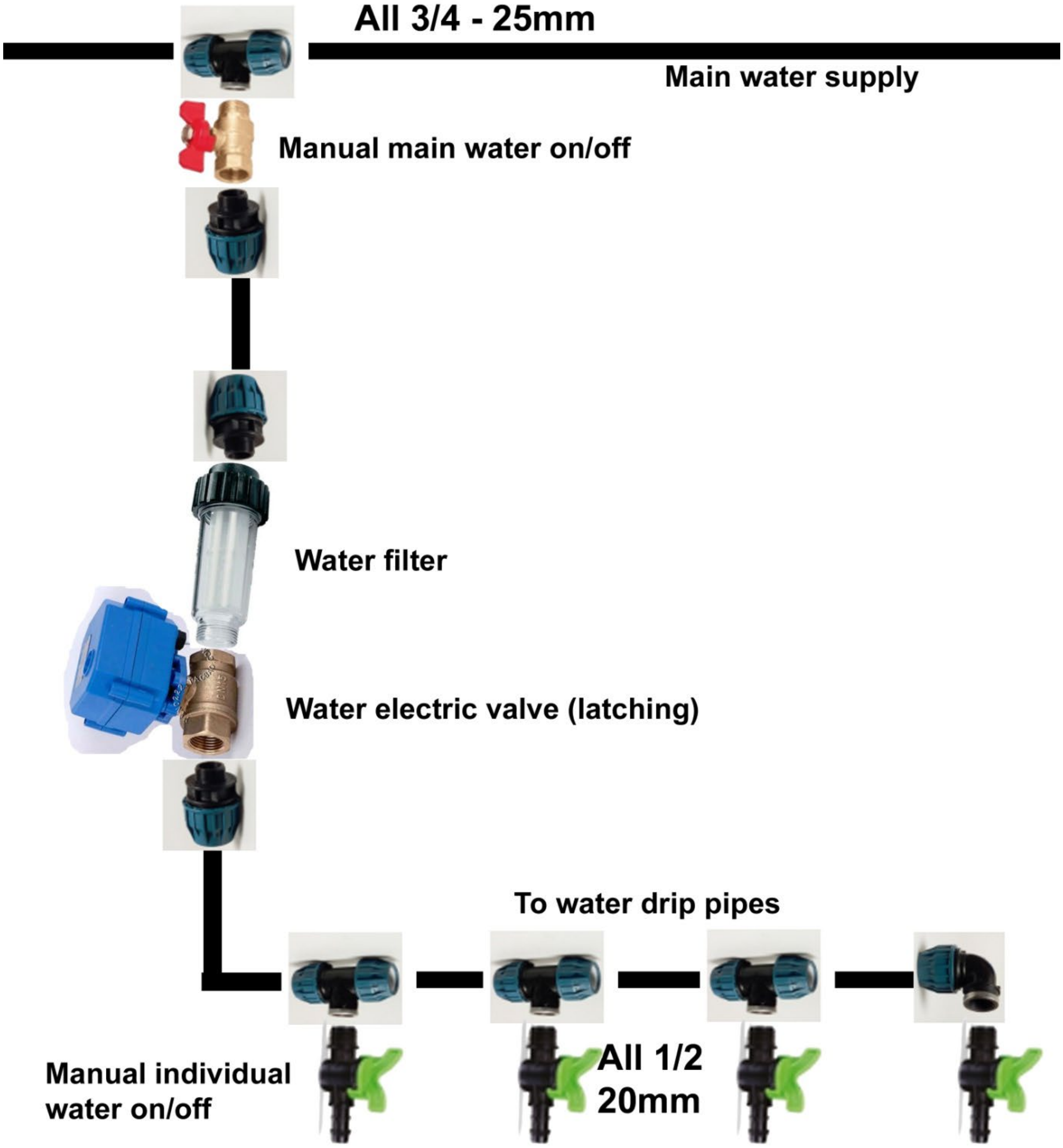
l = 2400mm

h = 2200mm

Source: Hamilton V. Niculescu via Google Maps

Research Locations and Enclosure Specifications (contd.)

The irrigation system



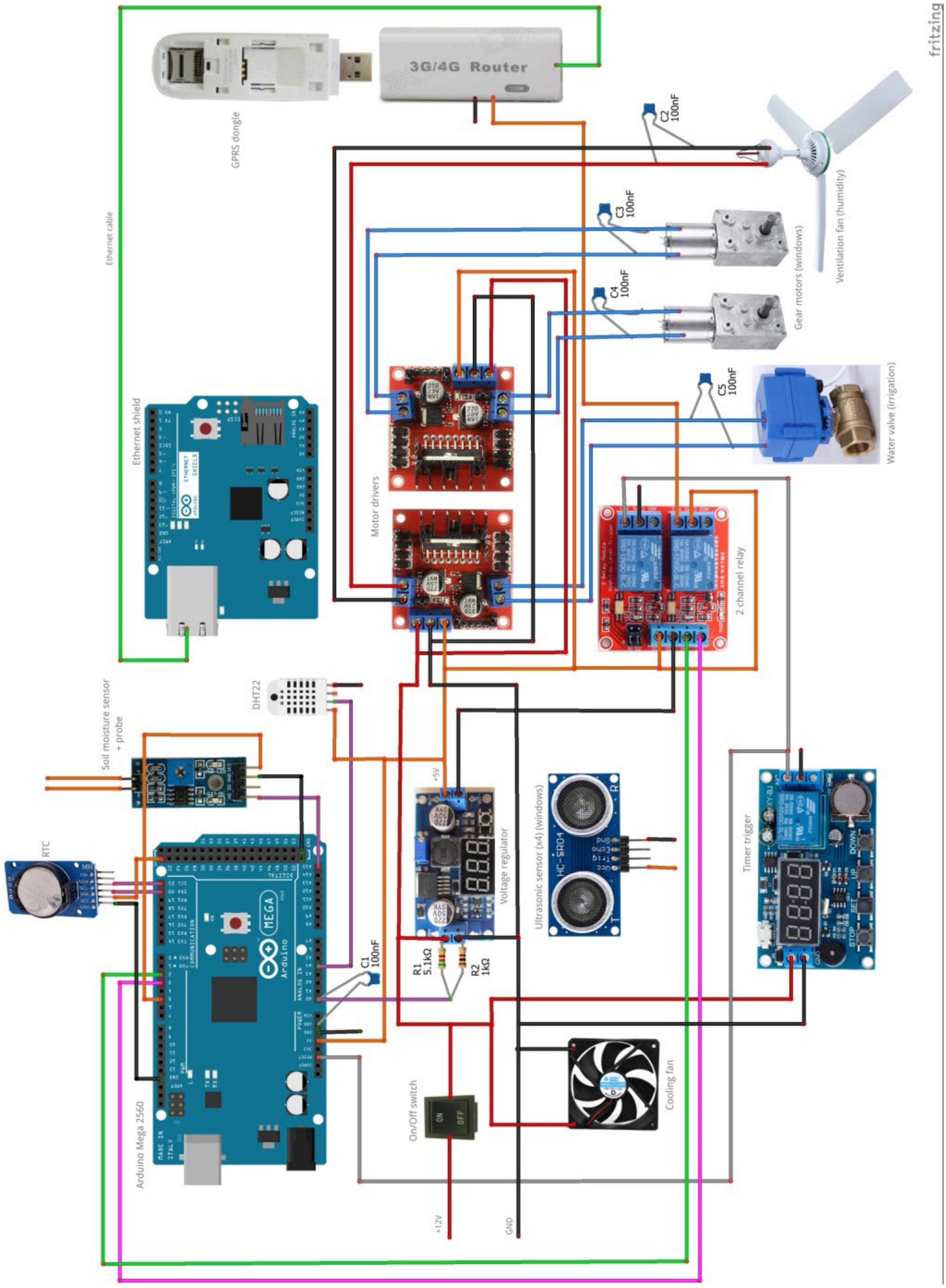
Layout of the proposed connections for the irrigation system. Source: Hamilton V. Niculescu

Research Locations and Enclosure Specifications (contd.)

The mechanical system

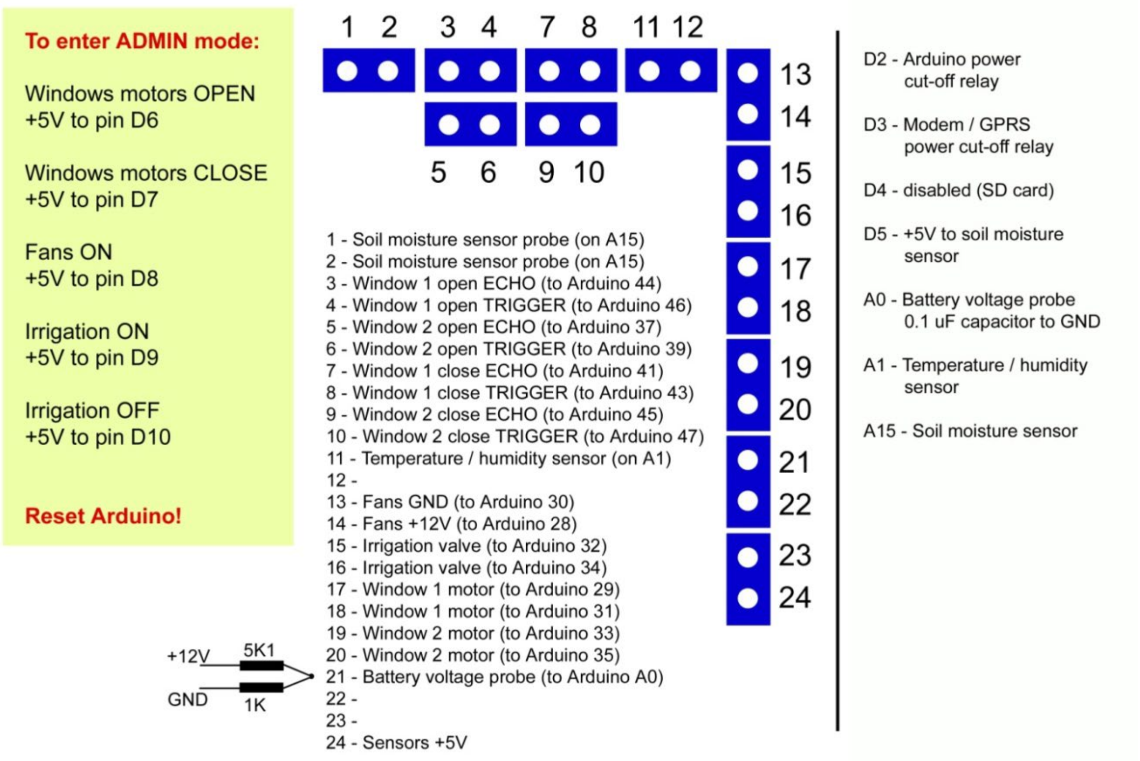
The proposed layout for the polycarbonate sliding windows, irrigation water valve, and ventilation fan. Source: Hamilton V. Niculescu

Appendix D **ACU – Schematics**



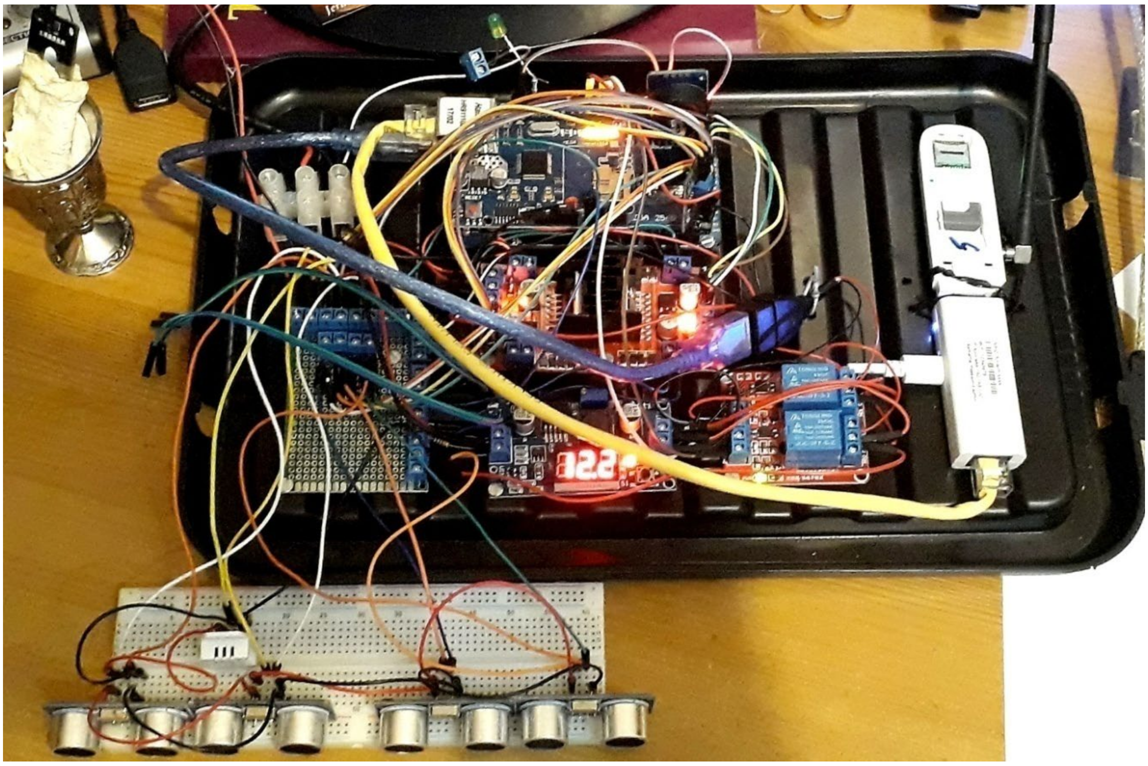
Electronic parts and wiring schematic. Source: Hamilton V. Niculescu via https://fritzing.org/

ACU – Schematics (contd.)



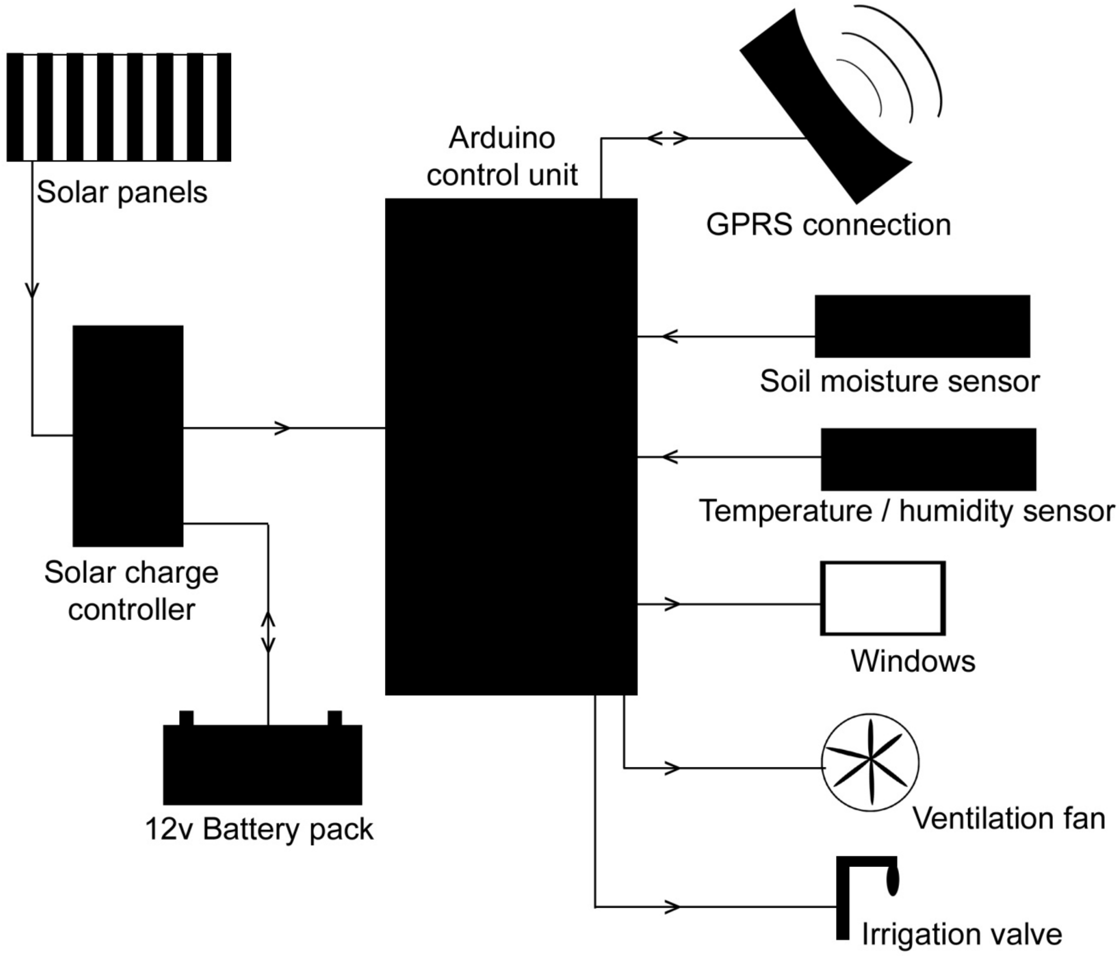
Input / output pinout description. Source: Hamilton V. Niculescu

ACU – Schematics (contd.)



The finished ACU. Source: Hamilton V. Niculescu

ACU – Schematics (contd.)



ACU and BGAS logic functional model. Source: Hamilton V. Niculescu

Appendix E **ACU – Pseudocode**

On start

- retrieve default values from EEPROM
- initialise variables, hardware, and communication ports
- reset actuators (close windows, close irrigation valve, stop ventilation fan)
- enable watchdog
- set automatic mode by default
- read current date and time from Real Time Clock (RTC)
- read battery voltage
    - read sensor values
    - if voltage greater than 10, act upon sensor data (control windows, irrigation valve, ventilation fan)
- add 30 seconds delay to allow for the online connection to be established

Main loop

- reset watchdog (keep alive)
- read sensor values
- check for any sensor errors
    - if an error occurred, do not take any action on the corresponding actuator (i.e., soil moisture sensor reading error = do not operate the water valve)
        - if the same error persists for 3 cycles (i.e., approximately 1 minute), take corrective actions (e.g., switch water off)
- check the battery voltage
        - if lower than 10 volts, take corrective actions (e.g., switch water off)
- retrieve the current working mode (manual/automatic)
- act upon the sensor readings (i.e., control the actuators) according to threshold values and current working mode
- check if there is an active internet connection
    - if **NO internet connection** available for more than 10 minutes, restart the ACU

ACU – Pseudocode (contd.)

- **else** - retrieve and parse the existing values from https://thingspeak.com (control and data channels)

  - update internal variables with the new values

  - attempt to save the ACU state (current time, sensor values and actuators' status) online at https://thingspeak.com

  - if necessary, store the new threshold values into EEPROM

- wait for 16 seconds

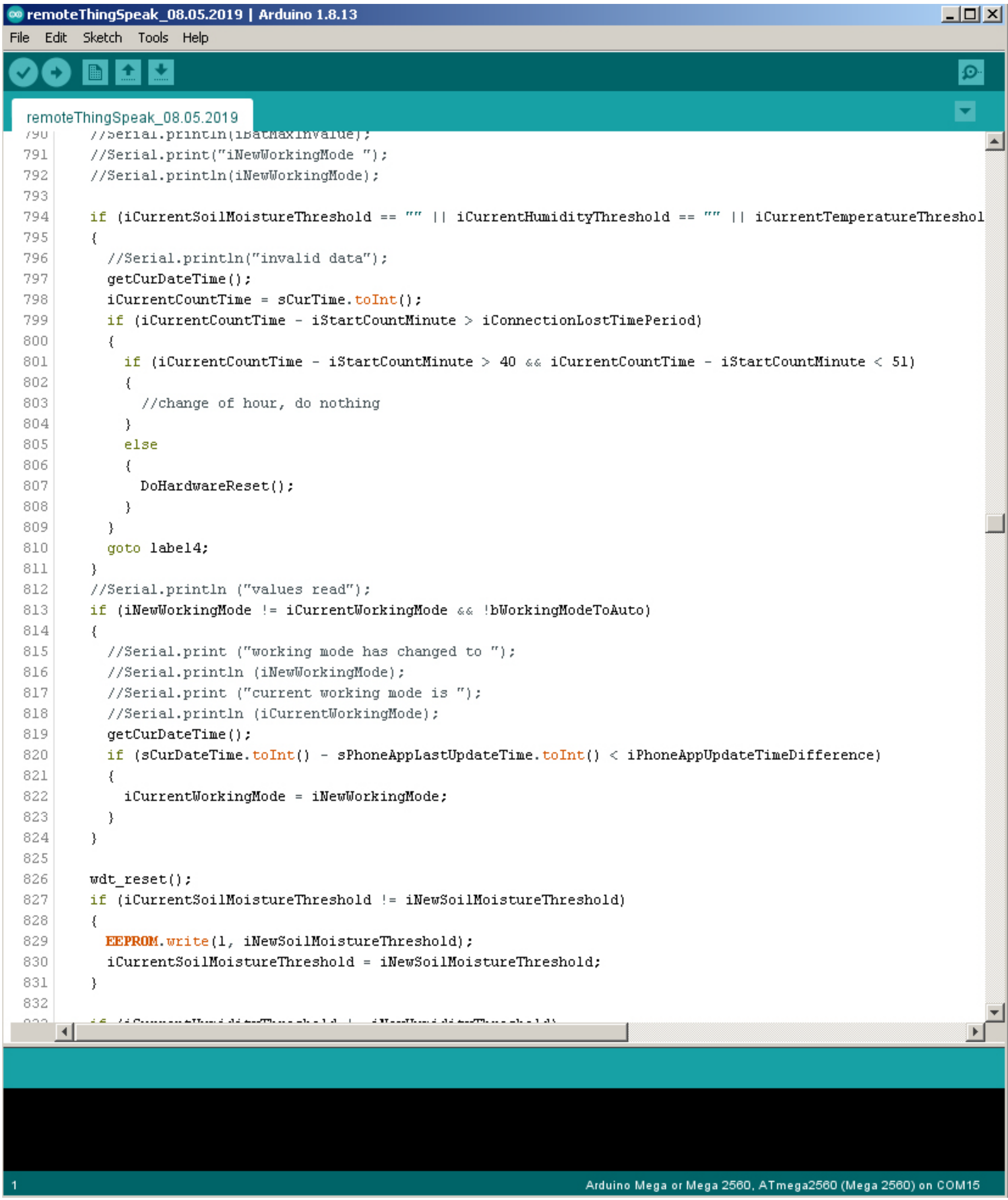
Additional procedures

- once a day, update the RTC with the time retrieved from the https://thingspeak.com server

  - at 3am every day, reset the Arduino board

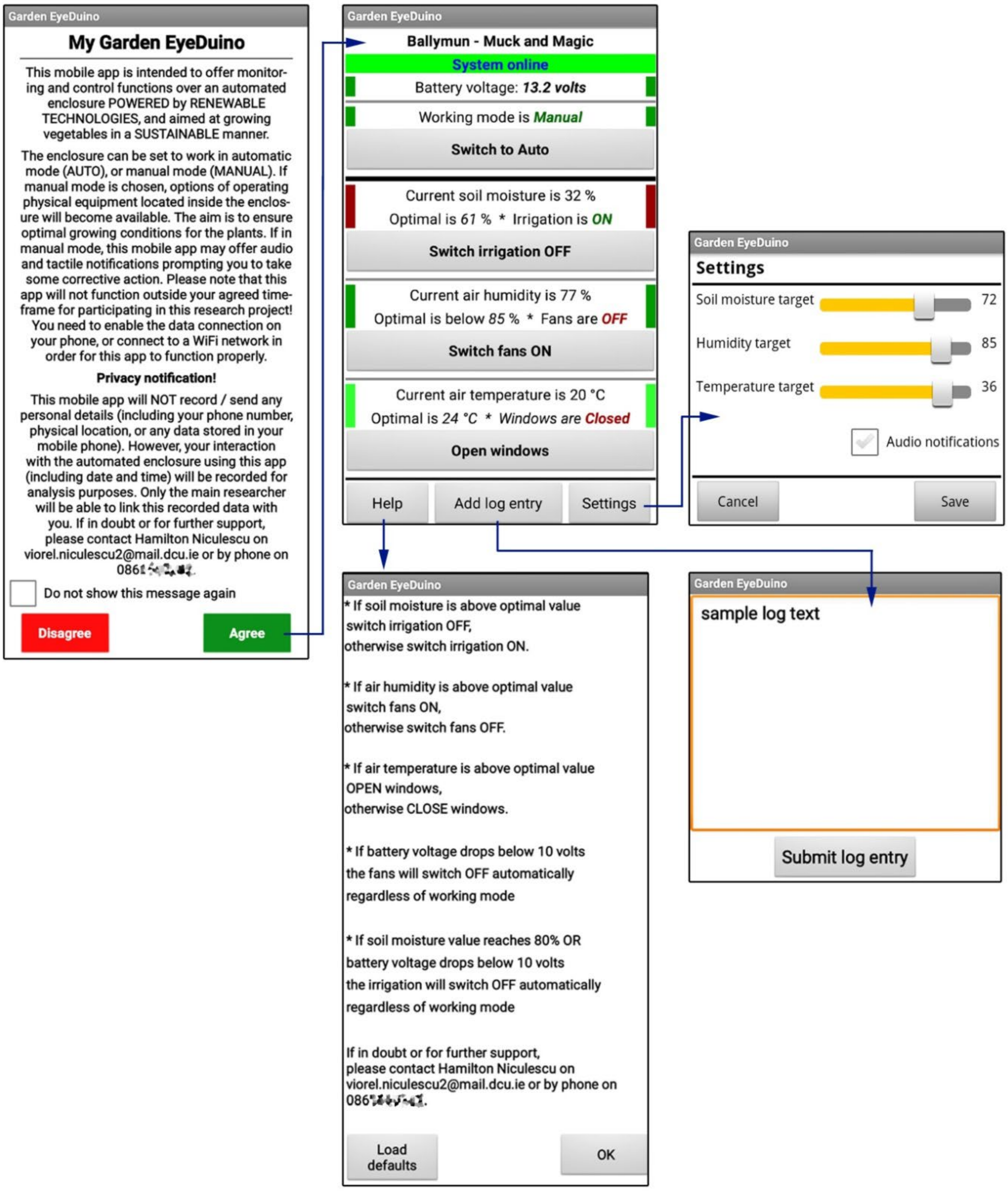
  - if the internet connection is unavailable for more than 10 minutes, switch to automatic working mode

ACU – Pseudocode (contd.)



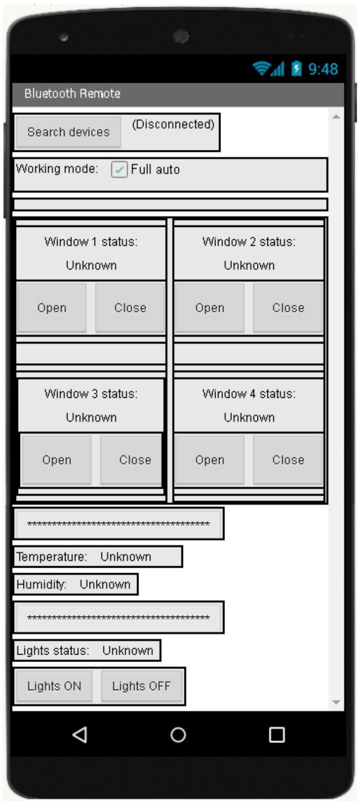
Sample code as it appears in the Arduino IDE (Integrated Development Environment). Source: Hamilton V. Niculescu

Appendix F *My Garden EyeDuino* app – Navigation & Design



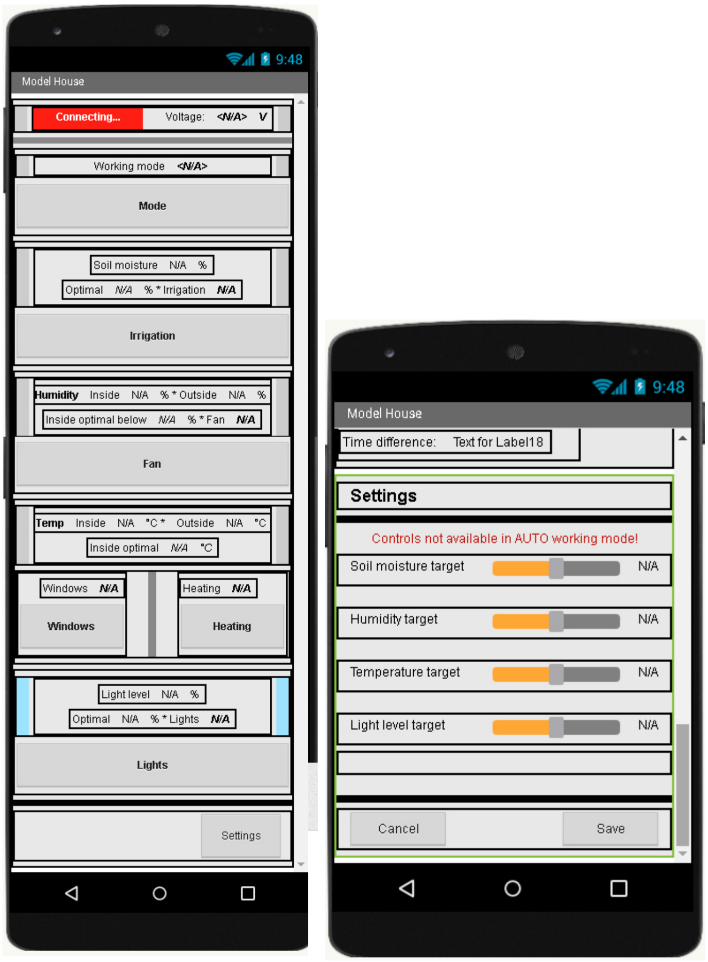
Mobile app interface and navigation flow. The working mobile phone app is included in the folder titled 'Portfolio' that accompanies this submission. Source: Hamilton V. Niculescu

Appendix G *My Garden EyeDuino* app – Development stages



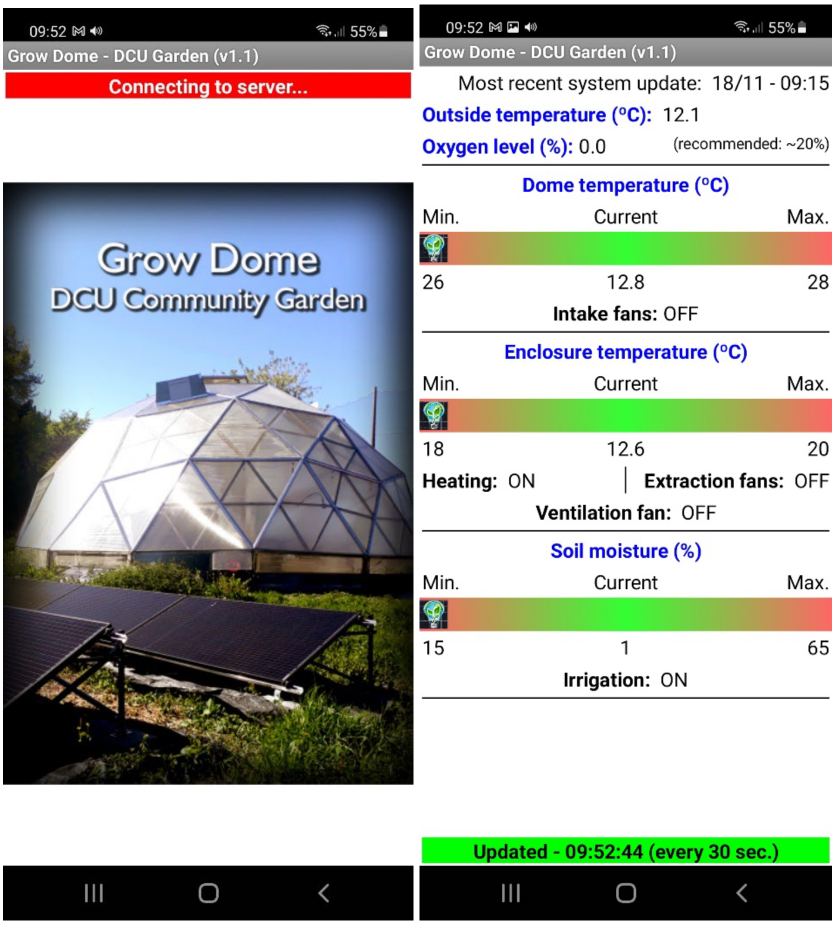
Initial version of the mobile app, with gardening automation technologies being controlled via Bluetooth communication. Source: Hamilton V. Niculescu via AppInventor/MIT

My Garden EyeDuino app – Development stages (contd.)



Experimental version of the mobile app, allowing to control automation features inside a plastic enclosure used for showcasing during conferences attended by the author. Source: Hamilton V. Niculescu via AppInventor/MIT

My Garden EyeDuino app – Development stages (contd.)

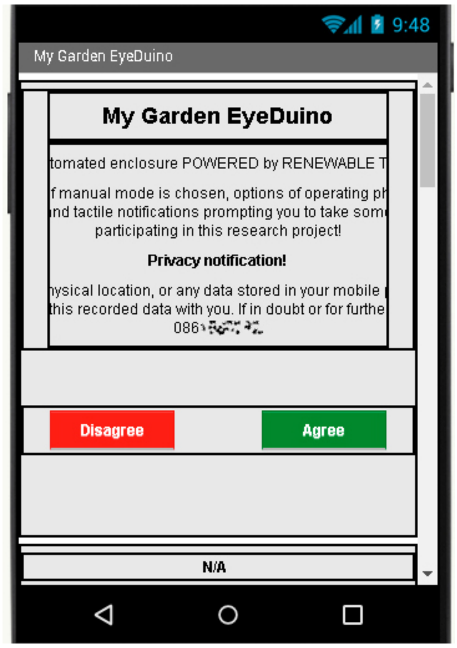


Extended version of the mobile app, titled Grow Dome – DCU Garden, commissioned by 'The Grow Dome Project' social enterprise. Source: Hamilton V. Niculescu

My Garden EyeDuino app – Development stages (contd.)

Early version of My Garden EyeDuino mobile app, where remote access to the BGAS was only granted during specific periods of time, to accommodate multiple participants at different time slots. This option was consequently replaced with a check against a unique API key stored on the online web server at https://thingspeak.com. Source: Hamilton V. Niculescu via AppInventor/MIT

My Garden EyeDuino app – Development stages (contd.)



The privacy notification screen was showing every time the user started the app. A checkbox was later added, for the user to be able to consequently disable this screen from being displayed. Source: Hamilton V. Niculescu via AppInventor/MIT

Appendix H My Garden EyeDuino app – Pseudocode

On start

- get settings from Tiny DB (privacy and sound notification status)
- check if the device has an internet connection
    - if **not available** - display an error message
    - **else** - initialise app

Initialise app

- initialise the start-up variables
- create the hyperlink to the online server (including API key)
- attempt to connect to the online server (***https://thingspeak.com***)
    - if connection **NOT successful**
        - leave controls disabled, except for the "Add log entry" button
        - display a connection error at the top of the screen
        - retry to connect to server every 30 seconds
    - **else** - attempt to retrieve online server data

Data retrieval

- if data retrieval **unsuccessful**
    - disable controls, except for the "Add log entry" button
    - display a connection error at the top of the screen
    - retry to retrieve data every 30 seconds (re-check if the connection is available)

- **else** - retrieve Ireland UTC time from http://api.timezonedb.com (not from the device*)
    - retrieve the latest ACU update time from ***https://thingspeak.com***
    - if the time difference between the two is **greater than 6 minutes**, assume that the ACU is offline, and get the time again after 30 seconds
    - **else** - enter normal app lifecycle

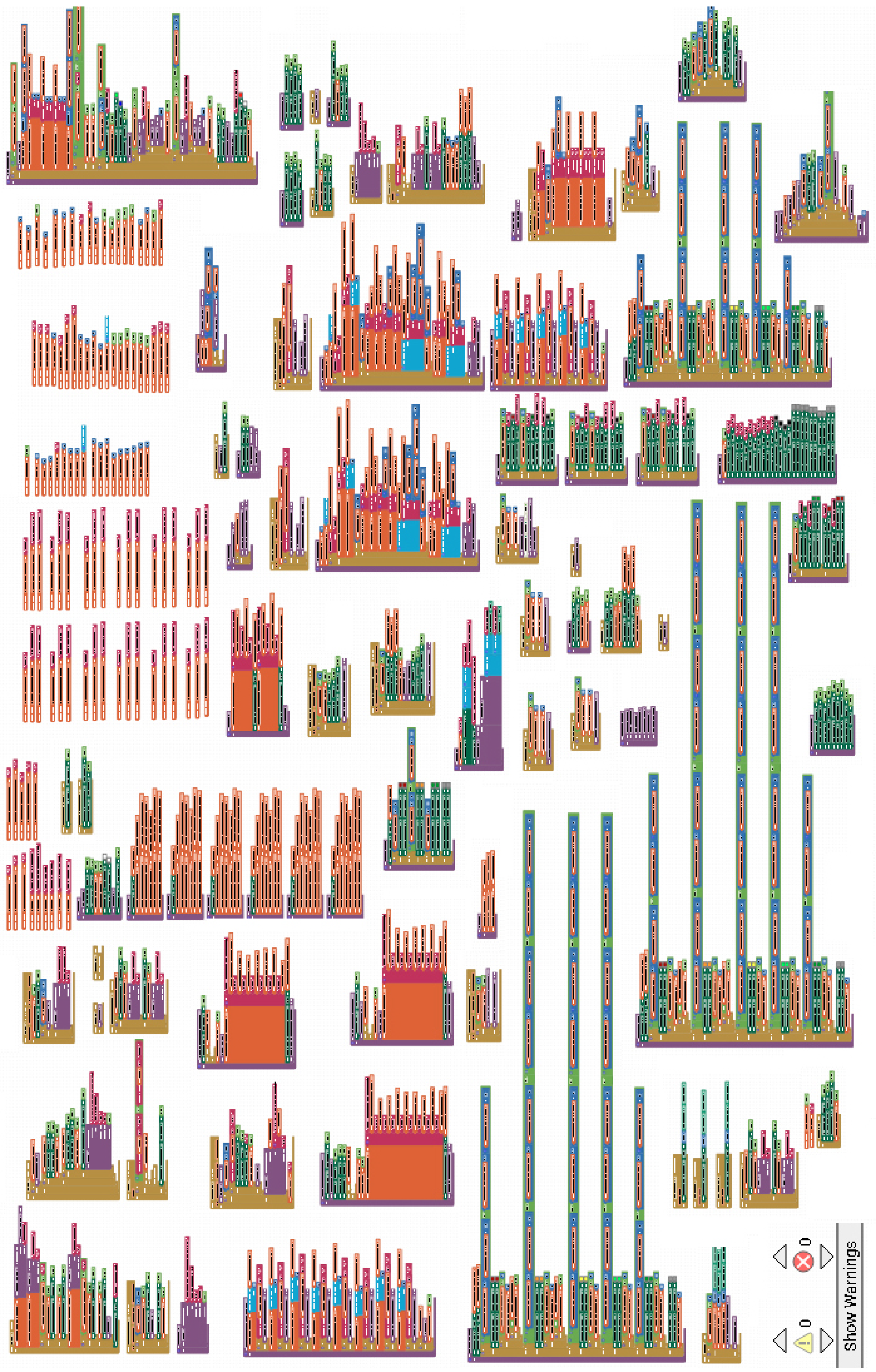
** In case the user travels abroad, within different time zones, the app will still retrieve Ireland's time*

My Garden EyeDuino app – Pseudocode (contd.)

Normal app cycle

- parse the data retrieved from ***https://thingspeak.com***
- enable and update controls as necessary
- log the current access date and time on ***https://thingspeak.com*** (data channel)
- monitor user's interaction with the interface and the controls
    - on user operating any controls
        - update variable values and the app interface
        - if required, save settings to Tiny DB (privacy and sound notifications)
        - attempt to update values on ***https://thingspeak.com*** (control channel)
    - on user sending a log - send an email notification to the researcher
    - check the battery voltage value
        - if **below 10 volts**, disable specific controls for actuators (i.e. irrigation valve, ventilation fan)
        - **else** – re-enable the controls
- attempt to retrieve data from ***https://thingspeak.com*** every 30 seconds (**Data retrieval**)

My Garden EyeDuino app – Pseudocode (contd.)



Code visualisation as it appears on the AppInventor online platform developed by MIT. Source: Hamilton V. Niculescu via AppInventor/MIT

Appendix I Research Site Agreement Form

AGREEMENT

This is to say that I ____

acting as ____ (administrator)

for ____ (location)

agree to allow **Mr Hamilton Viorel Niculescu (user)**, PhD student at Dublin City University, permission to **use the existing structure / build a new structure** on our location for the purpose of conducting part of his research study. The participants in the study will be recruited from within our existing members.

I understand that the period required for running this phase of the study starts September 2018 and ends December 2019.

There are no other obligations attached to any signing party of this agreement.

Date __________________

Signed ____

(administrator)

Signed ____

(user)

Appendix J **Sample Quantitative Data**

1	Created at	Working mode
623	2019-06-28 15:48:52 UTC	1
624	2019-06-29 02:27:51 UTC	1
625	2019-06-29 09:12:58 UTC	0
626	2019-06-29 09:13:02 UTC	0
627	2019-06-29 09:13:04 UTC	0
628	2019-06-29 20:50:56 UTC	1
629	2019-06-29 20:54:43 UTC	1
630	2019-06-29 21:56:51 UTC	1
631	2019-06-29 22:49:45 UTC	1
632	2019-06-30 02:14:00 UTC	1
633	2019-06-30 02:36:50 UTC	1
634	2019-06-30 03:28:52 UTC	1
635	2019-06-30 12:48:50 UTC	1
636	2019-07-01 06:02:08 UTC	1
637	2019-07-02 08:42:59 UTC	0
638	2019-07-02 08:43:06 UTC	0
639	2019-07-02 08:43:08 UTC	0
640	2019-07-02 08:43:13 UTC	0
641	2019-07-02 08:43:15 UTC	0
642	2019-07-02 13:56:54 UTC	1
643	2019-07-03 00:09:41 UTC	1
644	2019-07-03 08:37:38 UTC	0
645	2019-07-03 08:37:50 UTC	0
646	2019-07-03 08:37:53 UTC	0
647	2019-07-03 08:39:12 UTC	0
648	2019-07-03 08:39:15 UTC	0
649	2019-07-03 08:39:38 UTC	0

Date / time stamped data showing the system's working mode of one of the six enclosures, represented as 1 = automatic, 0 = manual. Source: Hamilton V. Niculescu via https://thingspeak.com

Sample Quantitative Data (contd.)

1	Created at	Battery voltage	Soil moisture	Irrigation	Air humidity	Fan	Temperature (centigrade)	Windows
352702	2019-06-22 15:19:57 UTC	13.9	62	0	48	0	32	1
352703	2019-06-22 15:20:23 UTC	13.8	62	0	47	0	31	1
352704	2019-06-22 15:20:46 UTC	13.7	62	0	47	0	32	1
352705	2019-06-22 15:21:10 UTC	13.8	62	0	46	0	32	1
352706	2019-06-22 15:21:30 UTC	13.7	62	0	46	0	32	1
352707	2019-06-22 15:21:50 UTC	13.8	62	0	47	0	32	1
352708	2019-06-22 15:22:11 UTC	13.8	62	0	46	0	31	1
352709	2019-06-22 15:22:36 UTC	13.9	62	0	47	0	31	1
352710	2019-06-22 15:23:00 UTC	13.8	62	0	48	0	31	1
352711	2019-06-22 15:23:24 UTC	13.8	62	0	48	0	31	1
352712	2019-06-22 15:23:49 UTC	13.9	62	0	48	0	31	1
352713	2019-06-22 15:24:13 UTC	13.8	62	0	49	0	31	1
352714	2019-06-22 15:24:39 UTC	13.7	62	0	48	0	31	1
352715	2019-06-22 15:25:01 UTC	13.8	62	0	49	0	31	1
352716	2019-06-22 15:25:26 UTC	13.8	62	0	49	0	31	1
352717	2019-06-22 15:25:50 UTC	13.8	62	0	49	0	31	1
352718	2019-06-22 15:26:31 UTC	13.8	62	0	50	0	31	1
352719	2019-06-22 15:26:55 UTC	13.8	62	0	49	0	30	1
352720	2019-06-22 15:27:15 UTC	13.9	62	0	50	0	30	1
352721	2019-06-22 15:27:57 UTC	13.8	62	0	50	0	30	1
352722	2019-06-22 15:28:22 UTC	13.8	62	0	51	0	30	1
352723	2019-06-22 15:28:46 UTC	13.8	62	0	51	0	30	1
352724	2019-06-22 15:29:10 UTC	13.9	62	0	52	0	29	1
352725	2019-06-22 15:29:34 UTC	13.9	62	0	52	0	29	1
352726	2019-06-22 15:29:58 UTC	13.9	62	0	52	0	29	1
352727	2019-06-22 15:30:18 UTC	13.7	62	0	53	0	29	1
352728	2019-06-22 15:30:43 UTC	13.8	62	0	53	0	28	1
352729	2019-06-22 15:31:09 UTC	13.8	62	0	54	0	28	1
352730	2019-06-22 15:31:34 UTC	13.9	62	0	54	0	28	1
352731	2019-06-22 15:31:59 UTC	13.9	62	0	55	0	28	1

System's current status and the climate conditions inside one of the six enclosures, with devices represented as 0 = OFF / Closed, 1 = ON / Open. Source: Hamilton V. Niculescu via https://thingspeak.com

Appendix K Sample Interview Questions

Interview questions (first round)

1.1. How would you define the notion of energy? What about renewable energy sources?

1.2. Would you like to tell me about your profession / job / hobbies?

1.3. Are you aware of any programmes at your workplace / school aimed at reducing energy waste / recycling facilities?

1.4. What about within your household? Does your family recycle reusable materials and try to reduce the amount of waste, especially food? (if Yes or NO -> why?)

1.5. Do you speak to other people about ways of reducing your household energy bills and / or food waste?

1.6. Are you or someone in your family using any technology aimed at monitoring your household energy consumption?

1.7. Does the word "technology" scare you, or makes you feel uncomfortable, when talking to other people for instance?

1.8. Let us say that a new, improved model of a device that you already own (like a mobile phone, TV set, laptop, etc.) becomes available on the market. How quickly would you be inclined to buy it?

1.9. Would you prefer to buy it online or from a regular shop? Please explain.

1.10. When buying new technologies, what are the most important aspects you would consider when choosing a model over another? Would you consider energy consumption or the price as being more important to you?

1.11. Let us say that you notice that your neighbour had a few solar panels installed on the roof on top of their house. What would your reaction be?

1.12. If your household were to be partly powered by renewable energy sources, such as photovoltaic solar panels, how do you think this would influence your lifestyle?

Sample Interview Questions (contd.)

Interview questions (second round)

2.1. Please describe your overall experience with being involved in this project for the past three months.

2.2. How did you find using a mobile phone app to remotely control the automated enclosure? Was it a pleasant or not so pleasant experience?

2.3. Please try and remember one occasion when you had troubles using the app.

2.4. How often do you reckon you were remotely checking the conditions inside the enclosure? Do you think this had any influence on other activities you may have had done otherwise?

2.5. Tell me how this experience has had any positive or negative influence on your lifestyle.

2.6. At this point in time (<*according to available quantitative data*>) you changed the system status from (<as indicated by quantitative data>). Can you remember what the reason was for you taking that decision?

2.7. Your objective was to ensure better growing conditions for the vegetables inside the enclosure. How was this making you feel?

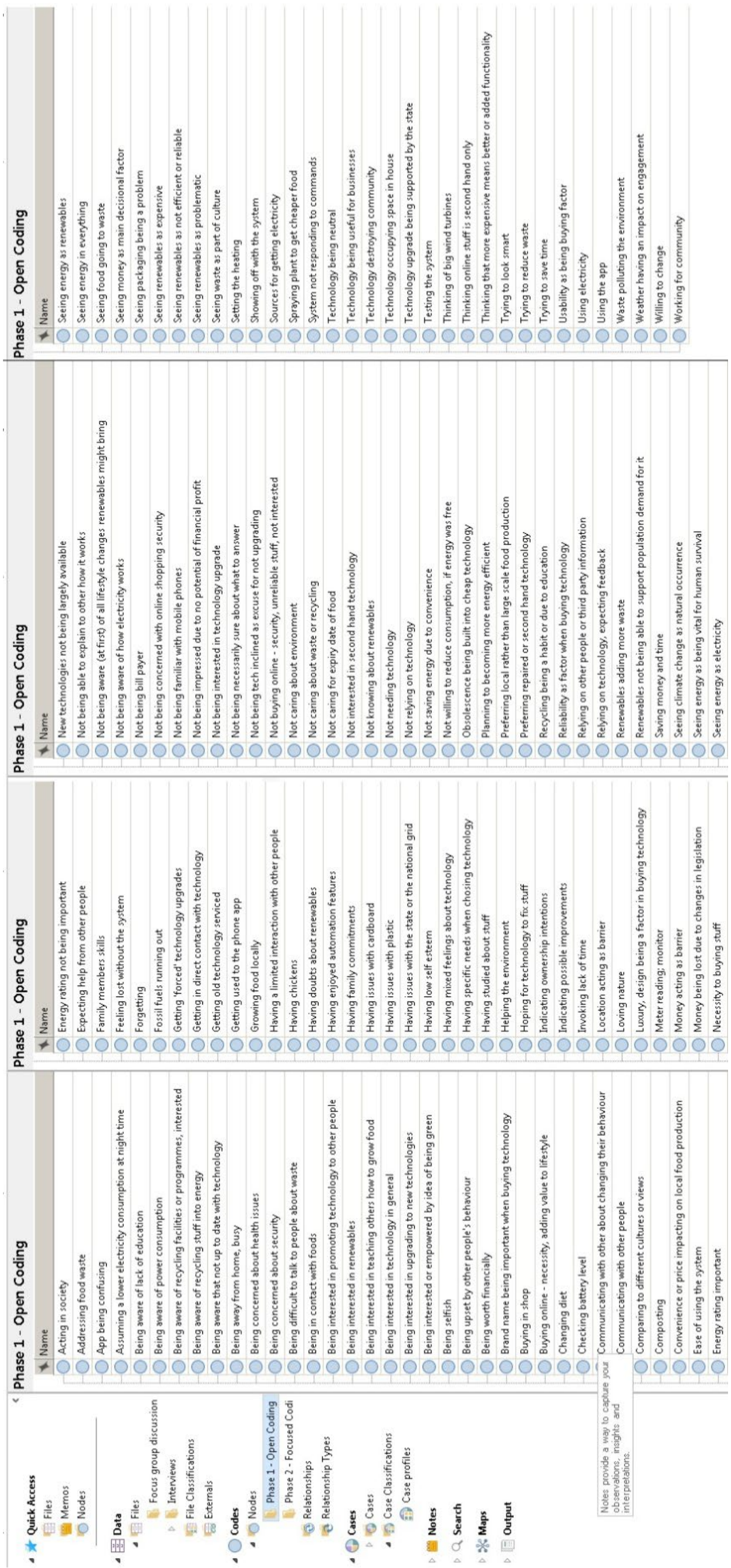
2.8. Would you now feel more comfortable if you were to speak to other people about renewable energy sources, like solar panels, or automation features that can assist with growing vegetables?

2.9. Would you say that now you are more aware of advantages and disadvantages of using renewable energy sources – solar panels in this case?

2.10. What were other people's reactions when you told them about your new activity?

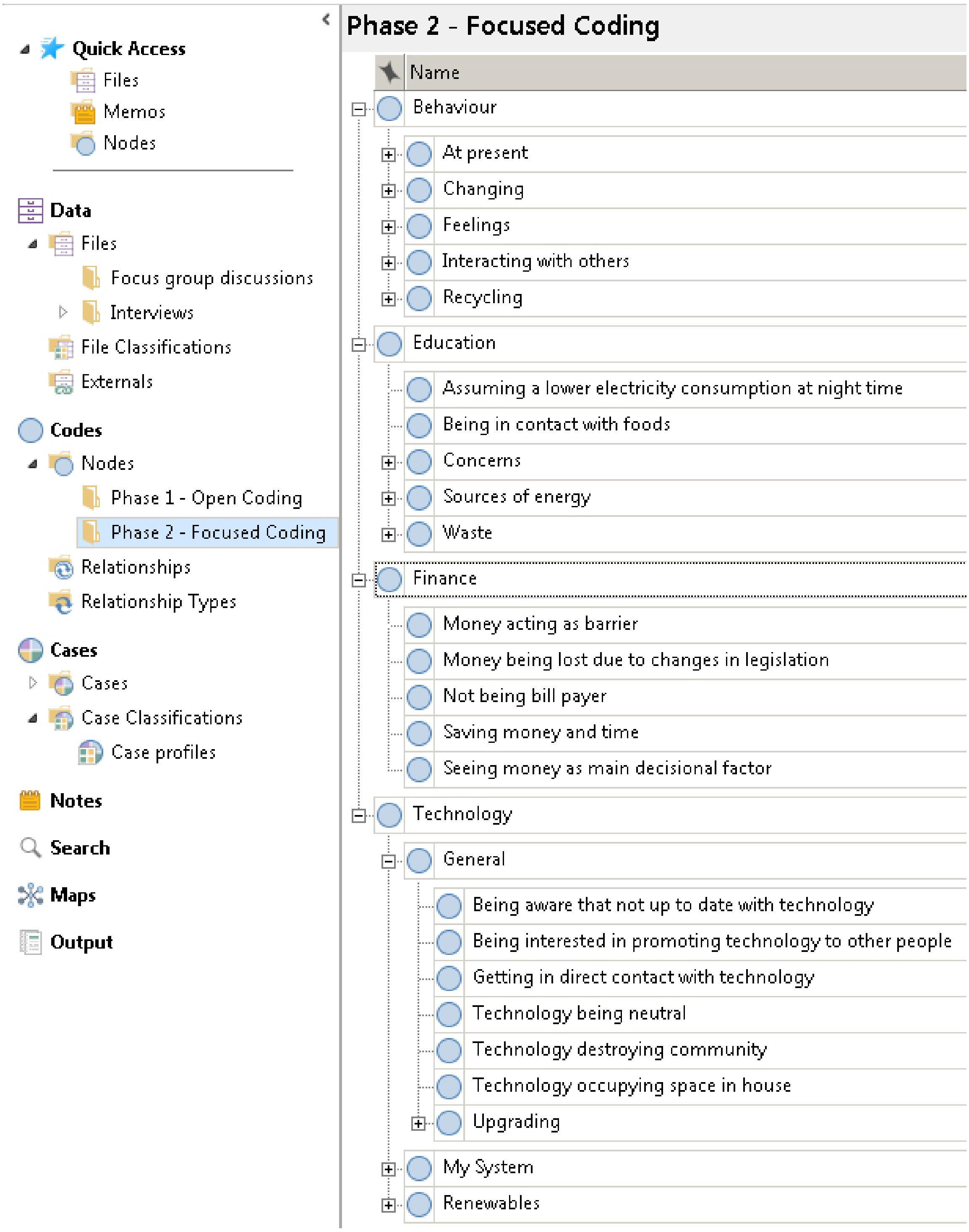
2.11. What would you change about this automated system to make it better, more accessible, or attractive to people?

Appendix L **NVivo Coding**



The open coding stage in NVivo software. Source: Hamilton V. Niculescu

NVivo Coding (contd.)



The focused coding stage in NVivo software. Source: Hamilton V. Niculescu

Appendix M **List of conferences**

Aug 2020 *A Constructivist Grounded Theory Study on the Impact of Automation on People and Gardening.* ICICTES 2020: XIV. International Conference on ICTs for Environment and Sustainability. Venice, Italy (virtual). (€450 funding received from Lean Launch Programme, Dublin City University)

Jun 2020 *Information Communication Technologies and Renewable Technologies' Impact on Irish People's Lifestyle: A Constructivist Grounded Theory Study.* ICICTSD 2020: XIV. International Conference on Information and Communication Technologies for Sustainable Development. Copenhagen, Denmark (virtual). (€400 funding received from Lean Launch Programme, Dublin City University)

Jul 2019 *Technology and Communication in Irish Culture.* The 7th European Conference on Arts & Humanities (ECAH2019). Brighton, UK. (€500 funding received from Dublin City University)

Jul 2019 *People's Engagement with Renewable Technologies - Roadblocks and Triggers.* The 7th European Conference on Sustainability, Energy & the Environment (ECSEE2019). Brighton, UK

Apr 2019 *Green Technologies at Your Green Fingertips.* South East Business Expo 2019. Waterford, Ireland (invited speaker)

Jan 2019 *Remote Monitoring and Control of Sustainable Automated Enclosures Aimed at Growing Vegetables.* The National Sustainability Summit 2019, Securing Ireland's Future. Citywest, Ireland (invited speaker)

May 2018 *People Engagement with (Renewable) Technology Systems – Roadblocks and Triggers.* Limerick Postgraduate Research Conference 2018, Connect Through Research. Limerick, Ireland

Mar 2018 *Remote Monitoring and Control of Sustainable Automated Enclosures Aimed at Growing Vegetables.* National Health Expo 2018. Citywest, Ireland (invited speaker)

Jan 2018 *Sustainable Automated Enclosures, Green Food Production, and People's Behaviour Change.* The National Sustainability Summit 2018, Securing Ireland's Future. Citywest, Ireland

Appendix N DCU Research Ethics Committee approval

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

DCU

Mr Hamilton Viorel Niculescu
School of Communication

28th January 2019

REC Reference: **DCUREC/2018_258**

Proposal Title: **Peoples' engagement with (renewable) technology systems. Roadblocks and Triggers**

Applicant(s): **Mr Hamilton Viorel Niculescu**

Dear Hamilton,

This research proposal qualifies under our Notification Procedure, as a low risk social research project. Therefore, the DCU Research Ethics Committee approves this project.

Materials used to recruit participants should state that ethical approval for this project has been obtained from the Dublin City University Research Ethics Committee.

Should substantial modifications to the research protocol be required at a later stage, a further amendment submission should be made to the REC.

Yours sincerely,

Dónal O' Gorman

Dr Dónal O'Gorman
Chairperson
DCU Research Ethics Committee

DCU
Research & Innovation

Taighde & Nuálaíocht Tacaíocht
Ollscoil Chathair Bhaile Átha Cliath,
Baile Átha Cliath, Éire

Research & Innovation Support
Dublin City University,
Dublin 9, Ireland

T +353 1 700 8000
F +353 1 700 8002
E research@dcu.ie
www.dcu.ie

Appendix O **Plain Language Statement**

Research project name: **People's engagement with (renewable) technology systems.**
Roadblocks and triggers.
Researcher's name: **Hamilton Viorel Niculescu**
Mobile: 086xxxxxxx
Email: viorel.niculescu2@mail.dcu.ie
School of Communications, Dublin City University

Personal Data – GDPR (General Data Protection Regulation) Compliance

- Your personal data will be collected and processed by the researcher only. No personal details will be made available to any third parties.
- The personal data that will be collected refer to your age, gender, education, employment status, property (house) owner, number of family members.
- The data collected during your participation in this research project will be solely used by the researcher for the purpose of identifying the factors influencing people's engagement with technology.
- The collected data will be held for a maximum of 15 months, after which it will be securely destroyed.
- Upon request, the collected data and analysis will be available to you for any amendments.
- You can withdraw from this research project at any stage, without any penalty or personal consequences.
- ***DCU Data Protection Officer***
  Mr Martin Ward
  data.protection@dcu.ie
  Ph: 7005118 / 7008257

Participation in this study is entirely voluntary. Should you agree to participate in this research study, you will be expected to:

- Remotely interact with the automated enclosure for a continuous period of three months, by using the mobile phone app provided free of charge by the researcher. The mobile phone app will stop working at the end of this trial period.
- Be available for two interviews, each approx. 45 min. long, one before the start of your three-month trial period, and the other after this period has ended. The interviews will be video, and audio recorded for the purpose of later data analysis.

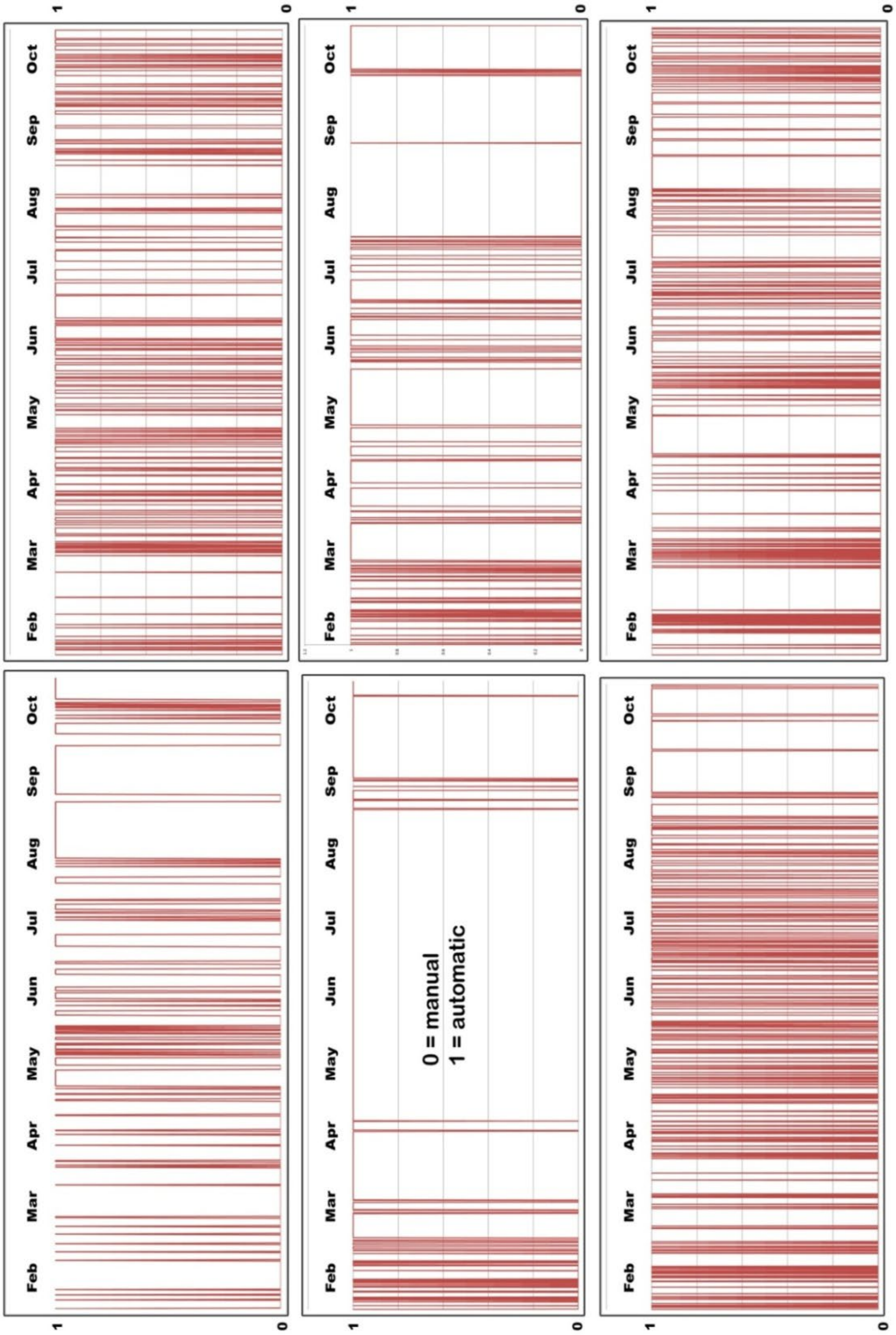
While there are no direct risks associated with using the mobile phone app to remotely control the enclosure, any physical work within the enclosure (attending to the vegetables) may pose some risks, not greater than those usually associated with working in any garden.

At the end of your trial period, you will learn about potential benefits and any disadvantages related to using mobile technology in combination with automated systems to grow vegetables. At the end of the growing season and of this research phase (November 2019) you will share any produce with the other two participants in the study.

Please be aware that due to the small size and design of this research study, anonymity cannot be fully guaranteed by the researcher, despite all the steps and procedures taken to anonymise your data. Confidentiality of information provided cannot always be guaranteed by the researcher and can only be protected within the limitations of the law.

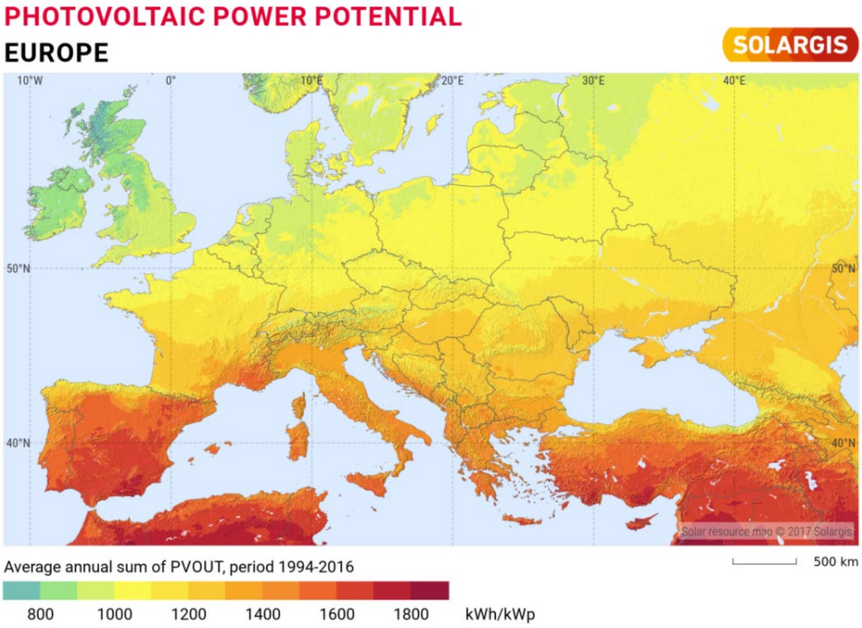
If participants have concerns about this study and wish to contact an independent person, please contact:
The Secretary
Dublin City University Research Ethics Committee
c/o Research and Innovation Support
Dublin City University
Dublin 9
Tel. 01-7008000
Email: rec@dcu.ie

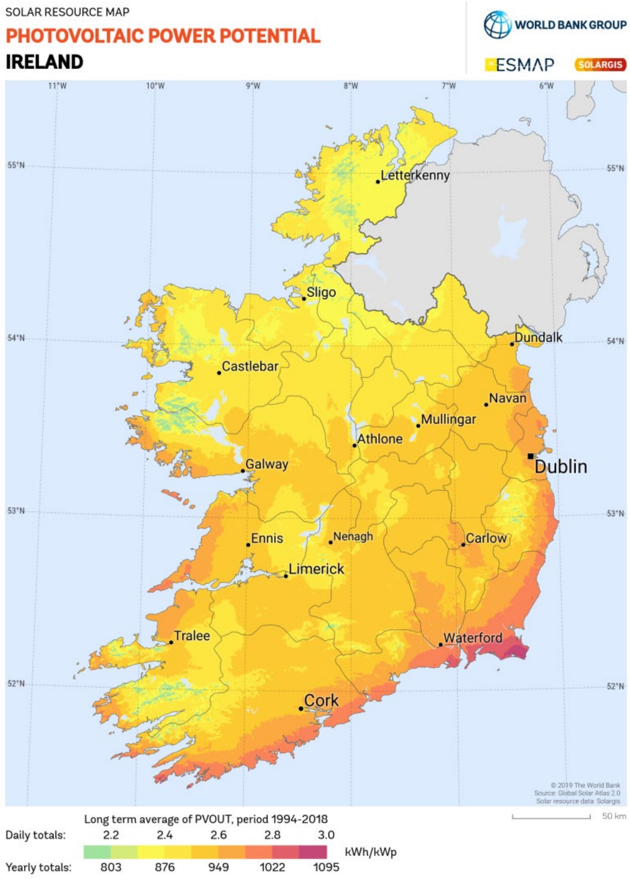
Appendix P **Participants' interaction with the six enclosures**



Quantitative data illustrating participants' interaction with the six enclosures over the nine-month period. 0 indicates that the system is performing in manual mode, 1 indicates automatic mode. Source: Hamilton V. Niculescu via https://thingspeak.com

Appendix Q **The insolation factor in Ireland**





Source: © 2019 The World Bank, Source: Global Solar Atlas 2.0, Solar resource data: Solargis, https://solargis.com

Appendix R **Drawing following focus group discussion**

Source: Hamilton V. Niculescu