The Living Lab

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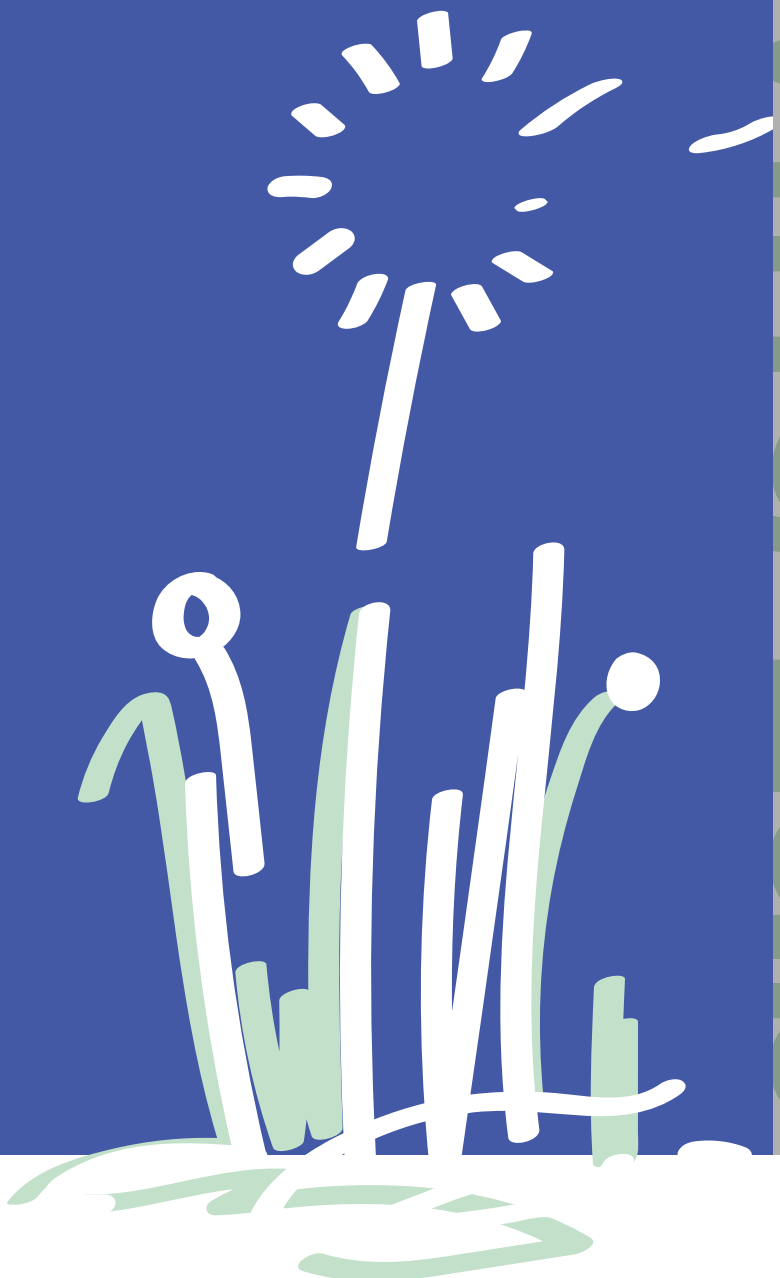

University of Dundee

The Living Lab

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EDITORIAL

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INTRODUCTION

Creating a new journal can be a substantial endeavour with numerous potential benefits, but there are also reasons why you might reconsider or think twice about launching one. The Living Lab journal exists to give researchers and practitioners a voice and to bring the work they do in furthering their objectives to a worldwide audience. It is for educationalists, scientists, artists, philosophers and poets who associate with the University of Dundee Botanic Garden Living Laboratory, and its key areas of ecological leadership; outdoor learning; education for sustainability, environmental art, philosophy and human ecology.

The journal is for specialists and students who are inspired by, and want to engage in, addressing the balance between the social and the ecosystem. The editors particularly welcome articles in these key areas of research, while encouraging PhD students associated with the Living Lab to contribute and explore their formative work within allied fields of curation, ecological science, health and wellbeing,

community engagement and education for sustainability. The editorial board of this journal believe that the benefits outweigh the disbenefits for a number of reasons, which include filling a gap in the existing literature and addressing the lack of dedicated platforms for early career researchers and their mentors, while allowing a sense of community to develop among researchers, educators and practitioners interested in this field. It Is hoped that the new journal can serve as a focal point for collaboration and discussion, shaping the discourse and influencing the direction of research and practices within this new domain; botanic garden and university campus as a living laboratory, potentially making a substantial impact in that field.

A living laboratory is essentially a real-world environment where research, experiments and innovations are conducted to explore and implement new ideas, technologies or practices. It's a setting where researchers, scientists, engineers and other experts work in collaboration with communities, businesses or institutions to test hypotheses, analyse data and develop solutions in a practical and tangible way. These laboratories often involve actual communities or spaces where various experiments or studies are carried out, allowing researchers to observe, collect data, and analyse the results in a real-world context. In this instance, a garden and university campus are aligned to a city that serve as a scalable living laboratory for testing sustainable technologies, urban planning initiatives, or behavioural studies. The concept promotes hands-on learning, interdisciplinary collaboration, and the application of theoretical knowledge in real-world scenarios. It's a way to bridge the gap between theory and practice, fostering innovation and sustainable solutions for diverse fields such as urban planning, environmental science, healthcare and more.

In this first journal, the papers present formative work taking place in the period of 2020-2023; a transitional period marking a rite of passage as the University of Dundee Botanic Garden came of age, 50 years after its opening and development along ecological lines. It is a relatively new garden and yet one already imbued with emotion and intimately connected to the development of the university and city of Dundee. A place imbued with emotion and yet existing in the interstitial space between the town and gown. A place of education, entertainment, outreach and since 2020, research. A place where art, science and a good day out can co-exist. A place that explores the human and more than human relationship with the world.

This inaugural edition of the Botanic Garden Living Lab journal itself epitomises the principles of a living laboratory; a co-creative initiative, integrating research and innovation, presenting an opportunity for students and academic staff to jointly contribute to a collaborative project—the

journal—exploring sustainability and associated issues. The Living Lab, however, is a virtual entity that also reaches out to professional staff and external bodies, tackling a broad reach of projects and collaborations. Not only is the Botanic Garden Living Lab timely but so too is this journal. We live in a fast-changing world where the need for a clear insight into our impact on the planet and its balance of physical components and biological systems, is ever more prevalent. With this, is the increased importance of our understanding of how the planet functions through ecological balance and sustainability. To gain an appreciation of the principles underpinning ecological and environmental balance and the interdisciplinary nature of that knowledge demands objectivity, accountability, integrity on the part of the knowledge providers and selfless leadership; all in a quest to meet current challenges of food security, improved air, water and soil quality, and sustained biodiversity, fundamental to any functioning ecosystem. To achieve this we need to acknowledge, develop and enable quality educational support in sustainability at all levels, from professionals and research academics to amateur enthusiasts and the young child innocently exploring the urban green environment.

Throughout this journal and indeed as manifests through the Living Lab, interdisciplinary networking and collaboration sits firmly within our remit. There is a resounding emphasis on evidence-based science whilst reaching out to all sectors of the populous, focusing our aim to engage and enthuse future generations. The goalposts, however, continue to move as we find ourselves in an increasingly 'alien' world where remote learning and teaching has become the 'new norm', and emphasis on nature connectivity and outdoor learning has become increasingly more important.

This first edition of the journal sees the Living Lab well into its second year with several original PhD students nearing completion. Included in this edition are articles from representatives across the Living Lab: PhD students actively researching education for sustainability and biodiversity through a diverse set of projects, academic supervisors reporting on their own related research, the Living Lab Director, and the Botanic Garden Curator. All have key roles to play in illustrating and enacting the various aspirations of the Living Lab.

As Liz Lakin reports in the first article of this inaugural issue of the journal, the inception of the Living Lab can be traced back to a recently established doctoral program that emphasises fostering cross-disciplinary collaboration among seasoned researchers and post-doctoral/doctoral students and local, national and international partners. Liz begins by exploring the concept of a Living Lab, before

providing a reflective review of the past two years, chronicling the Living Lab's evolution. The narrative then shifts towards the future to capture the aspirations for the upcoming phase.

Given the Living Lab's integral role within the University of Dundee Botanic Garden, it is imperative to grasp the history and work of a contemporary botanic garden regarding its curatorial practices and its interconnection with the social environment, aiming to advance sustainable development. Using a systematic approach, Botanic Garden Curator Kevin Frediani reviews the evolution of Western botanic gardens by investigating the external factors that have shaped their collection acquisitions. Kevin then utilises his findings to explore the epistemic role of the curator. The discussion then moves to evaluating the sustainable development framework before recognising the potential of nature-based solutions alongside a Just Transition as ways to inform policy and guide practices.

The next article is the first of three from PhD students at the University. Commencing with John Hale's paper, we learn about the Daffodil DNA project taking place in post-16 biology education across the UK in partnership with STEM partners, the James Hutton Institute and the University of Dundee. Drawing from citizen science and merging this with classroom practices, John provides us with an overview of the laboratory procedures undertaken by the students involved—with teacher support. A crucial component of this study is the 'life-changing' feedback offered by the students after their participation, not only in the project itself but also through presenting their findings at the Royal Society Summer Science Exhibition. John proposes that the Daffodil DNA Project presents a potential model for inquiry-based learning in biology education, highlighting the significance of genuine scientific exploration and collaboration.

Remaining with plant biology and education, Kara McHugh reports on her three-month professional internship working within a university botanic garden where she explored science communication with various audiences, including school pupils and teachers along with the general public. After defining the meaning of science communication and reviewing its importance, Kara sets out to inform how she leveraged her expertise in molecular biology and protein biochemistry to create a novel educational and recreational resource that showcases plants that possess medicinal properties. The purpose of this new resource was to enhance the sense of nature connectedness for visitors to the botanic garden by providing information and entertainment. The resource is due to be launched in 2024 when Kara will investigate the impact of the resource.

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The third paper from the University's doctoral students is from Carmela Garcia Manas who provides us with a literature review focusing on education for social sustainability in the early years. Carmela commences by delving into the literature that underscores the imperative for integrating sustainable education into early childhood education. It subsequently provides a brief overview of previously published research initiatives centred on the three dimensions of sustainability—environmental, social and economic. Throughout the paper, Carmela challenges some core assumptions of what it means to be sustainable and argues that this understanding needs to be integral to early years education.

The final article in this first issue considers education for sustainable development through computer-mediated communication (CMC). Through the lens of social leadership, Marie Beresford-Dey, Andrea Cooper, Mike Crabb, Kristi Herd and Lorraine Syme-Smith report on a mixed methods study investigating one botanic garden's use of CMC tools such as social media and their webpages. The results underscore the staff and volunteers' eagerness to boost the utilisation of CMC tools for improved community engagement and information dissemination. Additionally, the findings suggest a requirement for increased autonomy and an intrapreneurial mindset to heighten knowledge and reinforce collaborative efforts within networks that are not predetermined or dictated by organisational structures.

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THE UNIVERSITY OF DUNDEE BOTANIC GARDEN, LIVING LAB: THE POWER OF PARTNERSHIPS

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ABSTRACT

The University of Dundee Botanic Garden, Living Lab, is a co-creative initiative, integrating research and innovation, that presents an opportunity for students, academic staff, professional staff and external bodies to collaborate on projects exploring sustainability problems. It aims to host projects partnering with participants from different backgrounds, to collectively address real-world sustainability challenges by responding to opportunities. These challenges and opportunities include (but are not exclusive to) landscape issues, both green and blue infrastructure, education for sustainable development, nature connection, plant-blindness and nature-based solutions.

The Living Lab has grown out of a new doctoral programme with a focus on forming a cross disciplinary collaboration of established researchers, new post-doctoral students and self-funded PhDs and MSc's that began in January 2021. Partners include local, national and international schools, research-based centres such as the James Hutton Institute and the Royal Society, other universities and various NGOs nationally and internationally. This paper begins by exploring the

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concept of a Living Lab, then goes on to review the University of Dundee's Living Lab, based at the Botanic Garden. Drawing on reflective evaluation from stakeholders, this review looks back over the past two years, documenting the Living Lab's germination from a seed of an idea to the flourishing 'sapling' that it has developed into. The paper then refocuses to capture hopes and aspirations for the next phase as we put down our roots and extend our branches further across the University, Dundee, the UK and beyond.

Keywords: Living Lab, sustainability, education, partnerships, research and innovation, botanic gardens

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INTRODUCTION: UNIVERSITY OF DUNDEE BOTANIC GARDEN AND THE LIVING LAB

The University of Dundee (UoD) was founded in 1967 and the botanic garden, approved by the first Principal, James Drever, was opened in 1971. The botanists of the Old Medical School and Biological Sciences Department, together with the garden's first curator Eddie Kemp, established a modern-style garden with a physically and philosophically central native plants area laid out on ecological lines representing the plants associated together in their native habitats (Kemp, 1974). Since that time and 50 years on, the garden has expanded as a visitor attraction with its own visitor centre, garden of evolution and a focus on raising public awareness through engagement and education. The native area was remodelled from early 2014 to better align it with local habitats and their associated plants (Bisset, 1992: Hood and Reaney, 2013). Adopting this more contemporary approach, botanic gardens around the world are looking to nature and community-based solutions to help communities adapt and mitigate for the climate emergency, now based around unique contributions to climate change research, conservation and public engagement (Primack *et al.,* 2021). The UoD Botanic Garden, with the support of a wide stakeholder review, has begun to take forward a new strategy focussed on a nested set of aims and objectives, realigning the garden with the UoD, the City of Dundee ad the global challenges of biodiversity loss, increasing urban populations and climate change (Frediani, 2021).

At the UoD Botanic Garden, external interventions are evidenced within the research base of staff and students who together take forward the concept of a 'Living Lab' (Ibid.), based within the onsite Macro Micro building. The Macro Micro building, being an experimental construction conceived, designed and built by engineering students, staff and external partners, boasts the first zero carbon building in Scotland in 2013 (Burford *et al.,* 2013). The use of 'green buildings' as teaching tools for sustainability, was growing across the sector at the time (Cole, 2014, cited in Dabaieh *et al.,* 2018). At the time of construction in the early 2000s, the concept of a Living Lab was not used in the UoD in this context, however, the main pedagogic philosophy of learning by doing and experimenting in an urban environment, using critical inquiry, process-based learning, community design and community build, resonates with Living Lab ideologies (Salama, 2010; 2015, cited in Dabaieh *et al.,* 2018). Today the Macro Micro building forms the real and virtual home for the UoD, Botanic Garden Living Lab—a research hub established in 2020, now consisting of seven PhD students, an academic cross-university community and a network of primary and secondary schools reaching across Scotland, the UK and out to Jersey. The overarching research focus is 'Education for Sustainability', tightly aligning

the garden research with the UoD's mission, whilst supporting local community work beyond the garden wall.

THE LIVING LAB

According to Leminen & Schuurman (2022), the concept of the Living Lab within the context of technology innovation began to take off in 2006. The European Network of Living Labs was formed shortly afterwards. Schuurman & Leminen (2021) perceive Living Labs as mainly focusing on experimenting with novel technologies. In parallel to this technological evolution a pedagogic philosophy was developing, its roots however go back to at least the 1980s, when it was defined in terms of a co-creative process, integrating research and innovation on a given topic. The topic in question focused increasingly on sustainability and the concept, according the 'Alliance for Sustainability Leadership in Education' (EAUC, 2021), was recognised across tertiary education. The alliance goes on to state that, although applied in different ways depending on context and institution, Living Labs aim to establish partnerships connecting academic activities with non-academic partners (EAUC, 2021).

At the UoD Botanic Garden, the Living Lab grew out of a new doctoral programme with an initial focus on developing an interdisciplinary collaboration of established researchers, post-doctoral students, self-funded PhDs and MSc's commencing in January 2021. The idea however, of a Centre for the Environment based at the botanic garden pre-dates, but later morphed into, the current Living Lab, by responding to a series of serendipitous occurrences, coming together in 2019:

- A more active involvement between the garden and the University environment-related teaching.
- Establishing and maintaining a student-facing database on the garden's two ponds, comprising both biotic and abiotic data.
- The earlier development of the Macro-Micro low energy building by the Engineering School at the UoD. The intention was for this building to be available for PhD students and active research. It had remained unoccupied for several years.
- The arrival of the current curator with similar ideas on sustainability, education and outreach.
- Responding to the UoD's drive for 100 PhD projects with the Education for Sustainability, Nature connection and Outdoor Learning initiative.

- Increased and active interest in the PhD programme and the agreement to launch the Living Lab.

Since early 2020 the UoD Botanic Garden Living Lab has lived up to its name, eminently reflecting the assertions of Waheed (2017), by being a hub or centre where *'… real-world sustainability challenges are formally addressed in stakeholder partnerships. The Living Lab initiative hosts projects where participants from all stakeholder groups collectively address real-life sustainability challenges*' (Waheed, 2017, p.5).

The UoD Botanic Garden Living Lab specifically aims to:

- Provide opportunities for students, academic staff, professional staff and external bodies to *collaborate* on projects, whether academic research or citizen-based outreach, looking at real-life sustainability problems.
- *Host* projects with participants from different backgrounds partnering to collectively address real-world sustainability challenges and opportunities.

With the appointment of the Living Lab Director, in conjunction with the development of a series of outreach and research initiatives stretching across the UoD, reaching out to Dundee, Scotland, the UK and internationally, the Living Lab is progressing at pace; projects are out there to be sought and won, the time was right and still is for outreach, collaboration and development. Partners include local, national and international schools, research-based centres such as the James Hutton Institute (JHI) and the Royal Society (RS), other universities and various NGOs nationally and internationally.

EAUC's (2021) generic definition for a Living Lab, resonates well with the UoD Botanic Garden Living Lab, its main elements comprise the natural setting at the Botanic Garden: the Macro Micro Building; it is research-focused, but pragmatic in methodology and methods employed, depending upon the nature of the individual projects; it encompasses a diverse stakeholder community comprising academic and non-academic partners; members meet regularly (online and/or face to face when permitting) for knowledge-sharing, support and development. The medium-long term longevity of the Living Lab is assured within the very nature of its research projects. Fig. 1 represents this arrangement.

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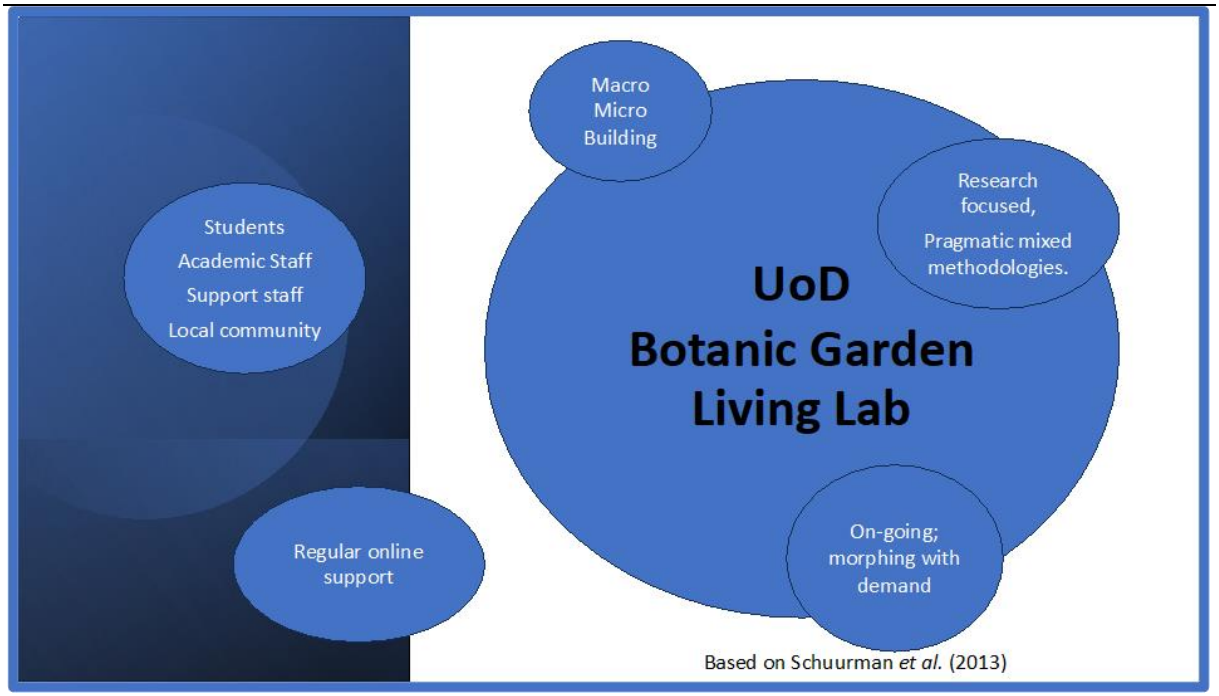

Fig 1: Defining elements of the UoD Botanic Garden Living Lab.

In 2022 following an active recruitment drive, The Living Lab Steering Group was formed. Still in its infancy this group comprises representatives from across the University, stakeholders from the various projects and external representation, for example: Garden Organic (https://www.gardenorganic.org.uk). The group acts as 'critical friend', with a view to strategically guiding the Living Lab into its next phase of operation, exploration and development.

THE STUDENTS

The advert on FindaPhD entitled 'Education for Sustainability, nature connectedness and outdoor learning', was submitted in early 2020. The response to this advert was staggering, generating a wealth of interest and enquiry, as indeed it still does. The limiting factor, however, was always funding. Being a self-funded PhD, it is the student's responsibility to seek and source funding. Several international students had access to various scholarships, however their sources would often not support an education-focused degree. Other students progressed to matriculation whilst applying for Scotland-based funding, the competitive nature of the application was soon realised, resulting in withdrawal from the programme. For all students, juggling work commitments to pay their fees and living expenses, alongside the demands of undertaking a PhD, the pressures are enormous.

By 2021 however four students commenced their studies within the Living Lab. They have since been joined by several others under the Education for Sustainability (EfS) umbrella. Additional students and their supervisors have joined the EfS cluster through their related work, whilst other UoD students involved with the various projects are active participants in this learning community. The PhD projects collectively demonstrate elements of public engagement, collaboration and mutual learning, involving to varying degrees, University students and staff, UK and international schools' students and staff, FE colleges and the wider professional and public arena.

THE PROJECTS

Education for sustainability, nature connection and outdoor learning

Research undertaken under the auspices of the Living Lab focuses on 'sustainability': an environmental, social and economic approach eschewing the depletion of natural resources to maintain an ecological balance (Lakin, 2021). An understanding of biodiversity (the myriad of organisms and habitats fundamental to sustained functioning of the environment) and our impact on this, is arguably at the heart of sustainability. To place this in context, research adopts an ecosystem services approach to the environment thereby recognising the different services afforded in terms of productivity, ecological support, environmental regulation, and cultural services, including human well-being (*Ibid*). Education and environmental awareness clearly have a role to play in influencing and directing human activity if impact is to remain sustainable. The PhD cluster projects aim to explore the many facts of outdoor learning as a vehicle to development and engage a sense of nature connectiveness and understanding. The context and focus are through statutory and further/higher education activities, as well as public and family engagement in outdoor initiatives such as citizen science projects and facilities including other botanic gardens.

Several small and medium scale research initiatives within this arena have been in operations for several years, for example a series of annual pond dipping sessions at the UoD Botanic Garden that contribute data to a longitudinal database exploring the impact of human activity on the water environment within the garden. So too a small-scale exploration of outdoor learning and nature connectiveness with both initial teacher education students and undergraduate environmental science and geography students. This latter research went on to indicate a tentative positive correlation between outdoor learning and nature connectiveness, suggesting further research and application would be beneficial (Barrable & Lakin, 2019).

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The following research 'snapshots' serve to highlight the application and realisation of our aspirations in terms of the Living Lab.

The daffodil project (https://www.dundee.ac.uk/projects/scottish-daffodil-project)

The venture into the genetic phylogeny of the native daffodil, established in partnership with the RS, is poised for its third year. The eight Scottish High Schools, a secondary school in Jersey and an FE college in England have all completed their practical work before heading into the summer break. JHI and Plant Sciences UK continue to provide a suite of STEM partneROY(a prerequisite to the funding) and the UoD School of Life Sciences supports the bioinformatics aspects of the programme. The Daffodil Executive group is currently exploring funding opportunities to enable the project to progress beyond the RS start-up funding. This is understandably limited to one academic year plus a possible extension, for any one school. The group is currently in discussions with JHI, Plant Sciences UK and Nanopore (suppliers of the DNA processing equipment). Representatives of the Daffodil Executive group recently presented at a Scotland-based Science Education conference, recruiting three new schools for the next round of the project. A postdoc and STEM partner also presented aspects of the project independently at the molecular biology 'IonBru' event, and the PhD student masterminding the whole project was invited to London by Nanopore to contribute to 'London Calling'; a schools' event where he conducted a series of Project-related practicals with 60+ schools.

Social sustainability through sociodramatic play in early childhood education

The Deputy Sustainability Coordinator and Teacher at a nursery in London, currently in her second year of the PhD, explores the observation that effective and engaged social interactions are vital for sustainable development, within a culture of shared values, behaviours and attitudes. Her empirical work takes this exploration further within the context of Early Childhood Education.

Primary education and further education

Two other RUK students, in the preliminary stages of their PhDs, independently explore education for sustainability within their respective fields, whilst establishing appropriate links across the education spectrum.

Learning for Sustainability—government funded research

Two Scotland-based students, two years into their PhDs, have recently worked as research assistants to a Scottish Government funded research project into Learning for Sustainability. A valuable

opportunity for them both and staff (several are members of the Living Lab) involved in this very successful project, the mutual benefits were later shared with the PhD Cluster Group.

*The Dundee Wee Forest projects (*https://www.dundee.ac.uk/stories/wee-forests-make-big-impact-dundee-community*)*

This Scottish Government-associated community engagement project, now in its second year, continues to attract small-scale extension funding enabling schools and their local communities to create shared nature-rich environments linking across Scotland through NatureScot https://www.nature.scot and EarthWatch https://earthwatch.org.uk.

Medicinal plants

A medical plants education resource, exploring the science behind the historic use of plants as medicinal aids, is poised for launch in the autumn 2023. A trail of display boards is currently in production, set to support the resource within the botanic garden. A molecular biology PhD student at the James Hutton Institute (JHI), the creator of the educational resource, continues to engage with the Living Lab community, having established a STEM partner role with Carnoustie High School in Angus. They are in the throes of applying for RS funding for a project that takes the essence of the medicinal plants resource to a molecular level, involving both JHI and the botanic garden, under the auspices of the Living Lab.

New projects—the River Garry, a river lost?

As the PhD cluster continues to flourish and expand new projects, one project is developing in association with archivists and hydrological partners from within and outwith the University. The project begins with the UoD archive data (c. 1969 – 1981) on the River Garry significantly impacted by the construction of the North of Scotland Hydro-Electric scheme. These data recount a story comprising sociological, hydrological and ecological impacts of the construction. The project involves the collation and analysis of this information together with contemporary monitoring in response to the restoration measures in place to revive and restore the River Garry to its former ecological status. The research looks to lessons learnt, whilst identifying mitigating actions that could prevent such impact in other similar national and international schemes. Set within an educational context, this multi and inter-disciplinary study is of relevance to social scientists, ecologists, educationalists and environmental practitioners with an interest in hydrology, human impact and sustainable development.

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Other opportunities for collaboration

Part of the philosophy underpinning the Living Lab is one of collaboration and not competition. A recently established collaboration between the Royal Botanic Garden Edinburgh (RBGE), St Andrews Botanic Garden and the UoD Botanic Garden is testament to this philosophy. Hosting the RGBE's Botanical Illustration course in the autumn is a case in point, together with submitting a joint proposal by all three gardens to present at a forthcoming professional conference in Edinburgh on the role of trees in sustainability. From a schools' education perspective, the three gardens continue to explore opportunities for collaborative and cross-fertilisation, with for example the Living Lab's Director being invited to join the Strategy Committee for the RBGE's latest education initiative.

LIVING LAB SUPPORT AND DEVELOPMENT

Cluster Meetings and the development of SEPAL (Sustainable Environments: Practice, Activism and Leadership):

Since their inauguration in 2020 the PhD monthly Cluster Meetings steadily transformed from the initial focus on individual projects and aspirations to a more pragmatic approach, exploring skills development and process as needs arose. This change ensued within the first year of the Living Lab development. It became apparent that following individual presentations of profile, research area and research aspirations, external contributions to the cluster were increasingly being invited to present their research. Interesting and valuable as this was, the more immediate individual needs of the students in terms of their research skills, understanding of process and procedures became increasingly prevalent. Cluster Meeting were time limited, so the need for refocusing was evident. Concurrently, discussions were afoot regarding the development of an educational 'research centre' similarly focussing on education for sustainability but with an enhanced emphasis on pedagogy and leadership. Within the spirit of collaboration not competition, this later virtual centre developed into SEPal (Sustainable Environments: Pedagogy and Leadership), with a strategic research agenda attracting speakers from across the UoD and beyond. The two resources, the Living Lab Cluster Meetings and SEPal become distinct, with a Memorandum of Understanding established between the two. By 2022, the focus of SEPal too began to morph, and pedagogy was replaced by practice in the title, and activism was introduced: SEPAL (Sustainable Environments: Practice, Activism and Leadership), continuing to attract its own healthy cross-section of academics and practitioners from across the UoD, Dundee and beyond. Several Living Lab students and supervisors remain regular contributors to SEPAL. An update on Living Lab activities is scheduled at the first input of the new academic year, thereby clearly reiterating the synergy between the two research centres.

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SO, WHERE ARE WE NOW?

Evaluation of The Living Lab, so far …

Now two and half years into the life of the Living Lab, it seemed timely to seek evaluative feedback from a sample of stakeholders. This feedback took the form of a single page word document (see Appendix 1), with a 'mood table' of descriptors on a scale of one to eight, and six evaluative free-response questions. The aim was to gain 'real-time' perceptions and reflections from across the Living Lab participants. The document was emailed to all members of the PhD Cluster, students and their tutors; the two internship students, all members of the Steering Group and other participants who either studied or assisted those who studied, under the auspices of the Living Lab. Collectively this constituted a cohort n = 29, with a return of 24%. The nature of the evaluation was one of quality assurance and therefore did not require ethical approval, however citations from the various respondents required informed consent, which was duly sought and given. The respondents represented the following contributors to the Living Lab (Table 1).

Table 1: Nature of Living Lab contributors to the Living Lab evaluation

	PhD student	**Staff**	**Onsite**	**Remote**
EfS	1			1
Psychology	1			1
Arts	1		1	
EfS Supervisor		3		2
Psychology		1		1
Arts				
Steering Group		(2)*	2	

* One represented under EfL supervisor and the other psychology.

Overall, the collective feedback was positive in terms of relevance, benefits and contribution to personal and academic development, citing 'inspirational', 'motivational' and 'enjoyable' as appropriate adjectives to describe respondents' experience and membership of the Living Lab. Specifics were associated with perceived benefits and 'usefulness', the consensus cited developing a community of belonging that provided networking opportunities as well as a forum to share ideas, experiences and challenges. Students felt they gained motivation and confidence, staff perceived membership more pragmatically than personally.

A more detailed analysis of the feedback follows:

The 'mood-table' sought to capture what the experience of being a member of the Living Lab meant to the respondents, by selecting a number on the continuum between the two sets of descriptors (Table 2).

Table 2: 'Mood-table' identifying what being a member of the Living Lab means to the respondents, using a scale of one to eight between two sets of related descriptors.

Descriptor	1	2	3	4	5	6	7	8		***Row Total***
Unpleasant							**14%,** 14%	43% **28%**	Enjoyable	**N=7**
Not at all useful	1	2	3	4	5	14%	43% **14%**	**28%**	Really useful	**N=7**
Boring	1	2	3	4	5	14%	28%)	**57%**	Inspirational	**N=7**
Demotivating	1	2	3	4	5	14%	28%)	**57%**	Motivating	**N=7**
Column Total:						3	10	15		**27** ***Responses***

Legend: BOLD % are the student contributors and normal font % the members of staff responding.

It can be seen from Table 2 that there is an evidential skew by the students towards the higher-ranking end of the spectrum, selecting the more positive adjectives of 'really useful', 'inspirational' and motivating'. Only one student dropped to the slightly lower scale of '7' when describing the nature of the experience in terms of enjoyability. Staff however, appeared more reserved in their responses, with them all except one selecting an 8 for enjoyability but ranging between a 6 and a 7 for usefulness, inspirational and motivational: an aspect of the Living Lab that warrants tighter focus and attention.

Free-response questions yielded a greater insight into respondents' perception of the Living Lab as a research community, and these observations, acumens and future-visions, will be discussed in the following section.

DISCUSSION

The UoD Botanic Garden Living Lab aims to host projects within the sustainability arena, thereby enabling staff, students and external bodies to collaborate on initiatives within real-world settings, has strong echoes in the evaluations feedback. Even within the timescale of the Living Lab's

conception early in 2020 to the current day, its emphasis, and hence interpretation, has changed. This morphing is clearly represented in the feedback. The first cohort of students commenced their studies a couple of months prior to the COVID-19 lockdown in March 2020. At the time, university students were required to work remotely and the facilities at the garden were closed. This, together with recognised sides effects of lockdown, significantly impacted those students who travelled to Dundee specifically for their studies. As lockdown eased and the garden reopened, students were encouraged to use the facilities afforded by the Macro-Micro building. Not only was this opportunity a welcome release from the confines of enforced isolation but it also presented: '*… an extremely enjoyable (environment) … to have a quiet focussed facility to continue with writing and structuring my thesis. The environment is welcoming, spacious and surrounded by a … useful library, which makes this intense thinking time of crafting the writing an enjoyable process*.' (On campus PhD student)

This student goes on to state that as a break to distil one's thought, the garden itself affords a welcome and readily accessible venue (*Ibid.*). For those students who continued to work remotely, the monthly online Living Lab Cluster Meetings represented an invaluable resource for both them and their supervisors. A sense of community, unity and of belonging were echoed by several contributors to the evaluation; mainly students but supervisors also recognised the value of connecting with post graduate researchers (PGRs) engaged in related research projects. Collectively they espoused networking and collaboration opportunities afforded by the Cluster Meeting events: "I have much more information on my field of study and more connection now than I would have had without [the Living Lab Cluster Meetings]" (Living Lab PhD student).

This opportunity to share their work, whilst getting to know others within the cluster was high on the students' perceived benefits of the community, a sentiment reported elsewhere (Waheed, 2017; Dabaieh *et al.,* 2018, & Zen *et al.,* 2019). Similarly, echoed by staff, was the frequency and regularity of the meetings enabling culture building with impact, within "… green health" sustainability-related initiatives (PhD Supervisor). This testimony is purported by Dabaieh *et al.,* (2018) and others (Zen *et al.,* 2019), espousing the benefits of research, teaching and learning through communities of practice set within a Living Lab philosophy.

In terms of personal development and enhancing study skills, student respondents unanimously reported that being part of the Living Lab community has enhanced their self-development … "I feel I have gained confidence and motivation" (Living Lab PhD student), whilst another reflects … "(It has)

… definitely helped me in the mid and latter stages of my reading and written research. It puts into perspective the artwork that is currently being installed in the garden and allows one to place art, science and educational school visits and research within the wider context of the UoD Botanic Garden and the broader UoD strategy in public engagement" (Living Lab PhD student).

These statements resonate with Waheed's (2017) earlier claims that students working within the community of a Living Lab become more prepared as agents of change in their professional and personal lives. From the staff representatives, development was evidently viewed from the students' perspective reiterating the provision of a "venue" for students to gain experience of being involved in a "green health" project (PhD supervisor). Likewise, "… helping with PGR connection and knowledge of current activities" (another PhD supervisor), again suitably reflects Waheed's assertions (*Ibid, p.7*) regarding real-world sustainability issues and the value of a Living Lab approach. The only staff respondent interpreting the question from a personal perspective in terms of individual academic and professional development, responded singularly in the negative … "No" (PhD supervisor / Steering Group member). The measure of this response highlights some concern as continued involvement of staff is a key factor to the Living Lab; if there is no recognisable personal value added, this could impact contribution, possibly echoing the more reserved response of staff to the mood-table (Table 2). In his report on Living Labs, Waheed (2017) states that the benefits for academics of working within a Living Lab environment are that it provides a "test-bed" to "… conduct innovative, impactful and transdisciplinary research that involves direct engagement … implementation and further study of social, environmental and economic issues" (*Ibid, p.6*). I sense from the feedback, that we're not there yet in terms of staff synergy and ownership. Waheed went on to suggest that success results from collective solutions, ultimately attracting funding for research, rather than "… doing research to attract funding" (*Ibid, p.6*); a position we strongly aspire to, and if achieved would perhaps draw more staff into the fold.

Suggested areas for improvement and further development

A practical suggestion from an on-campus PhD student regards enhancing the on-site facilities as more students join the Living Lab cluster, was specifically to equip the Macro-Micro building with supportive office-style chairs more conducive to longer term sitting than meetings-style chairs.

Looking to the future, there was a strong emphasis from both staff and students reflecting the early focus and subsequent re-focusing of the Cluster Meetings. Interestingly, all respondents independently suggested opportunities for dissemination of work to date, for example: "Perhaps, we

could share presentations of our work after publication in order to gain a better understanding of each other's work and thoughts" (Living Lab PhD student). With an emphasis on the meetings being more pragmatic and process driven over the past few months, we run the risk of losing sight of one of the marked benefits of Living Lab, that of sharing and updating on projects. The sharing of technical skills, tips and procedures remain significant, but are we losing sight of the big picture? As echoed by staff respondents alike: "Wider opportunities for PGRs to engage through relevant topic discussions and opportunities for hosting and /or presenting" (PhD supervisor). Another example being: "Perhaps, method of dissemination of work being done. I know there are plans for a journal, but more informal communications would also be valuable and reach a wider audience" (another PhD supervisor).

The wider audience intimated in the second quote refers to other PGRs with the Division of Education and Society and across the UoD. One possible solution, as suggested by the SEPAL lead, would be to enhance the working partnership with SEPAL, mirroring the practice of regular blogs or news bulletins identifying research projects and opportunities for members (students and staff) to get involved.

Plans for a regular research conference, initially inhouse but with aspirations of being outward facing, are in the early developmental stages, providing an opportunity to celebrate success to date in terms of recruitment and outward recognition. For example, the inaugural members of the UoD Botanic Garden Living Lab have been awarded 'Highly Commended' under the University's Stephen Fry awards initiative. Each participant has a certificate to that effect and will be awarded these at the first conference. This collective celebration, to involve opportunities for research presentation and in-person discussion, will go some way towards making the community more dynamic and progressive.

Limitations

Despite the small return on the questionnaire (24 per cent, n=29) the spread of respondents appropriately represented the stakeholder profile of the Living Lab. This enabled feedback, albeit limited in number and in cases staff represented two roles for example, Steering Group member and supervisor, however the responses gave an eclectic perspective. This was also evident in the students' responses, the diverse background and degree of remoteness (one student was regularly onsite, the others attended remotely) was reflected in their perceptions of the Living Lab, its qualities and perceived value. The questionnaire, adapted from an Education Evaluation sent to

schools and other users of the garden, afforded a snap-shot response in the 'mood-table' with the opportunity for free-response to targeted questions. This worked well within those aims, however the 'descriptors' on the mood-table were self-limiting, for example 'unpleasant' is an emotive term that could, unconsciously influence a more positive return, indeed 100% of the returns were in the top two categories. Similarly, 'demotivating' is a strong term conjuring significant negative impact. Although this was not perceived by any respondents to be the case, perhaps more neutral terminology to the left of the table would have returned more useful and appropriate information. The aim is to undertake an exit evaluation when the first cohort of students complete their PhDs. Likewise with the stakeholders from the various projects and Steering Group members when they step down from the group. The evaluation questionnaire used for this exercise will be a revision of that employed in this current exercise.

Recommendations

- Work to ensure that staff within the Living Lab have greater ownership and synergy with the community, thereby forming a more holistic entity, with greater collective value built on individual autonomy and 'buy-in'. To achieve this the Living Lab needs to realise its aspirations of developing a pathway route for PhD and Professional Doctoral degrees and capitalising funding streams for targeted research.
- Equip the Macro-Micro building with supportive office-style chairs.
- Create opportunities annually or two yearly to share progress to date and celebrate success. Orchestrating a research conference in the new academic year is a case in point.
- Enhance collaboration with SEPAL.
- Establish regular online news bulletins/blogs identifying opportunities for research involvement, dissemination and presentation.
- Undertake an exit evaluation when projects are completed and members of the Living Lab step down from their position within its community. Revise the evaluation questionnaire in the light of lessons learnt.

CONCLUSION

The UoD Botanic Garden Living Lab to date evidently goes some way to fulfilling its aims of hosting research projects and providing opportunities for collaboration between UoD staff, students and the wider community. Set within an environment of promoting sustainability and enhanced biodiversity through education, practice and research, it reflects the assertions of Waheed, (2017) who states

that a "Living Lab catalyses change at two different levels. Firstly, it provides direct and relevant benefits to each stakeholder group through its projects and, secondly, it serves as a governance tool that can assist in the greater systemic transformations" (Waheed, 2017, p.5).

As we look to the future, we can respond to lessons learnt by, for example, reviewing the annual programme of the Living Lab Cluster Meetings, to better reflect the student journey by responding to their immediate needs. Other areas for development include ensuring onsite facilities are fit for purpose and endeavouring to support staff in their academic and professional development, as well as developing and encouraging opportunities for dissemination of research, both within the Living Lab, the wider UoD and beyond, whether through publication and/or conference presentation. Thereby continuing to aspire to the aims and aspirations of the Living Lab, our students, and colleagues, as captured in the following quotes: "It is a wonderful opportunity (being part of The Living Lab) not only to get published, but also to learn more and improve different skills during the course of the PhD" and "A wonderful facility, generously offered to the research PhD students. Thank you for the vision" (Living Lab PhD students).

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Appendix 1: Evaluation of the Living Lab, so far …

The Living Lab aims to:

- provide opportunities for students, academic staff, professional staff and external bodies to collaborate on projects, whether academic research or citizen-based outreach, looking at real-life sustainability problems.
- host projects with participants from different backgrounds partnering to collectively address real-world sustainability challenges and opportunities, these include [but are not exclusive] landscape issues both green and blue infrastructure, education for sustainable development, nature connection and nature-based solutions.

Thank you for being part of the Living Lab, to capture what the experience means to you and to ensure it really meets your needs, we'd be grateful for your feedback. To help focus your thoughts please use the following as broad areas for feedback. Thank you.

- Teacher / Lecturer / PhD Student / Student, other, please state [highlight as appropriate]

Please indicate how you feel about being part of the Living Lab by **highlighting relevant numbers** on the continuum between each of the two words:

Unpleasant	1	2	3	4	5	6	7	8	**Enjoyable**
Not at all useful	1	2	3	4	5	6	7	8	**Really useful**
Boring	1	2	3	4	5	6	7	8	**Inspirational**
Demotivating	1	2	3	4	5	6	7	8	**Motivating**
Column Total:									

Please explain a couple of your selections:

Other areas for feedback: ***Please explain all answers***

- **What do you think are the benefits of being part of the Living Lab?**
- **What were the most 'useful' aspect of being part of the Living Lab?**
- **Has being part of the Living Lab helped or hindered your studies/work?**
- **What aspects of the Living Lab could be improved and how?**
- **List at least 3 things you'll take with you regarding your involvement in the Living Lab**
- **Anything else you'd like to add?**

Thank you for your time – EJL Dr Liz Lakin

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THE ROLE OF CURATION IN BOTANIC GARDENS: PLATFORMS FOR ENVIRONMENTAL AND SOCIAL TRANSITION

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ABSTRACT

Botanic gardens collect, care for, distribute and display living organisms, preserved plant specimens, and their derived artifacts. As cultural collections, they are used for research, conservation, education and cultivated as living collections that provide tangible and intangible amenity. Curation is an integral consideration of this melee, which informs the content and confers value, through framing the public presentation and interpretation to further the mission of the host organisation. This paper reviews the evolution of western botanic gardens as institutions of power, inferred by knowledge. Exploring the key externalities that have informed their collection acquisitions since their renaissance origin while exploring the epistemic function of the curator's role. Looking to provide insight into how these collections can better be directed towards the prescient externalities that result from an imbalance of the human social and wider ecological system. The framework of a Sustainable Development is reviewed as the dominant sustainability narrative and top-down transformative solution pathway. While Nature-based Solutions are identified as potential tools to help mitigate and adapt to emerging challenges from anthropogenic climate change and continuing biodiversity loss. Finally, the concept of a Just Transition is identified to inform policy and direct practice from a bottom up and top-down process, to ensure equality for all stakeholders independent of their economic means or collection interests. An approach that could bring benefits

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for species conservation while providing a new lens for botanic garden research and curatorial practices. These include acknowledging the benefits of Indigenous and western knowledge systems and making intrinsic values work; integrating intrinsic values of the more-than-human. The case for botanic gardens to be considered as centres of knowledge or '*Hortus apertus*' is made to acknowledge the continual evolution of these institutions, and revaluation of their role in a time of global change.

Key words: #Botanic Gardens #Living collections #Curation #Just Transition #Nature-based Solutions

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INTRODUCTION

Interpreting the history of western botanic gardens is a complex story. One that has been predominantly voiced through the lens of people, whose objective harvests from plant collecting trips, are recorded, and exhibited as representations of displaced social reality, despite their highly subjective and malleable nature. As repositories for plant material culture, botanic gardens have re-counted their role in the advancement of western society, through acquiring, evaluating, and then distributing new sources of fibre, food, and fuel, thereby adding social and economic capital (Bourdieu, 1986; Blais, 2022). Plants are presented as trophies of wonder, beauty, and utility, oversimplifying the human story that idealises the acquisition and romanticises the materiality of plants (van der Veen, 2014). Such acts, propagate the monomyth or hero's journey of courageous men, discovering plants in distant landscapes and then transporting them to new cultivated spaces, as artefacts of an informed entrepreneurial intent (Campbell, 1993; Klyver, and Jennings, 2009). They unwittingly conceal their duplicity where the role of curation, in this melee has received less attention to date.

As hosts to a vast concentration of the world's plant diversity, botanic gardens have become the excepted authority of the conservation of wild collected plants (Smith, 2016). This position lies in direct opposition to the formative work of their precursors, which could awkwardly be framed as bioprospecting (Brockway, 2002; Beattie, et. al., 2011). Acting as significant facilitators in the environmental exploitation of plants, were agents of former imperial empires who sought to exploit the utility of plants in the service of mankind, initially identifying, then cultivating and translocating plants, as part of a colonial agricultural industrialisation and colonial expansion, that compounded through a cascade of land cover and land use change, that now impacts the earth system (Luyssaertet. *et. al.*, 2014; Azam-Ali, 2021).

Insight into addressing this gap, may be informed through a study of the agency of early pioneers, in botany and of frontiersmen, who were charged with collecting plants for entrepreneurial and imperial objectives (McCracken, 1997). Collectors were employed in bioprospecting activities, unknowingly or otherwise, providing the primary means of plant appropriation, that once recognised presents an alternative lens to interpret history, that is not always acknowledged in the collection displays (Williams, 2004; Gratzfeld, 2016). Through such accretion, the modes of storytelling thus far employed have promoted their ethnobotany and ethnography, as a result of the dominant epistemologies having prioritised narratives that promote plant acquisition for utility, material, or aesthetic benefits (Rakow and Lee, 2015; Irving, 2018a, 2018b). This consumptive form of cultural

interpretation and presentation of knowledge reinforces an imperial legacy if unchecked, but also allows consideration of what multiplicity of alternative stories, voices and dialogues could be encouraged to emerge, should we transcend the nature-culture binary that currently structures the approach to displays (Woodward, 2012; Boehi, and Xaba, 2021; Hassouna, 2023).

This extirpation of the role of curator is one that ought to benefit from a wider lens of enquiry, such as anthropology, as it has also emerged through its own false ceilings, as Berlin's (1992), exploration of folk classification exemplifies. Any aid to enlightenment must also study the primacy of western scientific knowledge, with an equally weighted consideration of the wider localised knowledge systems that the plants originate (Gadgil, Berkes, and Folke., 1993; Cornish and Nesbitt, 2018). This includes the identification and naming systems applied for millennia to biodiversity, so movement is encouraged towards a more holistic consideration of nature and nature's linkages with people can be gained (Berlin, 1973; Salick, Konchar, and Nesbitt, 2014; von Zinnenburg Carroll; 2017 Bahuchet, 2021). This would move us towards a more inclusive transcultural and global history of botanic gardens, which has yet to fully acknowledge the displacement of Indigenous knowledge embedded in its history (Howard, 1954; Sachsenmaier, 2006; Hill *et. al.*, 2020).

Instead, contemporary histories underplay the colonial ambition and imperial domination of one country over another, that led to the development of a global network of botanic gardens, and displacement of local knowledge systems (Brush, 1993; Daes, 2001). This results in a legacy of disproportionate relationships, whose imprint remains as a legacy of plant eponyms, disproportionally celebrating western male names, reflecting broader colonisation hegemonies rooted in European powers of the 18th, 19th, and 20th centuries (Gillman, and Wright, 2020; Westwood, *et. al.* 2021; Gadgil, Berkes, and Folke, 2021; Park, et al., 2023).

Botanic Gardens seen through this lens of social and environmental injustice, bear witness to cultural legacies that see botanic gardens as more than mere centres of plant diversity for research, education, conservation, and amenity, but as landscapes of colonialism that are also deeply racialised, converging on extractive capitalism and environmental racism (Antonelli, 2020; Neves, 2021). The built structures of such institutions often house (ethno-)botanical museums and herbaria to complement their living collections (Miller-Rushing, Primack and Bonney, 2012). These are curated with policies, procedures and practices that are increasingly aligned to globally determined aims and objectives that seek to conserve wild collected plant material for conservation purposes (Cullen, 2004; Gratzfeld, 2016). These are institutions of power, which have established the enviable position as the embodiment of public trust, authority, and power, based on the significance of both

their collections and their scholarship, in combination with policies to facilitate public access (Forbes, 2008). They are also places embodied with emotion, functioning as sites of recreation and of encounter with nature. They have the potential to explore ever more creative ways for human beings to relate to their natural environment adding value and imparting knowledge (Kemp, 1978; Heyd, 2006; Frediani, McGilchrist, and McGeorge, 2022).

The ontology derived from classifying these different temporal histories of botanic gardens, will not only chart the acquisition of living and derived plant material culture, but also draws attention to the wider socio-political and economic context under which the collections were acquired. The following literature review provides a synthesises of the current state of knowledge using such a lens, seeking to learn from different approaches that have or are being explored in wider fields of curatorial practice adopted in allied fields. It calls attention to new areas of social innovation and environmental reconciliation in museums and galleries, which require further investigation and research. It is important to recognise that living collections can help raise awareness and support the realignment of an unbalanced social system to be sustained within the limits of the earth system that supports it through contributing to the Sustainable Development Goals (SDG's) and adapting to climate change (Schulman, and Lehvävirta, 2011; Blackmore, 2019). This survey therefore includes a review of the emerging role of botanic gardens in the recently established field of sustainability science, revealing emergent areas of interest that are naturally aligned to such as Nature-based Solutions as well highlighting the ethical benefit of adopting a 'Just Transition Framework,' 'Regenerative' or 'Circular Economy' approach to institutional planning (Andreucci, et. al., 2021). It provides the potential means to address the environmental and the socio-political objectives raised above, framing future work in both a global and local context (Natural England, JNCC (Joint Nature Conservation Committee), Natural Resources Wales, NatureScot & Northern Ireland Environment Agency, 2021).

Finally, the review explores curatorial motivations, which have led to the current ways of knowing or understanding this medium and presenting living collections. The outcome is the beneficial learning from parallel fields of knowledge in contemporary museology (Desvallées and Mairesse, 2010). This is an area of study that may yield many new epistemologies, which can help provide a refined lens to help re-frame the future direction for the curation of living and cultural collections in a metamodern world (Vermeulen, and Van Den Akker, 2010)

METHODS

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A systematic literature review was conducted to provide an overview of botanic garden curatorial research to date. A search for publications addressing curation as a theoretical concept, as well as the adoption, management, planning and implementation, of social and environmental initiatives was conducted in March 2023 using the 'Publish or Perish' citation analysis software programme to access and interrogate a range of search engines (Harzig, 2007). Using separate keyword searches from Google Scholar, Scopus, PubMed and OpenAlex - formerly known as Microsoft academic search engines, chosen for their broad range of coverage, but also reviewing textbooks, web-based industry resources, professional technical handbooks, and institutional reports. A total of 200 research articles regarding the curation and history of botanic gardens were reviewed and compared. In the second step, the abstract and introduction sections were read, and papers entirely focused on curation, curatorial practices and living collections and their management were retained in the sample. This step served to reduce the number of reviewed publications to 81 (see also Figure 1). These resources were further combed with variations on the phrases "Sustainable Development" and with a focus on local urban benefit through "Green infrastructure" or GI / GBI and "Nature-based Solutions." The GBI phrase relating to Green and Blue Infrastructure being a formative term to NbS and is often confused with debates around "greenspace" from a planning perspective that were identified through background reading (Taylor and Hochuli, 2017; Elmqvist, 2019). As a result, a final dataset of 37 publications was obtained (see appendix 1). The following themes were emergent from the literature search and formed the outline for this review: the history of botanic gardens and curatorial practice, botanic garden as living museums, role of curation, the epistemologies of curation, Sustainable Development linked to NbS and framed within the context of a Just Transition.

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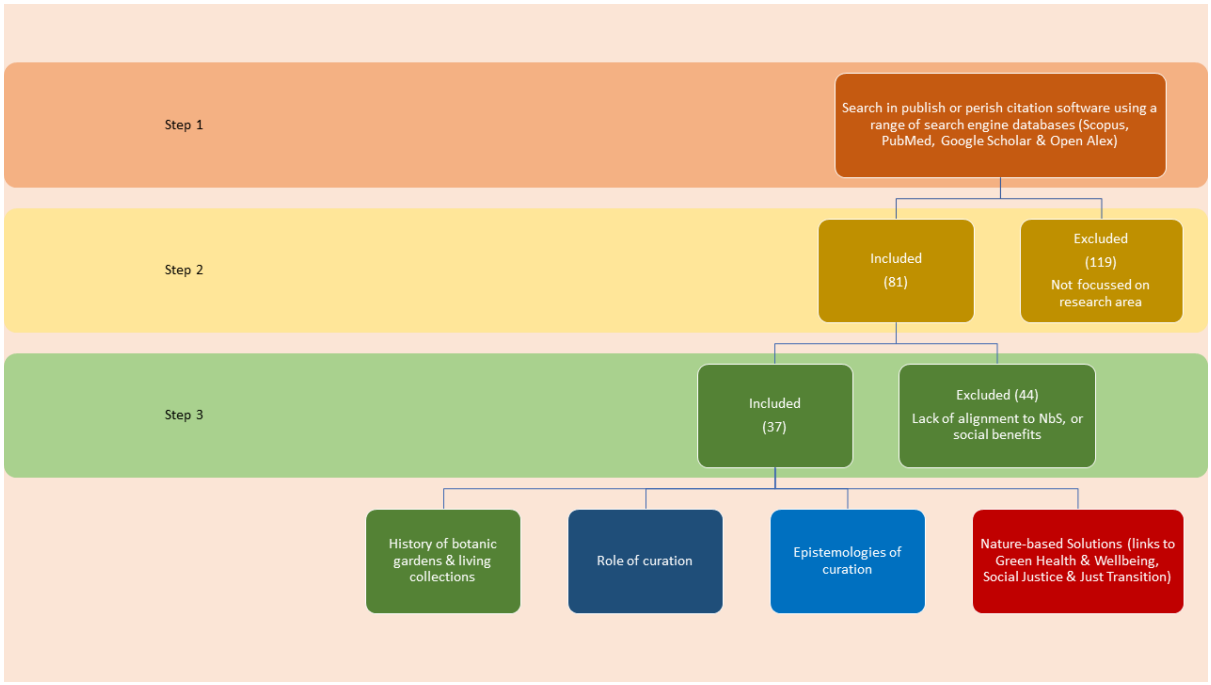

Figure 1: Representation of the review process described in the methods section of this review.

RESULTS

In this section, the main results are described, starting with the fundamentals of the history of botanic gardens, their curation, and curatorial practices. Subsequently, relevant epistemologies are identified and explored within the context of emerging social and environmental themes including Sustainable Development, NbS and a Just Transition.

i) History of botanic gardens and their living collections

From the cloistered medieval gardens associated with monastic orders, the rise of the western renaissance physic gardens emerged as independent entities during the 15th and 16th century (Forbes, 2016). Such gardens that were adorned with plants, labelled for their medicinal usage, and grown under the curatorial eye of apothecaries prior to pharmacological and medical training (Frediani, 2009a). These gardens quickly adapted, as Europeans travelled the world 'discovering' places, which were new to them, from whence they brought back exotic plants and animals which were subsequently displayed in early physic gardens and / or menageries. The acquisition of biological material reflects a cline of transition from physic garden of utility to botanic and menagerie to zoological gardens, which transformed how these collections were used, accessed, and perceived during the scientific revolution (Baratay and Hardouin-Fugier, 2004). The pursuit of

scientific enquiry underpinning medical knowledge in Europe, grew in parallel with an interest in economic botany that underpinned the fibre, food, and medicine during the industrial age, growing cities and supporting urban populations at home at the centre of imperial powers (Baber, 2016). This was especially acute in 18th century Great Britain, where the Royal Botanic Garden Kew was tasked to coordinate a network of satellite colonial gardens, to service the imperial and colonial ambition (Brockway, 2002; Endersby, 2019). In the following summary, Forbes (2008) draws attention to the power and privilege they acquired during this period of expansive growth:

"Botanic gardens have had a particular source of power derived from the economic, environmental, social, and cultural values of the plants in their collections. Indeed, botanic gardens have changed the world through their explorations and expositions of plant collections and are implicated in significant social change."

The role of botanic gardens in contributing to social change and innovation has included a sequence of remarkable events. First, their contribution to medicine, second the way they have profoundly changed the nature of our relationship with the natural world, third as an engine for the appropriation and development of cash crops during the era of colonialism, and fourth as an agent for the commodification of the natural world (Forbes, 2008).

The 20th century witnessed a transformative time for biology, marking a period of large scale social, political, and economic change (Steffen, *et. al.*, 2015). It was a revolution of productive growth of the social system, facilitated through an era of new scientific understanding, with the application of genetic technologies to various fields, including agriculture and medicine (Hao and Xiao, 2015; Hamdan, et al. 2022). A time of ever more rapid modes of communication helped to cultivate awareness of the growing human influence over planet Earth (Grinin, Grinin, and Korotayev, 2022; Ingo and Love, 2023). It raises awareness of a period of history that describes and defines the ultimate human communal hubris, known as the Anthropocene Epoch, playing out the tragedy of the commons at a global scale (Hardin, 1968; Monastersky, 2015).

Surprisingly, most botanic gardens world-wide originated in the latter half of this period, particularly in countries with rapid development such as China (Sanders, Ryken and Stewart, 2018). The location of these post-industrial late 20th century botanic gardens, being serendipitously juxtaposed to their visitor base in ease of access to urban or peri-urban populations (see Figure 1). Such placement provides an ideal platform to promote environmental awareness and grow their visitor income, to reinvest and help underpin a persistent mission in global plant conservation and need to inform sustainable development (Budowski, 1976; Golding, *et. al.*, 2010; Delmas, Larpin, and Haevermans,

2011; Powledge, 2011; Rae, 2011; Smith, 2016). This leads to the suggestion that botanic gardens have a significant role to play in contributing to environmental reconciliation in the twenty-first century (Forbes, 2008).

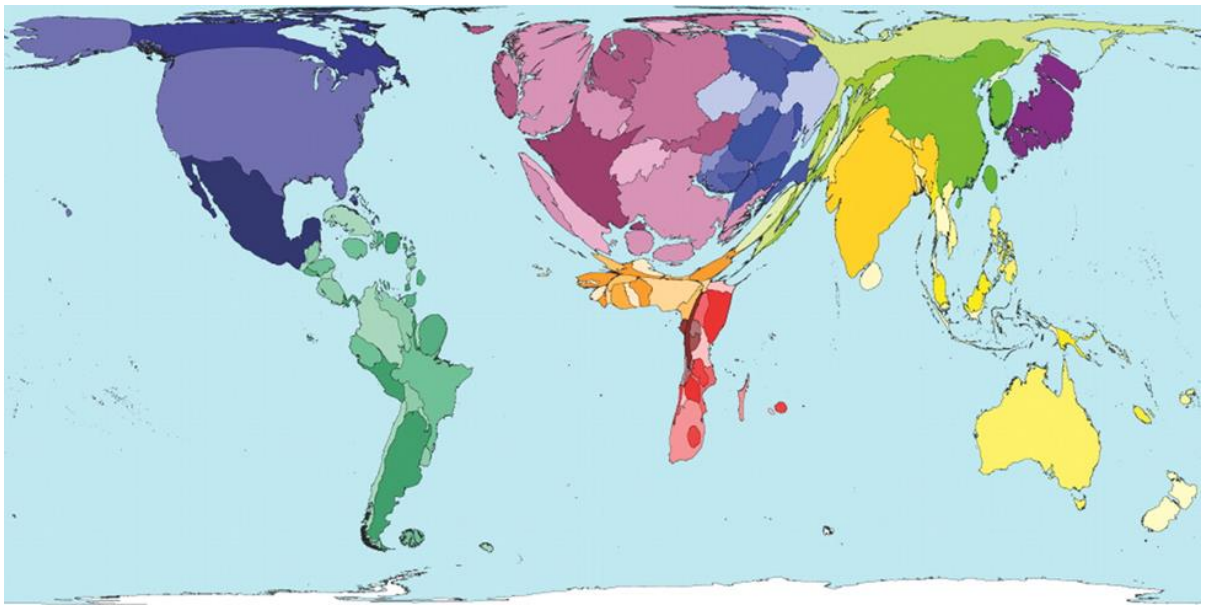

Figure 2: World map of botanic gardens (territory size is proportional to number of gardens). From http://www.worldmapper.org/, originally accessed August 2008 and first published in Golding et al. (2010). Creative Commons License, copyright 2006 SASI Group (University of Sheffield, UK) and Mark Newman (University of Michigan, USA).

Today botanic gardens frame themselves as centres of conservation and legitimate repositories for the world's threatened plants, while helping to network and grow their interest to serve multiple purposes, including research, alongside conservation, education, public engagement, and enjoyment (Smith and Harvey-Brown, 2018; Gardner, 2021). Botanic gardens are collaboratively working to inform and support the development of a Global Strategy for Plant Conservation (GSPC; Secretariat of the CBD 2002). They are also assisting in a global program of the UN's Convention on Biological Diversity that was adopted under the Convention on Biological Diversity (CBD) in 2002 as a policy response to the dire situation of plant life. This programme has subsequently been updated and further approved in a revised period up to 2020 at the Conference of Parties to the CBD in Nagoya. This was part of a desire to continue to express the relevance of plant conservation and in turn try to slow the pace of plant extinction around the world (Sharrock and Jackson, 2016). Given the enormity of our current environmental woes, there is increasing dissonance being aired in the efficacy of such approaches to global conservation by all Non-Government Organisations (NGOs), and how they are currently aligning their efforts (Rammeloo and Aplin, 2007; Cibrian-Jaramillo, *et. al.*, 2013; Sutherland and Wordley, 2017; Griffith, *et. al.*, 2021). This leads to calls to review individual *ex-situ*

conservation goals and integrate the analysis into coordinated *ex-situ* conservation efforts especially growing capacity in areas of the world with high species diversity (Pautasso, and Parmentier, 2007; Griffith, et. al., 2020; Wood, et. al., 2020; Griffith, 2021). It is a conservation challenge that is echoed in a lack of progress in the global conservation efforts in other fields, including our crop wild relatives, which seem to suffer from a lack of coordinated effort in situ with ex situ, rather than a lack of underpinning science (Dempewolf, Krishnan, and Guarino, 2023).

Counter to the posit of botanic gardens as *ex-situ* conservation centres in displaced spaces from their wild conspecifics, has been a movement to see botanic gardens as centres that can provide more holistic solutions to inform functional urban landscapes (Ward, et. al., 2010; Hirons, *et. al.*, 2021). This addresses issues that arise from the fastest growing habitat on earth – the urban habitat (Bindé, 1998). Botanic gardens, arboreta, and zoological gardens, are well placed to research, demonstrate, and communicate the potential of nature to benefit people and planet. This includes enabling bioclimatic and trait-based approaches to inform the selection of species that can help our cities adapt to climate change (Hällfors, et. al., 2010; Neves, 2019; Watkins, *et. al.*, 2021). There has been a shift in emphasis away from the taxonomic curatorial doctrine of the past 150 years, towards other ways of knowing, in support of a wider societal quest to change the ways in which biodiversity is conceptualized and practiced. This builds upon centennial histories of institutional culture, which have protected and elevated nature as if it were separate from society and/or as if biodiversity conservation were the exclusive purview of technocratic expertise (Miller, *et. al.*, 2004; Spencer and Cross, 2017). There is an aim to redirect its affiliates, to embrace new social roles in pursuit of wider sustainability goals that include people and the planet (Dodd and Jones, 2010).

In this way, botanic gardens represent spaces that become places, imbued with emotion through the actions and reactions of people who curate, tend and engage with their cultural collections, but also with the environment they grow in. Framed in the context of designed or planned landscapes, they can be considered cultivated places where stewardship is practiced engaging the visitor, contrasting stories of a historically richer biodiversity where collections were more significant than functional landscapes (Elshater, Abusaada, and AlWaer, 2022). The challenge of an ever-shifting baseline, where ‘green’ or ‘plant blindness’ is a perceptible challenge, and acts as a real barrier to progressing a vision of a liveable and biodiverse future (Vera, 2010; Stagg, 2020; Daniel, Russo, and Burford, 2023). It is stories that motivate people to do what it takes to make the world we need, rather than accept the world we have inherited (Stagg and Dillon, 2022). Facilitating a move towards a Just Transition for everyone defined simply as “care and share” versus “control and hold” (Gilbert, 2021).

ii) Botanic gardens as living museums.

Botanic gardens and their collections are more than just an institutional expression of a human trait to collect and classify. Collecting and collections are the centre of their purpose to save, understand, and interpret plants for the benefit of wider society (Hohn, 2007: 4; Wyse Jackson and Sutherland, 2017). They embody a social purpose and epistemology that is more widely shared by museums in an effort to understand and interpret who we are, how we live, our history, our natural surroundings, and our technological and creative endeavours (Hill, 1915; Errington, Honeyman, and Stocklmeyer, 2001; Alexander, Alexander, and Decker, 2017). There is a shared origin derived from the historical accretion of cultural material (Drayton, 2000; Forgan, 2005; Blais, 2022). However, in anthropology curation has become something of a contested term, having grown as a profession of museum studies or 'museology,' informed by the perceived need and therefore imposition of order from chaos (Shott, 1996). It is a practice that is realised through categorising material culture systematically into collections, using nomenclature to mark paradigms created within colonial structures of power (Brulon Soares and Leshchenko, 2018).

To address such concerns, the 'material turn' has been coined as a term, marking a change in epistemology that signified a new relationship between things and people, in development since the 1970s, as a phenomena that mirrors changing approaches to exhibition design in museums (Schulze, 2014). This trend acknowledges the relevance of former curatorial approaches of the 18th and 19th centuries, which rendered them less relevant or indeed acceptable to audiences in the later 20th century (Micklewright and O'Malley, 2022). A reappraisal has given way to what is known as a '*New Museology*,' coming to the fore in the late 1980's and dominating the curatorial approach of the late 20th century and influencing art gallery practice as well as museums (Maroević, 1998, p. 93).

A reflection of the greater awareness of the social and political role that museums had come to encompass and resulting in museums engaging in more meaningful community participation in curatorial practices is taking place worldwide (Rugg and Sedgwick, 2007). It is about acknowledging that curatorial practice is not value neutral but reflects power relations (Chatterjee, 2021). It is also important to raise awareness of the need to address concerns that regard equality, social justice, and human rights (Nightingale and Sandell, 2012, p. 1). A trend has continued to gain traction during the last five decades as museums have evolved from being research and educational institutions, to becoming social institutions that not only research, document and communicate cultural and natural heritage, but also actively shape society (Nightingale and Mahal, 2012). Botanic gardens have only more recently made tentative steps towards this trend, by seeking to engage and learn from

museums, to help broaden their audiences and engage with wider community concerns and needs (Donaldson, 2009; Dodd and Jones, 2010; Neves, 2019).

In visualising this transition, we can reimagine botanic gardens as more than mere centres of plant material exchange, with evolved form and focus that has developed over phases of institutional development. A new role emerges, adapting and serving social needs, represented through a timeline aligned to emergent plant use themes (Frediani, 2009a and Figure 3). The result is an arrow of time that charts phases of categories of focus by aggregated botanical institutions that is informed by reported histories of past stewards and stakeholders, which can be set within the context of their wider socio-economic context (Hill, 1915, Heyd, 2006, Frediani, 2009b). This trajectory is evidenced through institutional publications and a temporal analysis of their stated aims, but also witnessed in the nomenclature of plant names, and traces of recorded living and pressed material displayed and catalogued in their living and herbarium collections (Green, 1927; Nicolson, 1991; Nualart, *et. al.*, 2017).

In theory, this evolving role has been informed through critical thinking and regular review, in practice it is planned through the framework of curatorial direction captured in collection and management plans, plans that lack robust evidence base and instead are iteratively progressed through ‘serendipitous collectionism,’ which is still commonly found in botanic gardens that lack collection plans (Heywood, 1992; Borsch, and Löhne, 2014; Volis, 2017). Such ‘curators' whim’ is a potential pitfall for the living collections that are accessioned into the garden, in the same way as stamp collections – whim. This last word deliberately chosen for its etymology, derived as a shortened form of ‘whimwham’ or "fanciful object" (q.v.). meaning "caprice, fancy, sudden turn or inclination of the mind" which was first recorded in the 1690s, a shortened form of whimsy – from the Scandinavian (Old Norse hvima "to let the eyes wander," Norwegian kvima "to flutter"), but herein mentioned for the lack of forethought it implies (Etymology online, 2023a).

The former models of institutional governance based around individual interests are increasingly less fit for purpose, as their use takes place in a rapidly changing social, political, and environmental arena. In contrast, exemplar collections are regularly evaluated and improved upon in the light of emerging science, policy, and practice (Gates, 2007; Aplin, 2013; Aplin, 2014; Hohn, 2022). A task this review suggests should include stakeholder interests – if lessons from museology are to be deeply embedded.

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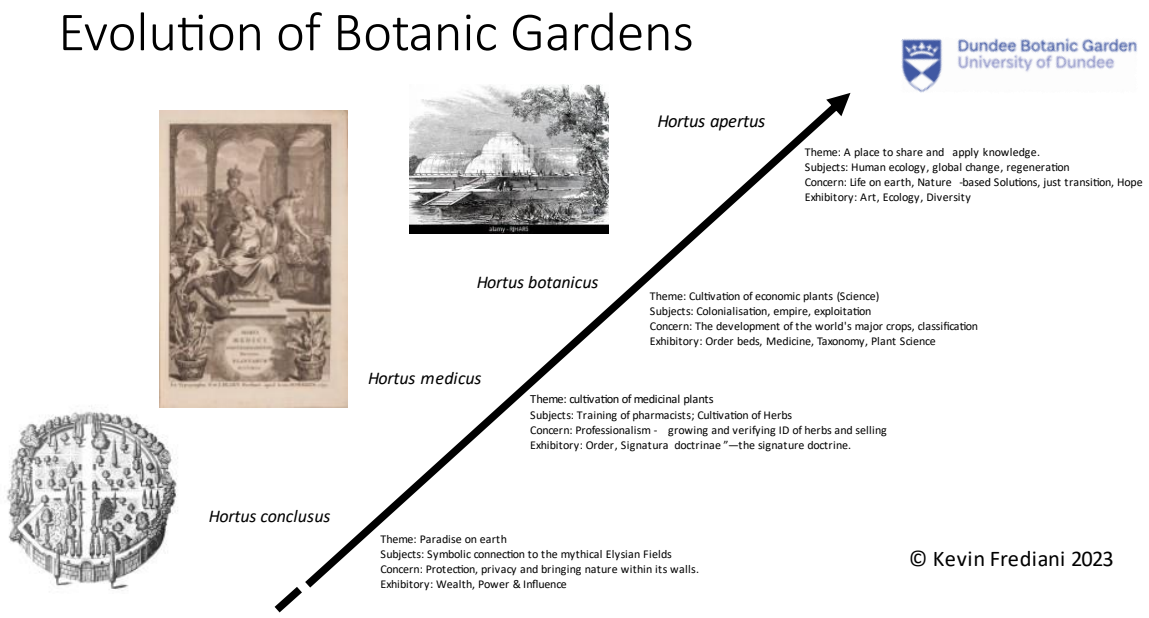

Figure 3: The historic trajectory of botanic gardens (c) Frediani 2023. Timelines overlap but a generalised acceptance of medieval cloistered gardens (Hortus conclusus) being in fashion between 600AD and 1500AD linked to religious orders and autocracy, the renaissance garden was prevalent between 1350 and 1650 – opening the way of the Hortus medicus as an institution – the first being Orto Botanico di Padova founded in 1545. As the world opened to European traders and colonial powers, plants and seeds brought back by traders and Hortus botanicus became the repository of the 17th century bioprospecting for economic gain and scientific enquiry for economic benefit, until the late 20th century when the environmental nexus and international agreements led to a conservation ethic and transition to social and environmental outcomes.

iii) The role of curation

Curation in the context of botanic gardens can be considered as much of an art as a science. With an etymology we can trace to the late 14c., its original meaning is related to early medical practice "to restore to health or a sound state," from Old French curer and directly from Latin curare "take care of," hence, in medical language, "treat medically, cure" (Etymology online, 2023b). Potentially reflecting the historical association of plants in the early botanic gardens for medical preparations and use – although plausible, note that no references has been found to support such a claim in this literature review. The history of curators in botanic gardens can be more substantially supported through exploring the diversity and variability of the living collections they have housed, by association with the external influences imposed on the curators by their governance authority, as much as by the stated agency of its administrative host, through its evolving vision, mission and values (Cunningham, 1996; Miller, *et. al.*, 2004; Faraji, and Karimi, 2022). Perceived as being outward

facing, curators are shaped as much by their own world views and those of their peers, who lead to their 'presented world settings,' as they are by the governance structures and provincial culture they work and reside within (Sanders, Ryken & Stewart, 2018; RBG Kew, 2020). The oldest having evolved from a circumscribed history, correlated to wealth, power and exploitation, which have adapted over time, to reflect the needs of their time and been joined by new iterations of gardens (Hill, 1915; Krishnan and Novy, 2016). In the modern age, they are increasingly influenced through global networks, that collaborate in common frameworks to address the emergent needs of the wider environmental, social and economic challenges relating to international priorities, such as the Convention on Biological Diversity (CBD) and laws related to access to genetic resources and associated traditional knowledge and benefit-sharing (BGCI, 2012; Smith and Harvey-Brown, 2017). Such frameworks, while fostering global collaboration, can also significantly impact the existing social and cultural factors that play a crucial role in the curatorial decision-making process. These frameworks not only shape how these elements interact with one another but also influence their dynamic with additional determinants like reaction to changes in latest information or emergent knowledge, to local legal structures, and any financial incentives or resources. This intricate interplay is part of what Mezirow (2000) terms the perspective transformational process.

The perspective transformation theory explains that when people encounter an unfamiliar situation, it pushes them to alter their regular pattern of thinking, from a set of "habitual expectations," known as perspectives, which can lead to a new reference point, causing them to reflect on their beliefs, norms, values, ideas, and expectations (Mezirow, 2000). Through this reflection process, curators as individuals but also as professional educators, not only develop the potential for new perspectives that become the pivotal point of relating to self, and others, but also become a means to shift perspectives in the wider society they serve (Illeris, 2014).

The following table seeks to capture areas of botanic garden practice, policy and procedures that are shared within the field of museum studies or museology:

Table 1: The integrity of museology as a field of study, encompasses all aspects of the museal landscape that botanic gardens share (Hohn, 2007, 2022 and selected literature cited herein).

Key area	**Impact on curatorial practices (policy, procedure, and practice)**	**Selected bibliography**
Governing collections	Guide and limit what is collected through the creation or revision of curatorial documents such as a Living Collections Policy and a Living Collections Management Plan.	Leadley & Greene, 1998; Gratzfeld, 2016; RBG Kew, 2020; Hohn, 2022

Developing collections	collections evolve over time informed by access to new exploration of the globe, but also to cultural exchange. It has become an essential role of curators to acquire new plants to ensure their collections remain current, meaningful and have value for the future. Plants being acquired through field collection, exchange via other gardens, purchase, or donation.	Hurka, 1994; Alpin & Heywood, 2008; Kitching, Sharrock & Smith, 2023
Documenting collections	Without minimum standards of documentation, a collection, or plants within a collection, has little value, relevance and can tell no story. The information added to the plant records ensures the collections are distinguished from a random assemblage of plants with no meaning to collections with high horticultural, scientific, conservational, educational, and cultural value.	Allen, et. al., 2001; Smith, 2016.
Maintaining and conserving collections	Making sure that adequate management, plant care and horticultural practices are in place with emphasis on conserving *ex-situ* (also known as 'preservation') and protecting the collections for future generations. This includes avoiding the decline in a species fitness through propagation and continual *ex-situ* collection management.	Heywood, 2017; Ensslin, *et. al.*, 2015; Volis, 2017
Collections and their research	The search to discover new plant knowledge and to record, interpret and disseminate this information. Interpretation and programming – to support collections-based interpretation, programming, and outreach and to make the collections accessible physically and intellectually.	Dosmann, 2006; Chen & Sun, 2018
Collections and public programmes	Botanic gardens have an obvious and vital role to play in conserving plants, but conservation cannot succeed without education. Gardens are uniquely placed to instruct people about the importance of plants in our lives and in the global ecosystem. By highlighting the threats that plants and habitats face, gardens can help people look at ways in which biodiversity can be protected.	Willison & Greene, 1994; Willison, 2006; He & Chen, 2012; Sellmann & Bogner, 2013; Bennett, 2014; Sanders, Ryken & Stewart, 2018

iv) Museology and epistemologies of curation

Museology or museum studies is the study of museums (Murphy, 2018). Through this lens, botanic gardens and their allied museums have learnt how to be understood, to exhibit a range of epistemologies or ways of knowing and potentially enhance understanding, depending on their

specific goals, mission, and approaches (Nomikou, 2015). The curatorial practices outlined in table 1, are commonly listed curatorial areas of work in museums and are embedded into the second version of BGCI accreditation standards manual (2022). They can help frame our understanding of knowledge attributes, or epistemologies, which has been represented under the different categorical headings that are captured in table 2 below:

Table 2: The theory of knowledge, or epistemologies, underpinning botanic garden curatorial approaches, especially regarding its methods, validity, and scope, and the distinction between justified belief and opinion.

Way of knowing	**Impact on curatorial practices**	**Selected bibliography**
Empirical and scientific	Botanic gardens have depended upon systematic observation, experimentation, and evidence-based research. They have aimed to understand plant biology, ecology, taxonomy, and conservation through rigorous scientific methods to validate claims, theories, and hypotheses related to plants and ecosystems.	Smith, 2019
Experimental and phenomenological	Botanic gardens come to value the opportunities they provide for visitors to engage in direct sensory experiences with plants and nature. This experiential approach fosters a life-world epistemology, emphasising the subjective, lived experiences and perceptions of individuals. Through personal encounters with plants, visitors can develop a deeper connection, appreciation, and understanding of the natural world.	APGA, 2009; Giovanetti, *et. al.*, 2020; Packer & Ballantyne, 2002
Indigenous and traditional knowledge	Botanic gardens have only more recently come to recognise and incorporate indigenous and traditional knowledge systems in their practices in notable areas of their work over more recent years. They have come to respect and collaborate with Indigenous communities in the later part of the 20th century, valuing their deep knowledge and understanding of plants, ecosystems, and sustainable land management. This epistemology acknowledges that diverse cultures possess unique ways of knowing and offers a more holistic perspective on nature.	Laird, 2010; Atran, 1998; Aguilar, 2001; Akpona, *et. al.*, 2009; Kimmerer, 2013
Educational epistemology	Botanic gardens often adopt educational epistemologies to facilitate learning and understanding among their visitors. They employ various pedagogical approaches, such as inquiry-based learning, direct experiences, and interpretive signage, to promote	Willison and Greene, 1994; Sanders, Ryken & Stewart, 2018

	knowledge acquisition and critical thinking. This epistemology recognises the role of education in nurturing curiosity, fostering connections with nature, and inspiring environmental stewardship.	
Historical and cultural epistemology	Botanic gardens often incorporate historical and cultural perspectives, acknowledging the significance of plants in human history, culture, and traditions. Curators regularly highlight the role of plants through their exhibitions, interpretation, and events, in medicine, food, art, and rituals, providing insights into diverse cultural epistemologies and the relationship between humans and plants over time.	Dun, 2017;
Collaboration and participatory epistemology	Modern botanic gardens have sought to adopt a collaborative and participatory epistemology, to help engage multiple stakeholders, including scientists, local communities, policymakers, and visitors. They have come to value diverse perspectives, promote dialogue, and involve stakeholders in decision-making processes in more recent times, informing new collections and displays. This epistemology recognises the importance of collective knowledge creation and the co-production of knowledge for addressing complex environmental challenges.	Lynch, 2015; Alexopoulos, & Moussouri, 2021; Melhem, et al. 2023.
Interdisciplinary epistemology	Botanic gardens often foster interdisciplinary collaboration among scientists, horticulturalists, educators, artists, and policymakers. By bringing together multiple disciplines, such as biology, ecology, anthropology, art, and sociology, botanic gardens promote a holistic understanding of plants and their significance from various epistemological angles.	Simson & Straus, 1997; Packer & Ballantyne, 2002; McCaffrey, 2007; Rodríguez-Labajos, 2022
Object or plant-based, visitor-centred, storytelling epistemology	This can be complementary as an interdisciplinary approach and aims to unleash, rather than mute, the real power of plants or plant derived objects. It would address human destructiveness, as well as celebrating human creativity and the wonders of nature in a manner first progressed by O'Neill (2006). It would respect the meaning-making practices of real, as opposed to idealized, imaginary visitors, and promote staff self-awareness in managing any risk of bureaucratic drift into introversion and avoidance of difficult issues. Incorporating a theory of justice, it would erode boundaries created by presentation traditions which, though	O'Neill, 2006; Bedford, 2001

	marginal to object experiences, discriminate in favour of specific social groups—often groups with whom staff identify.	

It is important to note that any individual botanic garden can and will vary in its approach to gaining and sharing knowledge, depending on the specific goals, philosophies, and contexts they have been directed to explore. National institutions have an ongoing prioritisation and support for scientific research and conservation, reflecting a global awareness of the loss of biodiversity. While most if not all gardens have an ongoing emphasis on displaying and interpreting the cultural heritage, use and life history of plants in their care, for public engagement. This is an approach shared with museum studies professionals, termed museology, whose research, and praxis may be a viable source of new insight into how to organise, arrange and manage their collections (Desvallées and Mairesse, 2010). The diversity of epistemologies that can further be advanced within botanic gardens includes epistemologies that museums and galleries have been exploring that align to wider fields of knowledge. For example, those informed by a cultural shift in the perceptions of colonial histories in museums that include colonial and anthropological epistemologies as outlined by Von Oswald, (2020) or placemaking epistemologies, advanced by Peña, (2006). These include areas being advanced under epistemologies of human health and wellbeing (Waylen, 2006; Dobson, 2018; Catahan and Woodruffe-Burton, 2019; Andrianou and Papaioannou, 2019; Nicol, and Pardoe, 2022). The need to enable a just transition includes a growing awareness of the need for diversity and inclusion in environmentalism (Bell, 2021), as we seek alternatives to Sustainable Development that include development that does not rely on the exploitation of fast depleting natural resources (O'Neill, *et. al.,* 2018; Reid, et. al., 2021; Kaul, *et. al.*, 2022).

In times of rapid global change and urbanisation, when over 50% of the global population live in cities, the role of botanic gardens must continue to develop, playing a strong role in promoting environmental sustainability, while demonstrating congruence through their own management practices (Primack and Miller-Rushing, 2009; Richardson, *et. al.*, 2016; Lopez-Villalobos, *et. al.* 2022; McNeill, 2022). There is the potential to align their business models to those of the bioeconomy, the green economy, and the sharing economy, which are currently relevant in academia, business, and policymaking (D'Amato, 2021). Such approaches reflect adaptive epistemologies, which can inform restorative thinking, that botanic gardens can support in restoring processes of ecological succession or at least to speed them up so that they could return to a state that has been lost due to a disturbance (Bradshaw, 1987). In other words, to help reset and let nature take over. As a consequence, botanic gardens have the opportunity to establish a role as introduction and

translocation centres and become major actors in the assessment of new germplasm, both of economically important but also functionally important plants to help cities become sustainable landscapes and natural systems be restored or primed (Hurka, 1994; Heywood, 2011; Aronson, 2014; Hardwick, *et. al.*, 2011; Heywood, 2017).

v) Sustainable Development and Sustainable Development Goals

Sustainable Development (SD) has guided global environmental reform since the Brundtland Report in 1987 (Currie-Alder, 2016; Ruggerio, 2021). However, from its outset, ambiguous characterisation faced criticism, leading to the more focussed Millennium Development Goals (MDGs) in 2000, that aimed to "address the problems of extreme poverty in its many dimensions – income poverty, hunger, disease, lack of adequate shelter, and exclusion, while promoting gender equality, education, and environmental sustainability" (Sachs, 2005:1-2). Despite having a focus on poverty, gender equality, and sustainability, they also fell short of ambition, due to their aspirational nature, being perceived as unachievable and lacking accountability (Vandemoortele, 2015). Subsequently being replaced in 2015 with the SDGs, that aim for a broader, more inclusive approach relating to various dimensions of fundamental human rights (McCloskey, 2015; Georgeson and Maslin, 2018). Underneath the ongoing challenges of ambition versus delivery, is the fundamental relationship between sustainable development and the reliance on economic growth, which has fuelled intense debate (Mitlin, 1992; Schepelmann, Goossens, and Makipaa, 2009; Boström, 2012; Ivković, 2016).

International actors exploring concepts of SD, have traditionally focussed on revolving themes around utility and maintaining natural capital, while grappling with encompassing concepts of intergenerational equity across divisions in environment, economy, and society (Daly, 2006). This triad has come to be reflected in terms such as People-Planet-Profit or Environment-Economy-Equity (Mensah, 2019). It is a holistic concept that seeks to continue to develop the thread of policy and practice that is caught in a mindset of economic growth, while addressing widening gaps of the society-nature relationship by seeking to establish universal Social and Environmental Standards (SESs), acknowledging that sustainable economic growth requires maintaining the health and integrity of the biosphere (Ruggerio, 2021). Alternative proposals for sustainable living are gaining traction at a provincial scale, progressing concepts like ecological swaraj, degrowth, and buen vivir (Kothari, Demaria, and Acosta, 2014; Whyte and Lamberton, 2020).

Throughout this process botanic gardens have been guided towards plant conservation ambitions, which align with the latest iteration in support of SDG's (Sharrock and Wyse-Jackson, 2016). Several SDG's, primarily SDG15 (Life on Land) are being highlighted for contributing to poverty eradication,

health, clean water, renewable energy, sustainable cities, responsible consumption, and climate action. Focusing on local stakeholders can enhance these connections. Recognising the increasing movement of global populations from the rural to the urban life, where the growing urban population of the world, set to reach 7 out of 10 people by 2050, emphasises the urgent need for sustainable urban ecosystems to be designed and developed that rebalance the social and ecological systems (United Nations, 2018; Marten, 2001; Newman and Jennings, 2012). Cities consume significant energy and produce high greenhouse gas emissions. Transitioning to post-carbon economies by integrating natural solutions can make cities more sustainable, resilient, and cost-effective (International Energy Agency, 2021). Embracing a systems perspective that frames cities as sustainable urban ecosystems offers hope for mitigating negative impacts while creating resilient, environmentally conscious urban spaces. Such spaces could adopt solutions that have been inspired by and are enabling urban nature, which is suggested to be more cost-effective, while simultaneously providing environmental, social, and economic benefits to the city and helping to build in a measure of future climate resilience (Seddon, et. al., 2020).

vi) Nature-based Solutions

The concept of Nature-based Solutions (NbS) lacks a clear, universally accepted definition, leading to potential misuse (Ershad Sarabi, et.al., 2019). Definitions proposed by the International Union for Conservation of Nature (IUCN) and the European Commission (EC) serve as primary reference points, differing in their emphasis on nature conservation and broader sustainability pillars (European Commission, 2015; Cohen-Shacham, et. al., 2016). They are promoted to business and society to plan for disaster risk reduction - effectively and adaptively, because they are cheap, effective, and scalable and backed by an established evidence base (United Nations Environmental Programme, 2020). At the national level, they extend beyond human well-being to support energy transition efforts toward achieving Net Zero, aiding disaster risk reduction through cost-effective, evidence-backed interventions (Razzaghi, 2022). Such solutions find endorsement by governments and social activists aligning with the idea of a Just Transition (European Commission, 2015; Macfarlane and Brett, 2022). However, despite their wide promotion, scholars caution against overestimating NbS's potential across all areas they are implemented (Ares, 2020; Seddon, et al, 2020; Anderson and Renaud, 2021; Improvement Services, 2021).

Originally conceived by scientific NGOs and financial bodies, NbS now align with social inclusion and are advocated to combat the climate crisis (Nesshöver, et. al., 2017). NbS encapsulate a range of nature-centric interventions with broad applications from habitat conservation to climate

adaptation, which are endorsed by various sectors for their multifaceted benefits to society and the environment (Cohen-Shacham, et. al., 2016; Nature, 2017; Vujcic, et. al., 2017). NbS, as per these definitions, look to deliver various benefits to human society. They encompass nature conservation, habitat restoration, and sustainable infrastructure alternatives, promoting active participation in environmental initiatives like locally grown food. They present an ideal tool for botanic gardens, who have historically been advocates of nearby nature, playing a role in urban greening and conserving urban biodiversity (Cavender, Smith, and Marfleet, 2019). NbS can be a further aid to progress this pioneering work, towards the objective of liveable and more sustainable urban landscapes (Richardson, et. al., 2016; Frediani, 2020; Kelly, Wilson, Kalaichelvam, and Knott, 2020; Miller, Bailey, and Smith, 2020; Rahayu, and Yusri, 2021). They can provide a local focus close to the garden's central place, but also can be leverage to the benefits of wider landscape restoration, where they are also able to be focussed to support the conservation of larger habitat patches, enabling better connections to ensure species survival and increasing resilience to climate change, identifying connectivity gaps at local and regional levels to focus conservation efforts (Hames et al., 2001; Foster, et. al., 2017).

vii) Just Transition

Originally coined as a term that was designed to link the promotion of clean technology with the assurance of green jobs, Just Transition is a new framework of analysis that brings together climate, energy, and environmental justice scholarships (McCauley and Heffron, 2018). Summarised in the manifesto of the Just Transition Alliance (2023) as a principle, a process, and a practice, it is seen to support and facilitate a transition to a low carbon economy (Wang and Low, 2021). It is the principle that a healthy economy and green environment can and should coexist, through a process that recognises that this vision should be achieved fairly, and not cost workers or the community residents their health, environment, jobs, or economic assets. It implies that in practice, the people who are most affected by pollution should be in the leadership of crafting policy solutions (Just Transition Alliance, 2023).

Central and regional governments have been adopting a Just Transition to embed biodiversity considerations in climate change adaptation and mitigation (Kriebel, *et. al.*, 2021). A shift to creating, restoring, or enabling functional and dynamic landscapes to emerge, that adopts and supports the integrated use of NbS. Nature often being promoted to bring multiple benefits to the local populations and biodiversity through creating functional landscapes that benefit through ecosystem services and mitigate or adapt cities in the age of the Anthropocene (Cannon and Kua, 2017). Where

humanities future, is increasingly tied to the sustainable development of urban landscapes, while restoring functional ecosystems globally, where increased resilience is designed into and softens the hard architecture of the urban ecosystem and provides liveable habitats for people while benefiting nearby nature in and through a time of global change.

DISCUSSION

This paper examines the evolution of botanic gardens, tracing their journey from secluded spaces to centres of plant diversity. It emphasizes their historical significance in conserving plants, educating the public, and fostering environmental awareness. It acknowledges the crucial role of Botanic Garden Conservation International (BGCI) in forming a global network for plant conservation. While celebrating their positive impact, the paper confronts the dissonance between conservation efforts and holistic approaches of botanic gardens, urging acknowledgment of past social injustices perpetuated by these institutions. It advocates for a shift in the dominant human culture, urging these institutions to challenge flawed systems and strive for a more sustainable future. This requires acknowledgement that these symptoms are the result of mutually reinforcing products of the same flawed systems they have been born from (Solomonian and Di Ruggiero, 2021).

Furthermore, it urges better integration of global conservation goals through wider collaborations to facilitate restoration ecology and metapopulation management, while encouraging local engagement with environmental challenges through Nature-based Solutions (NbS) and the Just Transition framework. This leverages the trusted position botanic gardens have in society, to help them become pivotal leaders in shaping urban landscapes and inspiring behavioural change toward sustainability (Symes and Hart, 2021; RBG Kew, 2021; University of Dundee, 2021).

The literature review emphasises the need for further research into the curatorial practices of botanic gardens:

i) History of botanic gardens and their curatorial practices: The evolution of practices from categorising and collecting cultural material to more inclusive, community-oriented approaches to sharing the knowledge they contain.

ii) The role of curation: Governing, developing, and documenting collections, acquiring new plants, and ensuring transparent and accessible documentation for wider inclusive engagement.

iii) The need to explore epistemologies of botanic gardens: Exploring various approaches, including the scientific and Indigenous ways of knowing, expanding the educational and interdisciplinary approaches, which inform the direction of these gardens.

iv) Sustainable Development and Nature-based Solutions: Critiquing imprecise definitions of sustainable development and exploring how NbS can promote sustainability and address environmental challenges in local ecosystems.

v) Just Transition: Adopting principles that balance social justice and environmental consciousness in navigating the complexities of botanic garden work.

Overall, this paper calls for deeper exploration and synthesis of botanic garden practices, stressing the importance of inclusive, sustainable approaches and their potential for positive societal and environmental impact.

CONCLUSIONS

This paper delves into the transformative journey of botanic gardens, tracing their evolution from exclusive spaces through eras of utility, exploration, and exploitation to their current focus on education and conservation. It emphasizes the multifaceted role of curation in governing, developing, documenting, and maintaining collections within these gardens. Highlighting the need for embracing the 'new museology' lens, the article suggests that botanic gardens must align with diverse epistemologies, including scientific, experiential, Indigenous, educational, historical, collaborative, interdisciplinary, and object-based approaches. This wider embrace offers a chance to enhance the relevance and value of living collections beyond the confines of plant conservation and botanical education. Moreover, it stresses the importance of these epistemologies in shaping curator views and practices, urging a shift from merely cataloguing biodiversity to genuinely valuing it as a fundamental aspect of our world. Embracing a wider set of epistemologies enables botanic gardens to engage a more diverse society, addressing complex global environmental challenges in collaboration with local stakeholders meaningfully.

Exploring the emergent role of botanic gardens in the context of Sustainable Development and Nature-based Solutions (NbS), the literature review has emphasised the dedication of botanic gardens to understanding and interpreting plants for societal benefit over an extended period. This paper shows that botanic gardens are adapting and demonstrating resilience in their duty, recognising the evolving curatorial practices of these institutions, while advocating for continuing the transition from exclusive approaches toward inclusive, community-oriented ones. Positioning

botanic gardens as agents of positive change within socio-political realms, it underscores their role in fostering sustainable local urban ecosystems for the benefit of local stakeholders. This aligns with international agendas on sustainable development, making it a tangible indicator of nearby sustainability efforts. The review highlighted the increasing adoption of the Just Transition framework at the national level, integrating biodiversity considerations and fostering landscapes beneficial to both people and nature. It is suggested that this framework offers guidance for botanic gardens adopting NbS as a tool to support their local work, aiding in achieving a balanced human ecology transformation.

In conclusion, the paper has highlighted the pivotal role botanic gardens provide in promoting sustainable practices, engaging the public, and tackling environmental challenges. It encourages further enrichment by expanding curators' knowledge base beyond the material culture of plants and integrating varied epistemologies to enrich their work. This shift can be supported and informed by engaging with allied professional areas that practice new museology, presents an opportunity for botanical curation to evolve into an active field of research and practice, strengthening its role as a knowledge institution, and transitioning from gardens as refugia of plants, to places of knowledge in how to transform the world. *'Hortus apertus'*, is proposed as the iterative development of botanic gardens, ensuring they remain crucial institutions fostering environmental awareness and conservation equitably and inclusively.

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Appendix 1: Publish or Perish citation analysis final dataset of 37 publications using method the outlined in this paper.

#	Reference	1° Key Words	Sources
1	Delmas, M., Larpin, D. & Haevermans, T., 2011	Curation, Botanic Garden	Google Scholar, Scopus, PubMed and OpenAlex
2	Griffith, M. P. 2021		
3	Packer, J. & Ballantyne, R., 2002		
4	Hill, A. W., 2015		
5	Hardwick, et. al., 2011		
6	Dosmann, M.S., 2006		
7	Zelenika, I., Moreau, T., Lane, O. & Zhao, J., 2018		
8	Dodd, J., & Jones, C., 2010		
9	Krishnan, S., and Novy, A., 2016		
10	Schulman, L., Lehvävirta, S. 2011		
11	Hohn, T. C., 2007		
12	Hohn, T. C., 2022		
13	Salick, J., Konchar, K., & Nesbitt, M. 2014		
14	Rae, D., 2011		
15	Faraji, L., and Karimi, M., 2022		
16	Wood, J., Ballou, J. D., Callicrate, T., Fant, J. B., Griffith, M. P., Kramer, A. T., ... & Havens, K., 2020.		
17	Sanders, D. L., Ryken, A. E., & Stewart, K. 2018		
18	Borsch, T., & Löhne, C. 2014		
19	Smith, P., 2019		
20	Spencer, R. & Cross, R., 2017		
21	Hirons, A. et. al., 2021		
22	Forbes, S. J., 2016		

23	Hällfors, M., Schulman, L., Lindén, L. & Hannu, R., 2010		
24	Cullen, J., 2004		
25	Knott, D., 2021		
26	Gardner, M. F., 2021		
27	Ward, C. D., Parker, C. M., & Shackleton, C. M., 2010		
28	Nicol, P., & Pardoe, H. 2022		
29	Daniel, J., Russo, A., & Burford, B., 2023		
30	Vujcic, et. al., 2017	Sustainable Development; Green infrastructure; GI / GBI; and Nature-based Solutions	
31	Kelly, D. A., Wilson, K., Kalaichelvam, A., & Knott, D., 2020		
32	Rahayu, E. M. D., & Yusri, S., 2021		
33	Elmqvist, T., 2019		
34	Reid, A., Dillon, J., Ardoin, N., & Ferreira, J. A., 2021		
35	Andreucci, M. B., Marvuglia, A., Baltov, M., & Hansen, P., 2021		
36	Natural England, JNCC, Natural Resources Wales, NatureScot & Northern Ireland Environment Agency, 2021		
37	Bell, K. (Ed.), 2021		

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THE EVOLUTION OF THE DAFFODIL DNA PROJECT: FROM A SINGLE CLASSROOM PROJECT TO HIGH QUALITY CITIZEN SCIENCE ACROSS A COUNTRY

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ABSTRACT

The Daffodil DNA Project is an innovative educational initiative aimed at investigating the impact of sustained authentic project work on post-16 biology education. The project focuses on engaging students in collaborative inquiry and developing their understanding of biology concepts through the study of daffodil chloroplast genomics. This article provides an overview of the project's background, methods, and initial outcomes. Preliminary outcomes of the project have demonstrated its scientific impact, resulting in the generation of 9 new draft daffodil chloroplast genomes from this citizen science project. Furthermore, participating schools showcased their findings at the Royal Society Summer Science Exhibition, enhancing public engagement with the project. Initial feedback from students indicates the transformative nature of the project, with one student describing the experience as "life changing." The success of the Daffodil DNA Project can be attributed to effective collaboration between the University of Dundee, the James Hutton Institute, schools, and STEM partners. Regular communication and knowledge sharing among participants have contributed to the project's achievements and the development of a shared identity as scientists. Overall, the Daffodil DNA Project

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presents a promising model for inquiry-based learning in biology education, emphasising the importance of authentic scientific investigation and collaboration. Future research will delve into the educational benefits of this approach and its potential applicability in diverse classroom settings.

Keywords: Education, inquiry, collaboration, plant science, citizen science.

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INTRODUCTION

The aim of this article is to bridge the gap between the initial case study of the Jersey Daffodil Project (Hale, Harkess & Könyves, *2024*) and the current Daffodil DNA Project which is administered by the University of Dundee.

The initial rationale for the project

The curricula for post-16 biology may well resemble the cellular organisation of a palisade mesophyll cell, with key concepts compartmentalised within each specification (AQA, 2021; OCR, 2020; Pearson Edexcel, 2018; SQA, 2022). Just as the cell may well segregate the enzymes for oxidative phosphorylation within the mitochondria, concepts can be siloed in the classroom. However, the evolutionary advantage of compartmentalisation within the cell is all aimed at the success of the cell, the success of the cell within the tissue and how the tissue supports the leaf's function as an organ within the organism. This vertical organisation of key concepts in biology education is rarely considered (Moore-Anderson, 2021), and as such the connections between the biochemistry of the cell and the role of the organism in an ecosystem may not be explicitly taught or implicitly considered by the student.

The vision of building an interconnected sequence through the OCR Biology A specification was the inspiration for this project (Hale, 2023) but sited within the local environment (Hale, 2022a). By taking the time to notice nature during the spring of 2018, the diversity of daffodils was phenomenal. They were not the ubiquitous yellow flowers seen around Mothering Sunday in the UK, but a myriad of different forms. From approximately 84 species (Royal Horticultural Society, 2017), amazingly over 30,000 different cultivars have been named (Willis, 2012), often with minute differences between the cultivars.

Citizen Science in the Classroom

Citizen science is an inclusive set of activities that enable communities to be part of a research project (Cooper, 2012) such as by collecting raw data such as Flower-Insect Timed Counts (Persson *et al*., 2023) or performing labour-intensive transcription services from secondary sources (Hill *et al*., 2012). Citizen science has been shown to have beneficial impacts on learners, from the domain specific skills such as developing an understanding of the scientific content and process (Krach, Gottlieb & Harris, 2018), to developing STEM career aspirations (Hiller & Kitsantas, 2015).

Initially the project looked to develop the "biologist's gaze" (Moore-Anderson, 2023) in students, whereby they see the similarities between individuals but start to acknowledge the differences. Specifically, students would need to take the knowledge of what makes a daffodil a daffodil, such as the parallel vascular network in the leaves, the number of petals and the corona as constants, with a few exceptions, and then look for the differences such as height, colours and corona morphology. Students, staff and the community were encouraged to upload their observations to an iNaturalist project (iNaturalist, 2023). Over 1,500 observations of daffodils were quickly added to the project. Grounded in citizen science, the students then selected the daffodils to biochemically interrogate as previously described (Hale, 2020).

Initial Findings from the Jersey Daffodil Project

The initial results during the Jersey Daffodil DNA project (Hale *et al*., 2023a; Hale *et al*., 2023b) allowed students to perform basic phylogenetic analysis using Geneious Prime 2019.1 (Hale, Harkess & Könyves, *in press*), however it was the impact on student learning and aspirations that warranted further study.

The cancellation of examinations following lockdowns during the COVID-19 pandemic and the need for evidence-based teacher assessed grades presented the opportunity to directly compare students that did not undertake the Jersey Daffodil Project with those that had with the same examination paper in the same controlled conditions. As described in Hale, Harkess & Könyves (*in press*), the results were phenomenal showing a marked improvement where the mean raw score increased by nearly a third. It should also be noted that the attitudes towards science, technology, engineering and mathematics (STEM subjects) also improved. This study did not identify the key drivers for these impacts on students. Potentially, it could be due to the narrative of the daffodil through the course, the improved teacher subject knowledge, the frequent opportunity to discuss biology that historically students find challenging (Hale, Harkess & Könyves, *in press*) or the role of inquiry-based learning in biology.

Collaborative inquiry and cognitive load

Through the Jersey Daffodil Project, a model of collaborative inquiry was developed whereby the students and teacher were equals in scientific endeavour, genuinely producing data that was new to science outside of the knowledge and experiences of all parties. The concept of collaborative inquiry has not been researched in the past, despite the role of collaboration being identified as a tool to increase engagement (Jao & McDougall, 2016) and motivation (Miller & Benz, 2008). Although inquiry in science education has been a key part of many curricula, it is not consistently defined, frequently conflated with

practical science (Ioannidou, Finch & Erduran, 2022). Additionally, how inquiry is enacted within the classroom varies across a spectrum of highly structured confirmatory investigations to completely open discovery-based learning with students in control of every decision (Akuma & Callaghan, 2018; Bevans & Price, 2016).

The further towards the open-ended inquiry the student is pushed, the greater the challenge there is on the student to develop a deeper learning of a particular topic (Barron & Darling-Hammond, 2008). It could be argued that this mandatory responsibility for their own learning leads to greater learning, but the efficacy has been robustly challenged (Kirschner, Sweller, & Clark, 2006) within the framework of cognitive load theory (Sweller, Ayres, & Kalyuga, 2011). As such there has been little research in the UK on the role of inquiry in the UK's science classrooms in recent years.

Cognitive Load Theory is a framework which offers an explanation as to why students may struggle to learn when presented with new material (Sweller, 2010). It takes into account the working memory being applied to the learning alongside the novel information and how it is presented. It has been elicited that discovery-based inquiries place too much load on the working memory of novice learners to enable effective learning to happen (Kirschner, Sweller, & Clark, 2006). Therefore, there is a need to scaffold inquiry activities to make them accessible to students.

Understandably, with the rich curricula of post-16 biology (QA, 2021; OCR, 2020; Pearson Edexcel, 2018; SQA, 2022) many teachers state that there are simply not enough hours in the course to deliver effective inquiry (Bevins, Lehane & Booth, 2019; Fitzgerald, Danaia & McKinnon, 2019; Sadler, Barab & Scott, 2007) so the question to be asked is whether the Jersey Daffodil DNA Project could be enacted within different classrooms successfully, and thus the Daffodil DNA Project was born.

The aims of the Daffodil DNA Project are:

1. To identify and assess any value of sustained authentic project work impact on post-16 student aspirations related to STEM fields.

2. To identify and assess the value of context-based inquiry work on the domain specific knowledge of post-16 students.

3. To determine whether sustained collaborative inquiry work has a positive effect on student STEM values.

4. To identify and assess any value of supported projects as a mechanism for subject specific professional development.

METHODS

Ethics

To minimise risk and allow swift data collection upon the commencement of the project, the decision was made to only use students over the age of 16. Teachers recruited their own students to the project. Although data from the teachers and scientists could be directly attributed at the point of collection, names and genders were anonymised with identifiable data excluded from the data following transcription. All participants were reminded of their right to withdrawal without any negative impacts. Schools and scientists agreed with informed consent to take part in the study following ethics approval by the University of Dundee (E2020-145).

Recruitment of schools

In the spring of 2021, schools were invited by the University of Dundee to attend one of two introductory presentations held virtually. Fourteen schools attended the sessions across Scotland with nine schools formally applying to participate. These schools were supported in applying for a Royal Society Partnership Grant alongside scientists (STEM partners) from the University of Dundee and the James Hutton Institute. In 2022 a further two schools joined through word of mouth.

STEM partners recruitment

A key aspect of the Royal Society Partnership relies upon schools working with active scientists. These scientists were voluntarily recruited through Public Engagement networks within the University of Dundee and James Hutton Institute in 2021. Thirteen scientists initially volunteered to support the project and individual schools. The majority of these scientists have continued to contribute to the project with further scientists onboarding in 2022.

Cultivar selection

University of Dundee Botanic Gardens liaised with Croft 16 and National Trust for Scotland to ascertain where there were opportunities to explore breeding within heritage daffodils. Collectively it was decided to investigate “Albatross”, “Empress”, “Lady Margaret Boscawen”, “Loch Fyne”, “Lucifer”, “Minnie Hume”, “Ornatus”, *Narcissus radiiflora* var. *Poeticus*, and “*Princeps*” as these cultivars would

enable a breeding history to be tested using biochemistry. Details of the recorded history of these cultivars can be found at https://dag.compbio.dundee.ac.uk/daffodils/. Each school received two cultivars, allowing the possible replication of data.

Wet laboratory procedures

In November 2021 and November 2022, teachers and technicians were invited to the University of Dundee and the James Hutton Institute to learn the required wet laboratory procedures. In the following spring, the teaching staff were supported by their STEM partner in the schools' laboratories/classrooms.

Each daffodil leaf was destarched by placing it in a dark cupboard 24 hours prior to DNA extraction. Approximately 0.1g of leaf material was mascerated with silica sand before students extracted the DNA using the Qiagen DNeasy kit (Qiagen, Manchester, UK). Each daffodil was subsequently sequenced using the Rapid DNA Sequencing Kit SQK-RAD004 (ONT, Oxford, UK) and the Flow Cell (R9.4.1, FLO-MIN106D) on the MinION device (ONT, Oxford, UK). Schools were provided with videos of each step (Duce, 2022).

Dry lab procedures

Basecalling was undertaken using Guppy v6.1.1 using default parameters. The students were then able to align their reads against the reference *N. poeticus* chloroplast genome (MH706763) using Geneious 2022.1. In addition to this, data was transferred to the University of Dundee and further analysed (Abbott, 2023) to produce higher quality assemblies. Details of the bioinformatics pipeline can be found at https://dag.compbio.dundee.ac.uk/daffodils/.

Assessing the impact of the project on individuals

Students were provided with a pre-and post-project questionnaire hosted on JISC to allow teachers to administer these questionnaires within the classroom at a convenient time. Teachers were interviewed so that individual responses could be tracked and this enabled changes on a personal level to be determined. In order to triangulate student changes with the teacher data, generalised data regarding students had to be collected, whereas specific data could be collected regarding the teachers' own project journey. Similarly, scientists were interviewed. Interviews were conducted via Microsoft Teams and recorded. Automated transcriptions were then assessed for accuracy and manually corrected before identifiable features were removed prior to analysis.

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RESULTS

Initial outcomes:

The impacts on the classroom are still being collected, however the scientific output has been highly successful, leading to nine new daffodil chloroplast genomes of varying completeness. This data has been deposited in the European Nucleotide Archive (Project: PRJEB578320). A comparison of similarity in phylogenetic analysis of the daffodil chloroplast sequences is shown in Fig. 1.

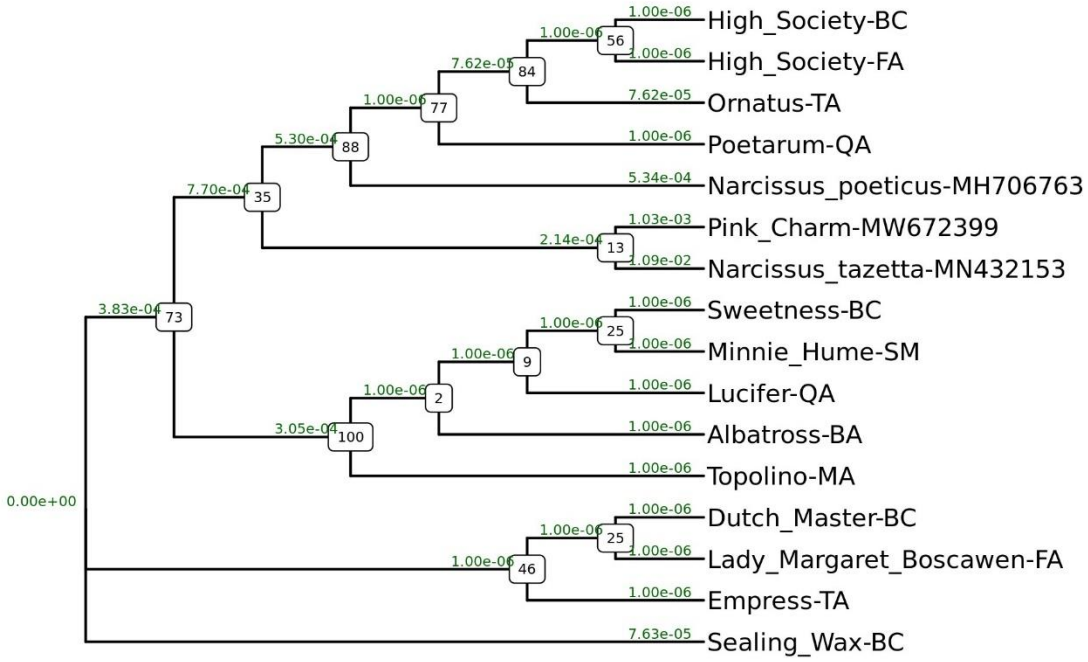

Figure 1. The resultant phylogenetic analysis based upon longread similarities of each school's final assembly.

Two of the participating schools represented the project at the Royal Society Summer Science Exhibition in 2022, engaging the public with their science. One student fed back to the Royal Society that this experience was "life changing."

CONCLUSION

The Daffodil DNA Project has significantly evolved from the initial seed in Jersey. Whereas the initial investigation was grounded in citizen science, the decision to angle the discovery to horticulture and

conservation of heritage cultivars has opened up a new avenue of discovery that potentially has commercial benefits as well as providing evidence of the interrelatedness of the different cultivars.

From the small concept study in Jersey, the Daffodil DNA Project has shown that students, teachers and their STEM partners can produce high quality data that is genuinely new to science, undoubtedly impacting on each and every participant's identity as scientists. A key aspect of the success has been the regular communication between the University of Dundee, the James Hutton Institute and the participating schools. As each collaboration is autonomous in their decision making and timelines, this has allowed each participant the opportunity to share their knowledge and experiences in an open monthly forum knowing the contribution will be valued by someone in the group.

As the qualitative data trickles into the project from the schools and STEM partners, it will ensure that its benefits can be explained.

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A SCIENTIST'S JOURNEY: LEARNING TO COMMUNICATE SCIENCE FOR IMPROVED NATURE CONNECTEDNESS

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ABSTRACT

With continuing concerns over the future of the natural world in the face of climate change, it is becoming increasingly important that people feel a sense of caring for, and responsibility towards, the environment. A feeling of 'nature connectedness' can be a useful means of predicting an individual's likelihood of making more sustainable life choices and is an area of great interest to researchers. Unfortunately, many people today struggle with so-called 'plant blindness' and low levels of nature connectedness. Through science communication, scientists can attempt to improve public knowledge and understanding of the natural world, thereby increasing individuals' appreciation for, and sense of connection to, nature. As a doctoral student at the early stages of my scientific research career, I had not had a great deal of experience with science communication for a public audience. However, as part of my doctoral training programme, I had the opportunity to undertake a professional internship to explore career options out with the university lab environment. During this internship, working within a university botanic garden in the East of Scotland, I had the opportunity to experience science communication for a variety of audiences including school pupils, school teachers and the general public. The intention was to use my

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molecular biology and protein biochemistry knowledge to produce a new educational and recreational resource highlighting plants with medicinal properties. The aim of the new resource was to inform and entertain visitors to the botanic garden in a manner that would improve these individuals' sense of nature connectedness.

Keywords: Nature connectedness; Interpretation, Medicinal plants, Botanic Garden

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INTRODUCTION

As part of my doctoral training programme, I undertook a three-month professional internship working within a university botanic garden in the East of Scotland. The internship was an opportunity to explore career options out with the area of academic scientific research. I was eager to discover the realities of working at the public-facing front of science, having spent the first two years of my doctoral training in a lab conducting molecular biology and protein biochemistry experiments, and the botanic garden provided an ideal environment for this. During initial discussions with my supervisor, we agreed that during the internship I would work to produce a new educational and entertainment resource highlighting plants with medicinal properties. The target audience of the medicinal plants trail was to be secondary school pupils (education) and members of the general public (entertainment). As I had little experience of communicating science to a public audience, I began work on the project by considering a simple question—what is science communication?

LITERATURE REVIEW

What is science communication?

According to the Oxford Reference definitions, science is "the systematic study of the structure and behaviour of the physical and natural world through observation, experimentation, and the testing of theories against the evidence obtained" (Oxford Reference 2017) and communication is "a process of interaction through messages or signals" (Oxford Reference 2020). Taken in combination, science communication can therefore be considered the use of speaking, writing or other tools to provide information which explains our understanding of the physical or natural world. Science communication can take many different formats depending on the subject matter and the intended audience.

The importance of science communication

In a 1998 article, Jane Lubchenco considered the role of science within society at the dawn of a new millennium. Lubchenco posited that public funding for science is provided in exchange for knowledge or technological contributions to society (Lubchenco, 1998). Indeed, for the current generation of early-career researchers, it is challenging to fully comprehend the extent to which the technologies that developed within their lifetimes have revolutionised both the possibilities and expectations of science. In the last 20 years, computational and technological advances have

enabled progression from the enormous effort and expense of the Human Genome Project (>90% sequencing of the human genetic code, completed after 13 years in 2003, at an estimated cost of around $3 billion) (The National Human Genome Research Institute 2022) to the Oxford Nanopore MinION (a pocket-sized portable sequencer, capable of whole genome sequencing, available for $1000) (Oxford Nanopore Technologies 2023). As highlighted by Lubchenco, it is clearly important to ensure such scientific advances are communicated to the public to secure future funding for research. However, I believe it is also relevant to consider the importance of science communication as a means of providing individuals with a greater sense of nature connectedness.

A relatively new term, nature connectedness can be considered a measure of an individual's attitudes towards the natural environment. Chen-Hsuan Cheng and Monroe (2012) suggested four key areas which contribute towards an individual's sense of nature connectedness:

1. Enjoyment of nature.
2. Empathy for creatures.
3. Sense of oneness with nature.
4. Sense of responsibility for the environment.

In the face of ongoing issues such as climate change and loss of biodiversity, it is important that people feel a strong sense of nature connectedness as this increases the likelihood of an individual valuing, respecting and protecting the environment (Whitburn *et al*. 2018). Additionally, increased nature connectedness is not only beneficial for the environment but is good for people too. In a survey for 2021 Mental Health Awareness week, 73 per cent of UK adults reported that connecting with nature was important for managing their mental health during the COVID-19 pandemic (Mental Health Foundation, 2021). Furthermore, researchers in Japan were able to measure the physiological health benefits of spending time in forest environments, so called *Shinrin-yoku* or forest bathing, in reductions in cortisol levels, pulse rate and blood pressure (Park *et al*, 2010).

The aims of science communication

The aims of a piece of science communication are dependent on the research area, target audience and format of the specific work. Despite the customised needs of individual projects, some core, shared objectives of science communication have been identified. One influential report by Burns *et al.* (2003) identified the five aims of science communication as:

1. Increased awareness.
2. Enjoyment.
3. Interest.

4. Opinion-forming.
5. Understanding.

Sanchez-Mora (2016) suggested the major outcomes of public engagement of science were:

1. Recognition that science exists.
2. Recognition that science is attractive.
3. Recognition that science is interesting.
4. Awareness that science is part of one's identity.

As a final example, in 2017 the National Academies of Sciences, Engineering and Medicine published a report listing the following as potential goals of science communication:

1. Sharing recent findings and excitement for science.
2. Increasing public appreciation of science.
3. Increasing knowledge and understanding of science.
4. Influencing opinions, policy, preferences, or behaviour.

Aims of the botanic garden

Historically, botanic gardens have predominantly served as conservation sites for rare or endangered plant species. However, in the 21st century botanic gardens have the potential to, and indeed must, serve new broader roles within their communities. In the botanic garden where this internship was completed, the curator recognises the identity of the garden "as a visitor attraction and centre for human well-being, in addition to traditional functions in research and education" (Frediani, 2021). Furthermore, the botanic garden also houses the Living Lab, a new doctoral training programme which promotes multi-disciplinary collaboration between the STEAM subjects (traditionally STEM; Science, Technology, Engineering and Maths, now with the additional inclusion of Art) working in the areas of education, sustainability and nature connectedness.

Aims of the medicinal plants science communication resource

It was with the above information in mind that the goals of the new medicinal plants science communication resource were considered. The resource was intended to be informative and entertaining, with a target audience of educational and recreational visitors to the botanic garden. By highlighting plants with medicinal uses and their intersections with human history, the resource was also intended to create a greater sense of nature connectedness for botanic garden visitors. It was agreed that the internship would work to create:

1. A trail of interpretive panels to be stationed next to the plants throughout the garden.

2. An accompanying guidebook with additional information.
3. Animated videos explaining some of the relevant molecular biology concepts.

METHODS

Part one – selecting medicinal plants

Work for the internship began with establishing which plants would be included in the medicinal plants trail. During discussions with the botanic garden education officer and curator it was agreed that a total of ten plants would be featured in the medicinal plants trail. The botanic garden includes areas dedicated to specific plants from different continents and climates, varying from Asia to the Mediterranean, as well as both tropical and arid glasshouses, providing a diverse range of plant species. One consideration for the selection of plants in the medicinal plants trail was to sample a diverse selection of plant species, spanning the physical and botanical range available in the botanic garden. A second consideration was to include plants with different growing seasons to ensure continuous points of visual interest for visitors to the botanic garden throughout the year.

It was next considered how to bring the medicinal plants trail together into a cohesive narrative. To help the medicinal plants trail improve the sense of nature connectedness felt by the botanic garden visitors, the decision was made to highlight the human stories associated with the discovery and use of medicinal plants. Documents existing from Ancient Egypt and Ancient Greece, the Ebers Papyrus and De Materia Medica respectively, describe the use of plants in a medicinal context, highlighting the extent of medicinal plants' involvement in human health throughout history (Bryan 1930, Gunther 1934, Magdalen College, University of Oxford 2014 & Metwaly *et al.* 2021). As human medical and scientific knowledge advanced, the stories of medicinal plants intersected with those of the scientists and doctors who studied them. As early as 1858, experiments conducted by 'the father of immunology' Louis Pasteur were able to reveal the antibacterial properties of garlic (Rupp 2014, Wong 2019). Research into the medicinal properties of plants continues today with scientists such as Dr Martha Yahimbu, whose work aims to identify new treatments for neglected tropical diseases (WIPO 2021).

Finally, the medicinal plants trail was also intended to function as an educational resource. To achieve this goal, it was decided to produce molecular biology animations for a subset of the medicinal plants in the trail. The animations would be used to explain the biology underlying how the plants help to treat different medical issues. In order for plants with reputed medicinal properties to be accepted for use in the 21st century, they require scientific validation. Regulations surrounding medicinal plants vary between different countries, but some fundamental requirements

include meeting safety and efficacy measurements (Bhosale & Banerjee 2019). Alternatively, sometimes a specific chemical can be identified as being responsible for a plant's medicinal properties, and this active molecule can be extracted or reproduced synthetically for use as a medicine. As defined by the European Patients Academy on Therapeutic Intervention (EUPATI 2020) "an active molecule is a chemical compound that has pharmacological or biological activity likely to be therapeutically useful".

With these considerations in mind, a literature review helped to identify potential plants to include in the medicinal plants trail. The ten selected plants were as follows:

1. Willow tree (*Salix alba*)
   Produces the active molecule salicylic acid, which is used to produce the painkiller aspirin (Desborough & Keeling 2017)
2. Foxgloves (*Digitalis purpurea*)
   Produces the active molecule digoxin, which is used as a medicine to treat heart failure (Edwards 2012).
3. Tea plant (*Camellia sinensis*)
   Produces the active molecule theophylline, which is used as a medicine to treat asthma (Ito *et al*. 1997).
4. Yew tree (*Taxus baccata*)
   Produces an active molecule which is used to make the chemotherapy medicine Taxol (Foa *et al*. 1994).
5. Snowdrops (*Galanthus spp*.)
   Produces the active molecule galantamine which is used as a medicine to help manage Alzheimer's disease symptoms (Royal College of Physicians 2017).
6. Autumn crocuses (*Colchicum autumnale*)
   Produces the active molecule colchicine which is used as a medicine to treat gout (Dasgeb *et al*. 2018).
7. Lesser periwinkle (*Vinca minor*)
   Produces the active molecule vincamine which benefits brain health (Farahanikia *et al*. 2011).
8. Garlic (*Allium sativum*)
   Produces the active molecule allicin which has antibacterial properties (Bayan *et al*. 2014).
9. Heather (*Calluna vulgaris*)

Is under active investigation, results show potential antibacterial properties (Vučić *et al*. 2014).

10. Juniper (*Juniperus communis*)

    Is currently under investigation for potential liver-protective effects that could benefit fatty-liver disease patients (Raina *et al*. 2019).

Part two – creation of pilot interpretive panels

As early research and medicinal plant selections were concluded, work turned towards the creation of a pilot interpretive panel. The interpretive panels were to be a central element of the medicinal plants trail, to be positioned next to the plants, around the garden. It was therefore a priority to ensure that the interpretive panels were well designed and appealing to botanic garden visitors. At this early stage of the project, it was unclear exactly what the content of the interpretive panels should be, so the decision was made to create a pilot interpretive panel to trial with members of the public.

A pilot interpretive panel was created for foxgloves (*D. purpurea*) and is represented in Fig. 1 below. Briefly, the pilot interpretive panel contained the following information:

1. The traditional medicine history of the plant.
2. The doctor involved in validating the medical properties of the plant.
3. The active molecule responsible for the plant's therapeutic benefit.

A chance to gather public feedback on the pilot interpretive panel was presented by an open day at the botanic garden during October 2022. Opportunist, informal conversations were had with members of the public who had attended the botanic garden open day, by approaching people as they neared the garden exit. Members of the public who agreed to provide informal feedback included the parents/grandparents of both pre-school and primary school aged children and adults without children (of various ages) including a teacher and a children's Brownie Guide leader. The following list of questions was pre-prepared for the open day:

1. Have you visited the botanic garden before?
2. Would you be interested in finding out more about medicinal plants?
3. Do you think a medicinal plants trail would improve visitor experience of the botanic garden?
4. What do you think of the pilot interpretive panel?

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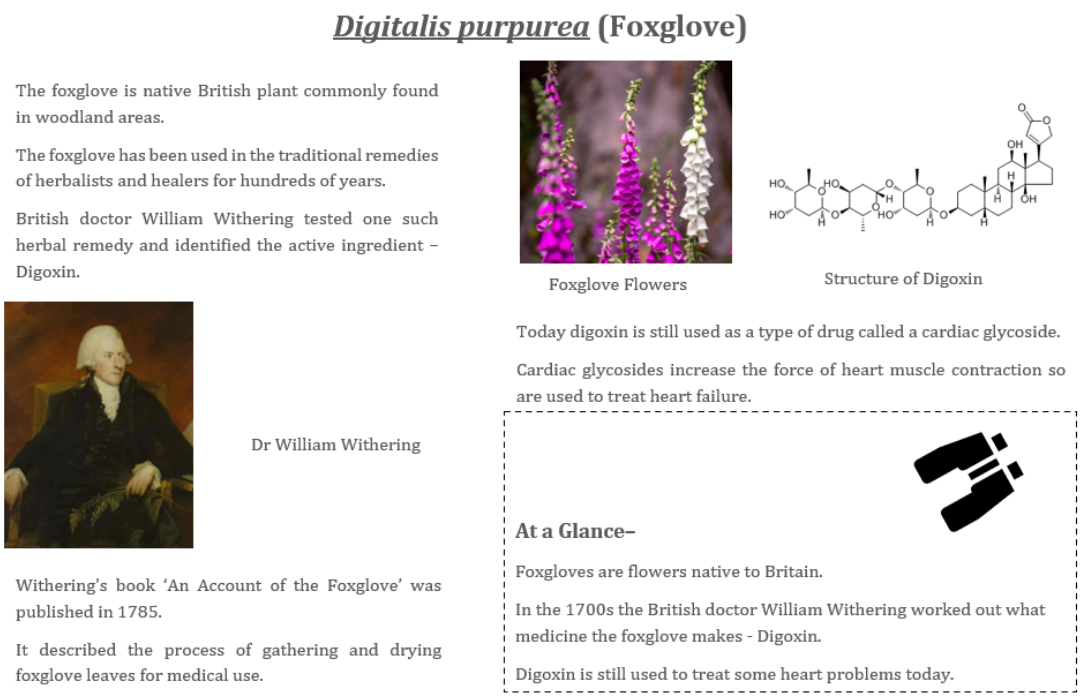

Figure 1. The pilot interpretive panel for *Digitalis purpurea* (foxglove)

The pilot interpretive panel created for *D. purpurea* as part of the medicinal plants trail, as shown to members of the public at the botanic garden open day in October 2022.

Most of the participants were repeat visitors to the botanic garden, while a small number were making their first visit due to the open day. All of the participants reported being interested in learning more about the medicinal properties of plants. Most of the participants had noticed examples of the other plants featured in the current trails present in the garden such as 'Plants for People' which highlights plants such as the rubber tree (*Hevea brasiliensis*) which produces latex (Rainforest Alliance 2012), and the paper reed (Cyperus papyrus) used to produce the ancient writing material papyrus (Beaulieu 2023). The participants were in agreement that resources such as plant trails were informative and interesting, and welcomed the idea of a new trail highlighting medicinal plants. However, the participants had a few criticisms of the pilot interpretive panel, primarily that it contained excessive text which may deter people from engaging with the resource. Evidence in the literature supports the idea that simple signage is a more effective means of communicating information to the public. In a study conducted at a national park in the United States of America, simple educational signs were installed to encourage members of the public to stay on designated trails, no participants spent longer than eight seconds reading the signs (Park *et*

al. 2008). Such findings suggest that it will be important for the interpretive panels in the medicinal plants trail to convey information quickly and effectively.

Despite gaining public insight into opinions of the new medicinal plants trail, the usefulness of the feedback was limited by the informal nature of the conversations with participants. More formal questions and data collection would have allowed for proper conclusions to be drawn. Nonetheless, I reconsidered my design ideas for the interpretive panels during the next meeting with my internship supervisor and the garden curator. The garden curator reiterated the public feedback that interpretive panels are most effective as signposts, serving to introduce a resource and direct those interested in learning more to additional information. It was therefore decided to swap to an image-based design for the interpretive panels. This presented an exciting new opportunity to collaborate with a medical and scientific illustrator to create original artwork that would form the basis of the interpretive panels.

Part three – revision of interpretive panels, working with a medical illustrator

During an initial consultation meeting with the illustrator, different design possibilities for the medicinal plants trail interpretive panels were considered. After reviewing the pilot interpretive panel, it was decided to aim for a very simple design to quickly capture the attention of botanic garden visitors. The first design element to be included was each plant's common name along with a complementary adjective indicating the medical usefulness of the plant. For examples, please refer to Table 1 below. Highlighting the connection between the medicinal plants and human health was considered a potentially effective means of helping to achieve the goal of enhancing botanic garden visitors' sense of nature connectedness.

Table 1. Descriptive titles for plants in the medicinal plants trail

Scientific Name	**Medicinal Plants Trail Title**
Allium sativum	Great Garlic
Calluna vulgaris	Helpful Heather
Camellia sinensis	Terrific Tea
Colchicum autumnale	Awesome Autumn Crocus
Digitalis purpurea	Fantastic Foxgloves
Galanthus spp.	Super Snowdrops
Juniperus communis	Generous Juniper
Salix alba	Wonderful Willow
Taxus baccata	Useful Yew

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Vinca minor	Practical Periwinkle

Next, focus turned towards the major focus of the interpretive panel design, the illustrations. It was decided to keep the interpretive panels focused on the plants they would be representing, through the creation of modernised botanical illustrations. Botanical illustrations are scientific artworks that depict the stages of growth and key features of plant species (Botanical Art and Artists 2022). Botanical illustrations were considered a useful design idea as they highlight the different features and life stages of plants, allowing garden visitors to recognise the medicinal plants during all seasons of the year. However, traditional botanical illustrations served an exclusively scientific purpose (Rix 2012), and therefore are often subtly coloured and extensively detailed. In order to be in-keeping with the public engagement goals of the medicinal plants trail, the new illustrations (Fig. 2) focused on simpler, brighter images.

(A) **(B)**

Figure 2. Examples of botanical illustrations

(A) A traditional botanical illustration of *Taxus baccata* (common yew) (free use via Rawpixel).

(B) Modernised botanical illustration of *Taxus baccata* (common yew) as produced for the medicinal plants trail.

Part 4 – Planning of the accompanying guidebook

Work was then carried out to produce a pilot version of the accompanying guidebook for the medicinal plants trail. The first draft was reviewed by two members of the university public engagement team for design assistance. In coordination with the re-configured illustrated interpretive panels, the guidebook was now going to be the primary source of written information for the medicinal plants trail. To contribute to the medicinal plants trail's goal of improving nature connectedness, focus was again placed on highlighting links to human health and the individuals who contributed to the scientific understanding of each medicinal plant. The following pieces of information were provided for each medicinal plant:

1. The interpretive panel title, including the plant's scientific and common name.
2. Information about the plant's growth habit.
3. The active molecule responsible for the plant's medicinal effect (if known).
4. The scientists or doctors involved in the research process of the medicinal plant.

The public engagement team were able to provide several points of feedback that helped to improve the initial guidebook design. Firstly, the design was swapped to a landscape orientation for more instinctive flow across the page for readers, and the background set to off-white to reduce contrast. Secondly, it was recommended to use a suitable font size and style to further increase reading ease. Additionally, it was advised to limit text to bullet points wherever possible to improve the speed with which readers can find information. This idea was also supported in the literature, "In today's fast-paced world, people are looking for information that is easy to digest and bullet points provide that by breaking down complex ideas into simple, bite-sized chunks" (Raitaluoto 2023) The medicinal plants trail accompanying guidebook design process is shown in Fig. 3 below.

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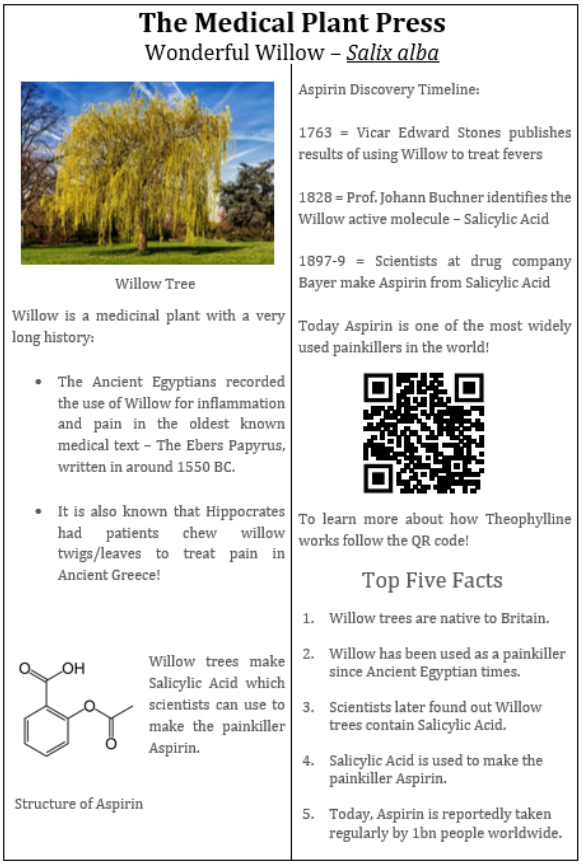
(A)



The Medical Plant Press

Wonderful Willow – *Salix alba*

Willow Tree

Willow is a medicinal plant with a very long history:

- The Ancient Egyptians recorded the use of Willow for inflammation and pain in the oldest known medical text – The Ebers Papyrus, written in around 1550 BC.
- It is also known that Hippocrates had patients chew willow twigs/leaves to treat pain in Ancient Greece!

Willow trees make Salicylic Acid which scientists can use to make the painkiller Aspirin.

Structure of Aspirin

Aspirin Discovery Timeline:

1763 = Vicar Edward Stones publishes results of using Willow to treat fevers

1828 = Prof. Johann Buchner identifies the Willow active molecule – Salicylic Acid

1897-9 = Scientists at drug company Bayer make Aspirin from Salicylic Acid

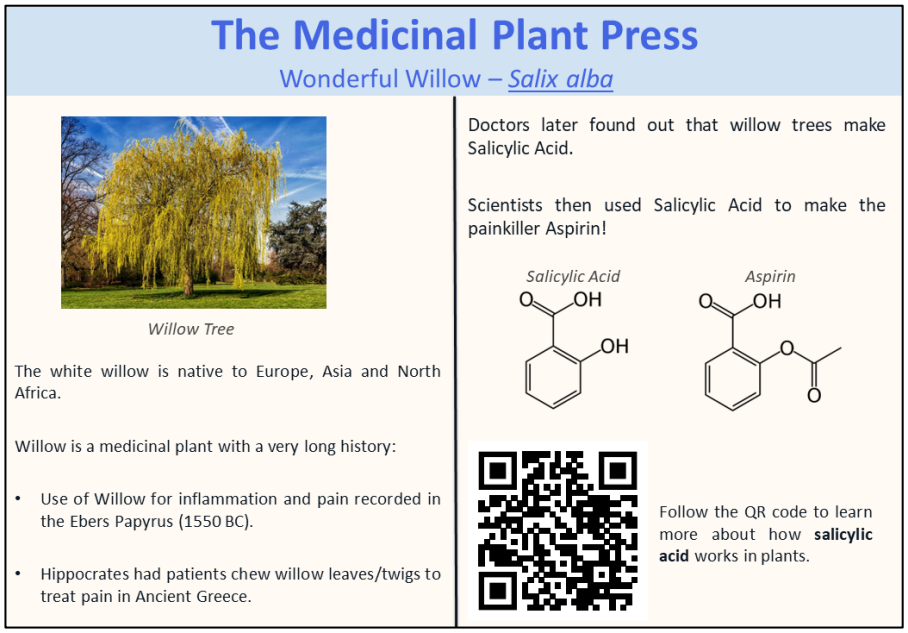
Today Aspirin is one of the most widely used painkillers in the world!

To learn more about how Theophylline works follow the QR code!

Top Five Facts

1. Willow trees are native to Britain.
2. Willow has been used as a painkiller since Ancient Egyptian times.
3. Scientists later found out Willow trees contain Salicylic Acid.
4. Salicylic Acid is used to make the painkiller Aspirin.
5. Today, Aspirin is reportedly taken regularly by 1bn people worldwide.

(B)



The Medicinal Plant Press

Wonderful Willow – *Salix alba*

Willow Tree

The white willow is native to Europe, Asia and North Africa.

Willow is a medicinal plant with a very long history:

- Use of Willow for inflammation and pain recorded in the Ebers Papyrus (1550 BC).
- Hippocrates had patients chew willow leaves/twigs to treat pain in Ancient Greece.

Doctors later found out that willow trees make Salicylic Acid.

Scientists then used Salicylic Acid to make the painkiller Aspirin!

Salicylic Acid *Aspirin*

Follow the QR code to learn more about how **salicylic acid** works in plants.

Figure 3. Medicinal plants trail accompanying guidebook design process

(A) Initial accompanying guidebook design idea.

(B) Re-drafted accompanying guidebook design.

Part 5 – Molecular biology animations

Another goal of the new medicinal plants trail was to serve as an educational resource, by including some more detailed molecular biology information. Information in the literature suggests that animations are becoming an increasingly popular method of communicating information in the modern age, as their use of both audio and visuals suit individuals with different learning styles (Prior 2023). Simple computer animations were therefore considered a suitable means of explaining some of the more complex scientific processes that underly the therapeutic benefits of medicinal plants.

Work in this area led to a collaboration with a local secondary school. Through discussions with a high school biology teacher, it was possible to assess the appropriate level of biological detail to include for a target audience ranging from secondary school pupils to the general public. Consistent with the earlier work on the interpretive panels and accompanying guidebook for the medicinal plants trail, the molecular biology animation designs focused on simple, clear images to communicate information. Metaphors and analogies relating the molecular biology processes to everyday items were also included in the animations, as these are often found to be useful communication tools (Thibodeau *et al*. 2019).

The analogy for use of digoxin as a treatment for heart failure is provided as an example (Fig. 4). The sodium/potassium pump can be thought of as a revolving door, controlling the flow of sodium and potassium across cell membranes. Digoxin can be thought of as a door wedge, it can be used to block the sodium/potassium pump, which increases the force of heart muscle contraction helping treat heart failure. The molecular biology animations will be hosted online, with QR code links provided in the medicinal plants trail accompanying guidebook.

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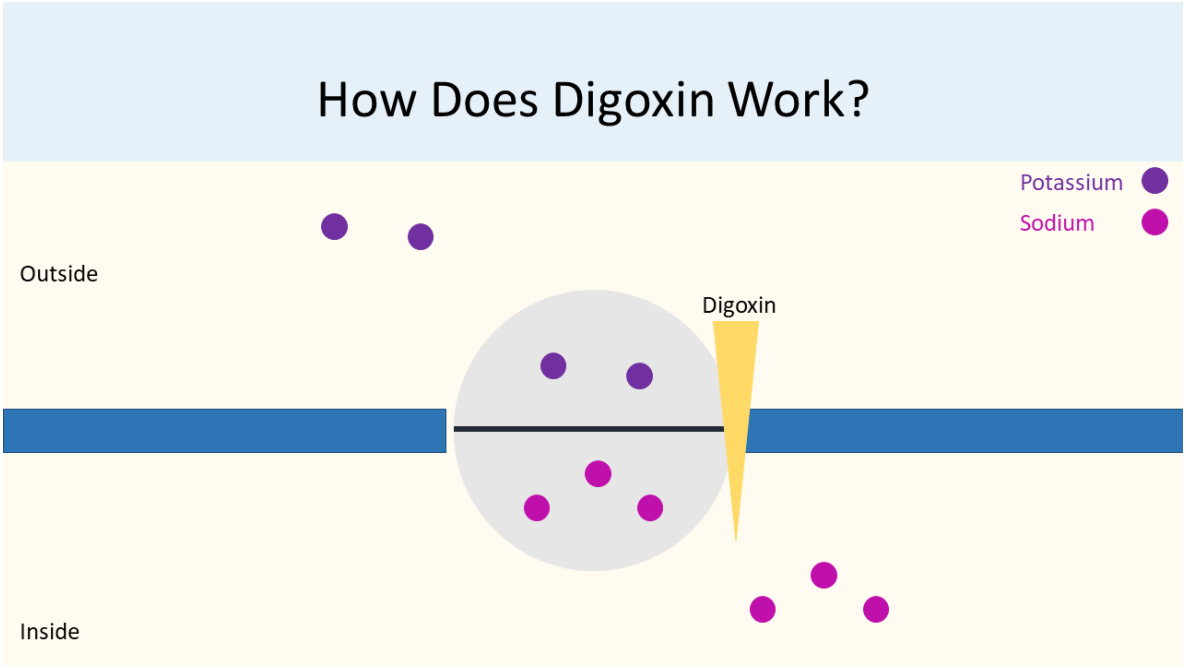

Figure 4. Still from the foxglove (*Digitalis purpurea*) molecular biology animation.
Example analogy used in the molecular biology animations to help explain scientific concepts, here the sodium/potassium pump is compared to a revolving door (grey circle) which can be blocked by digoxin, which acts like a door-wedge (yellow triangle).

DISCUSSION

Production of the new medicinal plants trail is now nearly complete. It will be interesting to monitor the public response to the new resource once it is installed in the botanic garden, and to discover the impact it may have on the sense of nature connectedness that visitors feel. It is hoped that by highlighting the unique and useful properties of the featured plants, the medicinal plants trail may serve to increase individuals' enjoyment of nature during their visit to the botanic garden, educate individuals about the plants around them and emphasise the importance of looking after the natural world, which harbours so many important plants that have been shaping the human journey since the dawn of civilisation.

Unfortunately, it has not yet been possible to collect formal feedback on the medicinal plant trail, making it impossible to draw any official conclusions about the success of the resource at improving botanic garden visitors' sense of nature connectedness. However, after installation and official launch, the intention is to run a survey or questionnaire to collect public feedback. This will allow proper analysis to be conducted.

The medicinal plants trail will also be used during a Royal Society Partnership Grant Project that has been developed as a spin-off of this internship project. During this new project, a local high school will conduct their own research project investigating plants with anti-microbial properties. As part of the anti-microbial plants research project, the pupils will visit the botanic garden and complete the medicinal plants trail, presenting another opportunity to collect formal feedback about the resource.

My time working on the production of a new medicinal plants trail for the botanic garden was an outstanding means of developing my public engagement and scientific communication skills. Throughout the process I had the opportunity to experience working with a wide range of different professionals including teachers, artists and graphic designers. I learned how to clearly and concisely present complex scientific concepts for non-experts, and some important design principles for making useful visual aids.

An unexpected outcome of my work on the medicinal plants trail was the positive impact the project had on my own sense of nature connectedness. Despite working towards a doctorate in the field of plant sciences, I found that in the process of taking a step back from the lab-bench and a look out at the wider context of plant sciences I reignited my own sense of wonder at, and oneness with, the natural world around me. Additionally, I found the process of scientific communication to a public audience very rewarding, reminding me of what first inspired my own childhood interest in plants.

In addition to the skills I developed and the things I learned while completing work on the medicinal plants science communication project, I also had the opportunity to work with some wonderful people in a variety of roles, and I am extremely grateful for the colleagues and friends that I met. I hope that the new medicinal plants trail will be a force for greater nature connectedness that is enjoyed by many botanic garden visitors for years to come.

CONCLUSION

In the modern world, it is important that people feel a strong sense of nature-connectedness to help ensure that plant and animal life is respected and protected in the face of climate change. Botanic gardens are one place interested members of the public can visit to spend time with nature and learn about plants. It is therefore useful to have interesting and informative resources available to engage and inform botanic garden visitors. This internship worked to produce one new resource about medicinal plants. By highlighting examples of plants which have had important roles in human health throughout history, and which continue to provide a source of new medicines today, it is hoped that the medicinal plants trail will improve garden visitors' sense of nature connectedness. As the project has not yet been installed in the botanic garden, it is not possible to confirm whether the

medicinal plants trail has achieved its aim, however this will be investigated upon the official launch in 2024.

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EDUCATION FOR SOCIAL SUSTAINABILITY IN EARLY YEARS: TOWARDS AN INCLUSIVE PERSPECTIVE – A LITERATURE REVIEW

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ABSTRACT

This paper begins by examining the broad literature that emphasises the need for sustainable education in early childhood education. It then briefly examines previously published research initiatives concerning the three dimensions of sustainability: environmental, social and economic, in early childhood education. It acknowledges that this is a broad issue and globally, there is much to be done socially. Finding strategies to instil sustainable attitudes and behaviours that require fundamental social skills, such as collaborative working and empathy in children at an early age, is crucial if we want them to become environmentally conscious instead of unconsciously adopting materialistic lives. In conclusion, the paper highlights the need for education for sustainability (EfS) to address its social dimension competently and for society to adopt a more inclusive perspective and view children as active contributors.

Keywords: Education for sustainability; Sustainable Development; Early childhood education

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INTRODUCTION

We live in a constantly changing world affected by climate change and the increasing destruction of life, leading to multidimensional social effects. Inequality has increased globally (Mahler *et al*., 2022), widening the gap between rich and poor and negatively affecting children's access to high-quality education, particularly during the COVID-19 pandemic (McNair *et al*., 2022). COVID-19 has been a worldwide disaster that has disproportionally afflicted all demographic groupings (Darvas, 2021). As a strategy to mitigate the pandemic, lockdowns were introduced, which eroded opportunities for children and adults to feel connected to the wider community and negatively affected their mental and physical well-being (Gromada *et al*., 2020). A social disconnection was forced on the world as social distancing measures were established. As the virus surpassed borders and boundaries, this interconnectivity forged an alliance among scientists and experts hailing from every corner of the world, pooling their expertise and resources to create a vaccine (Jull and Moore, 2020). We soon entered a paradoxical world filled with reminders of our interconnectedness while self-surrendering to confinement. The social impact of confinement has been detrimental, leading to a decline in people's interest in others as their experiences with social interactions decrease (Brownlee, 2020).

Additionally, given that the present political and economic institutions have demonstrated a lack of readiness to address these issues (Bengtsson, 2019), education is now, more than ever, vital in supporting societies in shifting to alternative methods of sustainable living. In 2006, the United Nations Educational, Scientific and Cultural Organization defined sustainable development as the balance of economic, social and environmental demands, but what does this look like in early childhood education and care (ECEC)?

This paper aims to contribute, study and engage in the debate of various literature, focusing more closely on the literature for sustainable education in early childhood education. It opens the door to the potential of reconsidering what education for sustainability (EfS) in a child's early years can become due to the broadness of the concept of sustainability. The first chapter explores how the social dimension of EfS is not yet sufficiently embedded in early childhood education. This article then develops into four major sections, with the arguments organised in a problem and solution framework. In the second chapter, social sustainability is explored through various literature. Then, given the guidelines for social sustainability in ECEC, the divisive perceptions of 'society' are identified as another worldwide issue in the third chapter. In the fourth chapter, the argument is made that we first need to change our perceptions of childhood to strengthen young children's interest in civil society. The fifth chapter focuses on those skills needed on the path towards a more

fair and just society in the search for a more sustainable world. Finally, the paper concludes with recommendations for advancement of EfS in early childhood education.

1. THE THREE DIMENSIONS OF SUSTAINABILITY: BALANCE OR GAP?

The term sustainability relates to three distinct sectors known as the three sustainability dimensions: environmental, social and economic. A closer look at the literature on sustainability in ECEC reveals many gaps and shortcomings. When approaching EfS (also known as learning for sustainability and education for sustainable development), the focus has been directed toward the environment and nature connectedness. In their systematic review, Tulin *et al*. (2021) revealed the gaps in the field of EfS. They showed that the most frequently discussed pillar of sustainability is the environment, then followed by all three dimensions of sustainability (multidisciplinary approach). Discussions regarding environmental sustainability have dominated research in recent years, whereas the social dimension is still lagging behind (Chatterji, 2021). The current hegemony of the environmental dimension in sustainability is blatant, but is it sufficient educationally?

EfS is a broad subject that aims to include the basic principles, rules, values and practices of sustainability in education processes within all dimensions (Kahriman *et al*., 2019; Vargas, 2000). According to an examination of the literature Paoli and Addeo (2019) produced on the notion of sustainable development, there is no clear and agreed conceptual and practical definition of this term. Additionally, the literature shows no consensus on how to approach the three dimensions of EfS. For example, McKenzie (2004) recognised the necessity for a truly multidisciplinary model of sustainability that considers the undeniable relationship among the three dimensions. In this context, perhaps the focus of environmental education has been too narrow, particularly in relation to social issues. At the same time, difficulties are encountered when identifying issues that are solely social because there are many overlaps among the dimensions of sustainable development and especially between the economic and social dimensions (Delli *et al*., 2021).

However, we must recognize that the objectives of education for sustainability in early years have focused on nature connection and environmental issues to develop a curriculum that is distant from its social core. Instead, education must support approaches to learning that include the principles of social justice, human rights, environmental protection, socioeconomic prosperity and peace (Droubi *et al*., 2023). The focus is on the importance of social connections and working together, with a particular emphasis on developing fundamental social skills in children at an early age to help them become environmentally conscious before unconsciously adopting materialistic lives (Droubi *et al*., 2023). These efforts are necessary for the survival of humanity. All of this without trying to

dissociate social sustainability from a genuinely multidisciplinary model of sustainability that considers the undeniable relationship among the three dimensions. After all, equity cannot be understood only as something social; it should also be understood from the perspective of how we relate to resources and their economic distribution. Moreover, good individual connections with nature alone do not guarantee the planetary future. Nothing alone does. In consonance with Zguir (2021), education urgently needs a shift from producing well-rounded workers for an uncertain future to be a conduit for intercultural communication, social justice and sustainability in the present.

2. SOCIAL SUSTAINABILITY IN ECEC

Social sustainability is about social justice. It addresses the social issues affecting most countries, including poverty, inequality, discrimination and isolation (Siraj-Blatchford, 2016). It is a 'life-promoting state within communities' (McKenzie, 2004, p. 12) that focuses on establishing conditions that encourage and feature positive social connections (Grindheim *et al*., 2019). Social justice can be a challenging subject. It requires bringing to the classroom difficult conversations and specific and complex knowledge.

Nevertheless, we must question how we address social issues without jeopardising a happy childhood. The realities of prejudice and discrimination affect children's development very early, as they seek to understand their social and cultural environment (Ostroff, 2022). As Ostroff (2022) puts it, it is not only age-appropriate but also essential to address tackling difficult subjects in our interactions with young children. Håkansson *et al*. (2019) highlighted the value of conflict and risk-taking through the radical democratic approach, which entails creating space for conflict in any democratic society to enhance the democratic process. In line with Håkansson *et al*. (2019), Grindheim *et al*. (2019) highlighted the importance of conflict as an agent of change. They explained how all three dimensions of sustainability provide solid ground for a curriculum where children can learn about farming (the ecological dimension) and directly experience the concepts of value and consumption (the economic dimension) while learning how to work together to achieve a common goal and while reflecting on how to deal with the problem of uneven distribution of resources (the social dimension). This approach seems particularly suitable when dealing with the complex aspects of sustainability. From this standpoint, the first step towards a solid ground for a curriculum in EfS in ECEC may involve a change in our social reality and perspective.

3. THE MISTAKEN PERCEPTIONS OF 'SOCIETY': IT IS NOT THEM. IT IS US

Education systems may even perpetuate social, racial and ethnic inequalities (Wolff *et al*., 2020). Very often, awareness campaigns by non-government organisations, many of which are supported by and within the school system, have created stereotypes without clearly explaining what causes social sustainability issues (Grindheim *et al*., 2019). We explain about a child in Africa walking miles to find clean water. However, we need to explain why this issue is so widespread in certain countries, how much colonialism damaged such countries and how much the capitalist system in its current form is worsening the situation. There is also a need to recognise that the current approach often creates a perception of the world based on 'us' and 'others', where 'us' refers to Western, capitalist democracies and 'others' to everything that does not fit in this frame (Grindheim *et al*., 2019). By focusing on providing children with tools to enhance their critical thinking and empathy skills in an environment where young children can dedicate sufficient educational time and space for their exploration and thoughtful discussions, educators can enable children to critically examine various aspects of biased conceptions, contents, contexts and systems that dominate their lives (Butler *et al*., 2019).

This is supported by Mahadew (2023) who argues that despite global and national imperatives to build an inclusive society, incidences of discrimination based on numerous marginalised identity markers are widely reported. According to her Mahadew (2023), the early years are an ideal moment for children to form initial attitudes towards different groups of people. Whether or not empathy begins with children noticing and accepting each other's shared and unique characteristics (Nichols *et al*., 2009), exposing children to various cultures, abilities and ways of being will help them perceive others as 'like them' (Ostroff, 2022, p. 17). From this perspective, we can challenge the current approach that the capitalist system has created and perceive society as one.

4. THE INTERCONNECTION OF SOCIETY IN EARLY CHILDHOOD EDUCATION: IT IS NOT US. IT IS THEM

The interconnection of society is one of the cornerstones of sustainable development. In her essay on social rights and freedoms, Brownlee (2020) considered a social connection to be a fundamental human right because upon it depends on other human rights. Therefore, some pertinent Sustainable Development Goals (SDGs), such as SDG four, that is, quality education, rely on the existence, development and quality of social connectedness. Social connections promote long-term physical health outcomes and emotional well-being (Holt-Lunstad, 2021). Research has shown that loss of belonging has been associated with stress, illness, decreased well-being and depression (University of Michigan, 1999). Likewise, Baumeister *et al*. (1995) argued that threats to our need to belong

could negatively affect our cognition, behaviour and emotions. In Allen *et al*. (2022), Baumeister and Leary state that recent events such as the COVID-19 pandemic and the increased focus on racial justice, demonstrated how the desire to form social connections and to fit in, and the inability to do so, can affect not only individual behaviour but also social movements. In early childhood, well-being and togetherness are inextricably linked (Hännikäinen, 2017).

The importance of effective and engaged social interactions for sustainable development was highlighted previously. Thus, EfS needs to support young children's interest in civil society, strengthen their social connections and help create self-confidence. Moreover, for that to happen, we need to envision young children not only as confident learners but as carriers of knowledge, values and attitudes and as active members of social reality. In their review of climate change education, Rousell *et al*. (2020) called for the need for researchers who engage collaboratively, imaginatively and creatively with children. Erwin *et al*. (2022) confirmed this by stating that young children's voices have been mostly excluded from studies of belonging. Most of these studies have been carried out on children rather than with them, implying that their first-hand observations, experiences and viewpoints are not befitting of research (Erwin *et al*., 2022). For this paper, childhood is not seen as a set period but as a "permanent structural category" (Corsaro, 2018, p. 30) where children learn and contribute appropriately for their stage of life (Phillips *et al*., 2020). It is essential to acknowledge and uphold children's right to be capable contributors to society, allowing them to bring their prior expertise and knowledge into the learning process (Cantor *et al*., 2021). Thus, it is everyone's responsibility to envision young children not only as confident learners (receptors) but as carriers of knowledge, skills, attitudes and values (transmitters) that could help to form and shape a culture of sustainability within their immediate nucleus as effective agents of social change (Nishiyama, 2017).

Children acquire the most sophisticated knowledge and skills from social interactions with peers and adults. This process of socialisation combined with active learning may well be the source of moral sensibility in adulthood (Woo *et al*., 2022). Only once children have gotten some practice at learning and growing together will they be strongly disposed to relate respect and empathise with others in a just and fair manner (Ostroff, 2022). In other words, children will benefit from support from an early age to promote social sustainability. They will be given agency to work toward solutions in collaboration with adults because they are members of the social reality (Quennerstedt & Quennerstedt, 2014), and as such they have the need to contribute to society. This is in line with Brownlee (2020), who states that young children have non-contingent fundamental social needs due their inability to meet their own needs. Brownlee (2020) further distinguishes between two types of

essential social needs, social-access needs and social-contribution needs. The former pertains to the need for stability and well-being in social interactions, while the latter involves the need to actively contribute to the lives of others. By prioritizing community relationships, social sustainability not only enhances each child's social capital and sense of belonging but also fosters problem-solving, awareness and critical thinking (Johansson & Rosell, 2021).

5. FUNDAMENTAL SOCIAL SKILLS FOR A JUST SOCIETY

Empathy plays a crucial role in sustainability research, as it has the potential to foster sustainable practices (Brown *et al*., 2019). Brown *et al*. (2019) assert that this is particularly evident when individuals develop empathic connections with the consequences of environmental damage, when they cultivate inclusive identities that extend beyond their immediate surroundings and when empathy encourages collective responses to environmental challenges. Empathy comes through when we greet shared pain with compassion and our medial orbital frontal cortex responds positively (Chierchia, 2017). Ostroff (2022, p. 22) distinguished between 'imagine other' and 'imagine self' as two different perspectives. Brown *et al*. (2019) and others argue that empathy is an important but previously underutilised variable in sustainability research. According to Brown *et al*. (2019), important life skills such as empathy have received little attention in research on sustainability. They state that combining a study of empathy for one another and empathy for nature can make significant progress in understanding sustainability challenges.

Sobel (2013) proposes developing children's empathy towards the natural world as the first phase of environmental education in early childhood through cultivating relationships with fauna. Along similar lines, what I propose is to develop the young children's empathy, sense of fairness and solidarity with others through cultivating their relationships with peers and adults alike. This proposal is grounded in the evidence presented in this paper. What's more, it can help to build human connections based on the relationship between diversity and interdependency (Gaztambide-Fernandez, 2012). This is supported by Guntersdorfer and Golubeva (2018), who state that integrating the ideas of empathy and emotional intelligence into the classroom is crucial for students' conceptual growth and the practical application of intercultural understanding.

Additionally, even though conflict will inevitably arise in early childhood education, children may learn conflict resolution techniques by collectively recognising issues and finding solutions (Grindheim *et al*., 2019). By working together, children gain a deeper procession of content information (Ostroff, 2022). Collaborative play allows children to copy others' strategies, encounter

opposing viewpoints and build new understandings, which helps develop their moral character (Tomasello, 2020).

CONCLUSIONS

In the context of EfS, what it means to be 'sustainable' is a core assumption that has been challenged throughout this paper. It is crucial to rethink EfS in the early years to break free from repeating unsustainable ways of being by adding fundamental social skills such as collaborative working and empathy into its framework. For this to happen, we need to:

- Acknowledge biases in educators' practices and enhance children's critical thinking and empathy, to challenge society's perception of 'us' and 'them'.
- Recognize children's right to be capable contributors to society who are part of the wider social world.
- Put social and emotional learning ahead of a list of standards.

Education for sustainability is a multifaceted discipline that encompasses environmental, social and economic dimensions. This paper argues the need to create a framework that equally involves all three dimensions of sustainability, highlighting the need for educators to explore further the social dimension to guarantee a sustainable future for the generations to come. Education may succeed where democratic systems have failed by empowering children to be advocates of social change and perspective adaptation (Droubi *et al*., 2023).

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A BOTANIC GARDEN AS A POTENTIAL SOCIAL LEADER IN EDUCATION FOR SUSTAINABLE DEVELOPMENT THROUGH COMPUTER-MEDIATED COMMUNICATION

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ABSTRACT

When many are experiencing the impact of human disconnect with the natural environment, botanic gardens are well-positioned to contribute to reconnection through sustainability education. Globally, whilst many botanic gardens highlight the impact of human endeavours on the natural world, we question the use of computer-mediated communications (CMC) to enhance knowledge sharing and encourage pro-sustainability actions across communities. Through the lens of social leadership and

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undertaking a mixed methods study, we explore the potential for one UK-based university botanic garden to lead on education for sustainability with the broader community using CMC. The findings highlight the desire of the staff and volunteers to increase the usage of CMC tools to enhance community engagement and disseminate information. Findings also indicate a need for greater autonomy and an intrapreneurial mindset to amplify knowledge and strengthen action across diverse networks that are not predesigned or imposed by organisational constructs.

Keywords: sustainability, education, digital technology, social leadership, botanic gardens, intrapreneurship.

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INTRODUCTION

Sustainable development has grown as a concept since its inclusion in the Brundtland Report (Brundtland Commission, 1987), where it was defined as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (p.15). More recently, the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017) highlighted a central focus on integrating sustainability into education as a catalyst for change, arguing that there has never been greater momentum for change than now. More than ever, sustainability education is necessary for everyone if we are to minimise human-related planetary destruction (Zelenika *et al*., 2018; UNESCO, 2020). As the realities of global climate change are becoming increasingly observable, education for sustainable development (ESD) permits everyone to critically review how the world is and visualise how the world might be in the future (The Quality Assurance Agency for Higher Education and Advance HE, 2021).

With over 3,000 botanic gardens (Romano, 2008) and, globally, an estimated 240 million physical visits per year (Zelenika *et al*., 2018), botanic gardens are well-placed to enhance ESD. Beyond the physical visits, there is an opportunity to extend ESD to a much larger audience by using computer-mediated communication (CMC) tools. As Romiszowski and Mason (1996) outlined, CMC elucidates how individuals share information through digital technology and can play a supportive role in facilitating conversational discourse (Ahern *et al., 1992)*. Such tools include social networking sites (SNS), for example, Facebook, X (formally Twitter), LinkedIn and Instagram. Note, due to the date of the data collection being completed before the rebranding from Twitter to X (Counts and Levine, 2023), we maintain the name Twitter throughout the paper. Through a small-scale case study of one botanic garden, we question to what extent and how a botanic garden uses CMC to lead ESD.

LITERATURE REVIEW

Education for sustainable development

The turning point for ESD was during the 1992 Rio de Janeiro Earth Summit, when the UN escalated Agenda 21, recognising the role of education as a necessity if we are to progress towards a sustainable future (United Nations, 1992). Complementing this, at the World Conference on Education for Sustainable Development, ESD was defined as "an approach to teaching and learning based on the ideals and principles that underlie sustainability" UNESCO (2009: 8). The blueprint for ESD is located within the United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), alongside its inclusion in landmark agreements, namely, the UN Framework Convention on Climate Change (UNFCC) and Convention on Biodiversity (United Nations, 2015; Maruna *et al.*, 2018). Essentially, ESD points to the practice of teaching for sustainability

(Grosseck *et al.*, 2019) regardless of the discipline, sector or field. As a result, it is crucial to recognise that educating for sustainable development requires diverse learning and teaching approaches to be accessible to all.

With the evermore pressing global concerns such as climate change and large-scale ecological and environmental degradation, sustainability is a topic that we all need to understand (Simionescu *et al*., 2020) if we are to respond to these issues as a global collective. Yet, according to Zelenika *et al*. (2018), promoting public engagement to encourage individual action continues to be challenging for institutions, organisations and governments. Still, the authors acknowledge using innovative methods to promote sustainable understanding and practices. Regardless of the learning format, ESD aims to change the approach to sustainability education by incorporating values, principles and successful practices into learning (Elmassah *et al*., 2021). For this reason, ESD is an educational change agenda (The Quality Assurance Agency for Higher Education and Advance HE, 2021).

One of the 17 SDGs in its own right, integrated, inclusive, quality education underpins all other SDGs as well. For example, promoting integrated water resource management, ocean sustainability, protection of biodiversity, mitigating and adapting to climate change, advancing sustainable cities and deepening social inclusion. Within UNESCO's (2017: 6) report,

> "*Education is both a goal in itself and a means for attaining all the other SDGs. It is not only an integral part of sustainable development but also a key enabler for it. That is why education represents an essential strategy in the pursuit of the SDGs.*"

Accordingly, education is a powerful means to develop a more sustainable future (Blessinger *et al*., 2018); it is a foundation for acting upon all sustainability goals constituting the environmental, economic and social realms for sustainable development (Albarenda-Tiana *et al*., 2018; Bolmsten and Kitada, 2020). With this view, ESD is a dominant force for a prosperous future as continuous, quality education enables individuals and communities to flourish through increased knowledge and skills development (David and Ibrahim, 2020). ESD supports people in identifying and addressing sustainability-threatening problems (UNESCO, 2008), enabling adaptive and responsive action to our ever-changing realities, and facilitating transformation to alternative planetary futures (Sharma and Kelly, 2014). If education is the inclusive and integrated keystone in tackling global issues, then we must consider education beyond formal education systems. Using CMC may provide a valuable medium for ESD to establish learning across the broad spectrum.

Botanic gardens

Whilst the focus for botanic gardens has typically centred on horticulture and taxonomy developments, more recently, emphasis surrounds addressing the broader *ex-situ* sustainability and

conservation challenges alongside public education (Wyse Jackson and Sutherland, 2000; Donaldson, 2009; Williams *et al*., 2015; Frediani, forthcoming). As noted by Zelenika *et al*. (2018), institutions such as botanic gardens, whilst holding documented collections of living plants for scientific research and plant conservation, 'there is a tremendous, yet untapped opportunity for gardens to re-connect communities with the natural world' (p.1582). Also, as Williams *et al*. (2015) highlighted, they constitute meaningful educational contexts and are working to increase audiences. From this, it is evident that education should be viewed as a principal function of botanic gardens (He and Chen, 2012; Gao and Weibang, 2018; Faraji and Karimi, 2020). In essence, ESD is a primary objective for botanic gardens (Willison, 2006).

Educational initiatives within botanic gardens register different forms. These include coordinating workshops, guided tours (Kneebone, 2006; Jensen, 2014), community outreach (Krishnan *et al*., 2019), adult education and certification programs, internships, family activities, children's summer camps, and field trips as part of school programs and teacher training (BGCI, 2010; Krishnan and Novy, 2016). Additionally, Faraji and Karimi (2020) report that community-based research and education collaborations provide meaningful opportunities for botanic gardens and nature-based organisations to contribute to sustainability education directly. Against this backdrop, and as a result of their multifaceted wealth of resources (Willison, 2006: 8), botanic gardens have a responsibility concerning ESD and challenging the public to live sustainably with others, including their relationship with the non-human world (Huckle, 1996: 35).

In addition to the environmental aspects, botanic gardens also hold responsibility for various economic (Benfield, 2013; Connell and Page, 2014; Flôres Limberger *et al*., 2014) and sociocultural elements (Connell, 2005; Ward *et al*., 2010; Frediani, forthcoming). As previously indicated, many of these elements are located within the SDGs, such as Responsible Consumption and Production, Good Health and Wellbeing, and Zero Hunger (United Nations, no date). Thus, the research underlines the value and importance of botanic gardens as an educational catalyst (Moskwa and Crilley, 2012; Catahan, 2018), going beyond horticulture. Indeed, Willison (2006) and Sellmann (2014) document that by providing information and sharing expertise to support the development of ESD programmes, particularly in the local environment, botanic gardens offer appropriate learning spaces. In turn, this aids in helping individuals and communities to make informed decisions about sustainability issues that may impact life, now or in the future; therefore, botanic gardens need to remain at the forefront of ESD.

Computer-mediated communication

A way for botanic gardens to remain at the forefront of education for sustainable development is to use CMC. CMC describes how people disseminate information to others using digital technology (Romiszowski and Mason, 1996) and can assist in conversational discourse (Ahern *et al*., 1992) between 'groups, or individuals separated by time and space' (Marani *et al*., 2020: 97). Whilst we are not suggesting that digital interaction replaces the direct contact of physical visits, where connecting with nature as a sensory experience takes place, there is a space to share ESD knowledge through CMC. The internet has no doubt revolutionised learning and offers powerful opportunities to utilise technology for educational purposes inside and outside of the formal classroom (Wang *et al*., 2022). Using CMC promotes self-directed learning (Asfar and Zainuddin, 2015), public awareness of environmental subjects such as climate change (Mavrodieva *et al*., 2019), and allows individuals and organisations to appear more visible (Treem *et al*., 2020). However, keeping abreast of CMC applications is crucial as these change over time in tandem with the development of new social norms and technology platforms (Treem et al., 2020). A popular application of CMC is disseminating information through SNS. Recognising this and the intensive use of social media by young people, alongside their interest in the sustainability and climate issues affecting the world (Thigpen and Tyson, 2021), has been one of the reasons behind our consideration of the use of this media. Moreover, the general use of social media across all age groups has increased, driven in part by this becoming the way of communication (Petricini, 2022), and this is seen as an important mechanism by which to share information on sustainability.

When developing digital content for internet distribution, creators must establish an imagined audience to guide online behaviour. The development of such an audience can consider behaviours displayed by a real audience, the creators' skills in developing socially acceptable content and the motivation to engage with social media content (Litt, 2012). The quality of digital interactions can vary depending on the platform used (Oz *et al*., 2018) and the skill set of those developing content. For successful use of CMC, organisations must consider i) the motivation that staff have to engage with specific media, ii) the knowledge that staff have in a given subject area, and iii) their overall skill in using technology (Le *et al*., 2022). Furthermore, many end-users can be classified as lurkers, where they will read the content but not engage with it (Cranefield *et al*., 2015). This passive online behaviour can be related to users' unwillingness to create a social investment in future content from a given source (Ellison *et al*., 2020).

CMCs, such as SNS and websites, have become significant for organising various human activities, including economic, social and political interactions (Asadullah *et al*., 2018). Whilst the use of CMCs is an opportunity to provide content developed to raise awareness and understanding through connectivity with their audience, studies investigating their impact on informing the public of

sustainability endeavours remain limited. Moreover, our exploration of the literature suggests a gap when positioning the research in the context of botanic gardens.

Social leadership

In this study, we do not consider 'leading' as an individual endeavour. Instead, we aim to understand 'leadership' in the field of ESD as a collective, knowledgeable community. Here, we draw from Guglielmo and Palsule (2014), who define a community as a group of individuals with a shared passion. Progressing from the industrial age, we require leadership that detaches from hierarchical power structures and advances knowledge and digital eras into the social age. The social era requires leadership forged through, among other things, communities, connections, networks, collaboration and communication (Stodd, 2016) and individuals being prosumers who are engaged, proactive contributors (Guglielmo and Palsule, 2014: xiv). All of these are central to social leadership (SL), a stance that underpins our research.

Leadership through an SL lens removes itself from many common concepts in leadership texts, such as leader-centric personalities and decision-making. Social leaders are altruistic (Saunderson, 2018) and drive change by constructing, connecting and engaging the power of diverse and inclusive communities where reputable meaning is co-created, curated and shared through narratives (Stodd, 2016; Saunderson, 2018). Social leaders orchestrate adaptive change across various groups and communities (Porteous, 2013: 524) and release geographical shackles (Guglielmo and Palsule, 2014). The power of SL builds upon discovery (Porteous, 2013), transparency, trust, integrity and collective ventures (Stodd, 2016); it is founded on content and reputation rather than ‘simple positional authority” (ibid., p.8).

Effective use of CMC can drive high levels of engagement and connection. In turn, through sharing co-constructed narratives to educate and empower the audience, not only does CMC help to build reputation and momentum, but according to Stodd (2016), it also brings about social change and, subsequently, environmental change. While we realise that not everyone has access to digital technology or wishes to utilise it, its use does mean that cross-boundary dialogic communication is enabled synchronously and asynchronously across a broad audience. Accordingly, digital technology is central to SL (Biro, 2013), with Stodd (2016: 33) reporting, “without the technology, you can't be a Social Leader”.

Bearing in mind the complex nature of botanic gardens in terms of their continuously evolving social and environmental roles and the communities they serve, SL is a valuable lens to explore the use of CMC in leading ESD. Social leaders balance the complexities between formal and informal

organisational structures. Therefore, it is particularly relevant to the context of the botanic garden situated within the larger organisation of a university.

In summary, the existing body of literature presents persuasive evidence of botanic gardens' role in advancing ESD, offering a unique and advantageous opportunity to integrate the different SDG fields (Leal Filho *et al*., 2019; Michael *et al*., 2020). The utilisation of CMC not only offers innovative avenues for botanic gardens to disseminate their expertise in ESD but also serves as a powerful catalyst in enhancing public awareness and fostering self-directed learning. As a result, we explore how one UK-based university botanic garden utilises opportunities to lead environmental ESD through CMCs and underpin our work with SL.

METHODOLOGY

In response to our research questions - (i) 'To what extent does a botanic garden use CMC to lead ESD?' and (ii) 'How does a botanic garden use CMC to lead ESD?', we adopted a case study methodology. Case studies allow researchers to penetrate multiple realities and unique portrayals of situations (Lincoln and Guba, 1985) whilst recognising the complexities and numerous variables in operation within any given case (Cohen *et al*., 2018). A case study is preferred when the research questions surrounding a contemporary social phenomenon are 'how' or 'why' (Yin, 2014). By way of such an approach and "bounding the case" (Yin, 2014: 33) within a social boundary (Gerring, 2017), this research aimed to explore the use of CMC in leading environmental ESD through an SL perspective within one botanic garden.

Context

The study was conducted in a UK university botanic garden, Sequoia Botanic Garden (pseudonym). The over 50-year-old garden is located on almost ten hectares in an affluent area of a coastal city. With a team of 32 paid and voluntary staff and three students, the garden accommodates over 80,000 visitors annually and works closely with multiple partners across the city and neighbouring regions. The garden hosts many activities, such as educational visitors, nature-based art exhibitions and theatre groups. As part of a larger organisation, this brings additional complexities to the garden's operational and strategic activities.

Like many botanic gardens, the site has seen the demise of botany and the rise of life (plant) sciences with a key focus on the impacts of climate change, population increases and conservation efforts. We purposefully selected the site as the garden is located within a wider organisation—a university—and this potentially increased the constraints and opportunities for ESD, therefore providing us with a deeper understanding of the impacts and possibilities. Moreover, the garden makes an ideal context

to explore the leading of environmental ESD using CMC tools because of the curator's unique and specific focus on environmental and ecological sustainability as a management approach and its role as a sustainable development research and outreach hub.

Research design

We employed a complementary mixed methods approach (Bazeley, 2018; Poth, 2018), drawing from content analysis and questionnaires. By collecting data and integrating the findings, we obtained a deeper understanding of the phenomenon by weaving two data types from different sources based on common themes.

Following the piloting for each data type, we collected data from the following sources:

1. *Content analysis*: A sample of social media platforms (such as Twitter, Instagram and Facebook) and the garden's web pages were selected for scrutiny and analysis through quantitative data (such as the number of followers and engagement) and qualitative content. Using the questionnaire themes as a starting point, we obtained and analysed data for three months (January to March 2022).
2. Questionnaire: The use of questionnaires enabled participant anonymity, which allowed more honesty (Blair *et al*., 2014). Using Jisc (no date) online survey platform offered an opportunity for volunteers and staff from the garden to anonymously share their insights on the garden's use of CMC to promote ESD. We obtained institutional ethical permission, and all respondents provided consent as part of the questionnaire design. We prepared a 23-item questionnaire with a series of short sections on:
    - General views on sustainability
    - Use of technology
    - Use of and views on social media
    - Views on the botanic garden's social, web pages, and other technologies.

Applying mixed methods, we elicited quantitative data in the form of yes/no or rating scale responses to provide a numerical description of participant opinion. Further, each section also allowed an opportunity for qualitative responses by providing additional space for participants to expand their answers to give greater insight. It also included four open-response questions surrounding the garden's strengths, weaknesses and recommendations for using CMC tools for ESD.

For this research, we have drawn from two independently generated data sources. We used descriptive analysis for the quantitative data. Cohen *et al*. (2018) note that descriptive analysis often uses frequencies and percentages and visual presentation showing the relationships between the

variables. The questionnaire themes were then utilised to drive the qualitative data analysis. An oscillating approach was applied to the data analysis through a back-and-forth movement between the questionnaire's quantitative descriptive statistics and qualitative thematic analysis (Beresford-Dey, 2020). The findings for the content analysis were then integrated. Throughout this phase, we used Bazeley's (2018: 282) reflective questions to aid the analysis:

- What have we learned?
- What do we know?
- How do all of the pieces of evidence fit together?
- Is there a story to tell?

Recruitment and sample

Taking a voluntary participation approach, participants were invited to complete the questionnaire via an email invitation, which the garden administrator shared across the garden's paid and voluntary staffing team. Whilst we recognise that the perspectives of different stakeholders, including the end-users of the garden, would be beneficial, we have targeted the staffing team in the first instance as they have specific knowledge of the garden working within the realms of the university alongside the garden's aims and vision. The sample consisted of 25 volunteers and paid staff, resulting in a 78 per cent response rate. None of the participants indicated being under thirty years old, twenty-two were between the ages of thirty and sixty-five, three identified as sixty-five or over, and two-thirds of the sample were male.

FINDINGS

The data from the 23-item questionnaire and the content analysis provided details surrounding the delivery of environmental sustainability at the botanic garden through CMC and how the participants perceived this. This section explores five themes drawn from the twenty-five participants, as reported above.

The topic of sustainability

All participants considered sustainability an important topic (Fig. 1). Also, 84 per cent of the respondents reported understanding the concept of sustainability well or very well, with some stating their professional and/or academic expertise. For example, having previously studied for a Master's degree in sustainability, working in the field and lecturing land-based studies. Regardless, with almost all respondents considering this an important subject, there was still a willingness to learn more about

the subject matter. One participant highlighted the need to "learn more from experts". Others indicated the need to know more about the positive and negative impact of action alongside cost-effective sustainability, particularly because the botanic garden was "tempered by financial challenges".

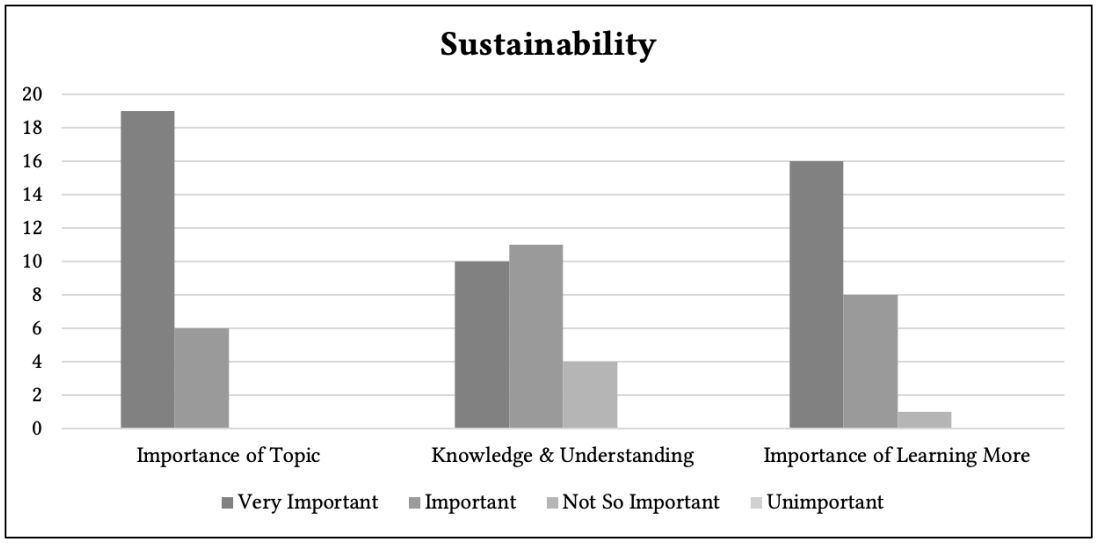

Fig. 1. Questionnaire data showing participant perceptions about sustainability.

Sustainability and CMC tools

Next, we explored the usefulness of CMC tools in sharing information on sustainability (Fig. 2). All participating voluntary and paid staff considered social media platforms helpful; the majority also reported web pages as valuable. Five respondents who indicated not utilising CMC tools highlighted various reasons, for example, lack of access to personal technology, lack of know-how, perceived as time-consuming, disengaging content and lack of information. One respondent commented that although they "look things up" when needed, they had not considered doing so concerning sustainability. Whilst it is crucial to consider individuals who do not have technological tools or know-how, for those who do, the provision of environmental sustainability information requires a proactive approach from the botanic garden's team to enhance user engagement by sharing valuable and current content through instant and simple methods—such as, through regular e-newsletters and various social networking sites. Unfortunately, none of the participants provided any insight as to why they thought CMC tools were useful.

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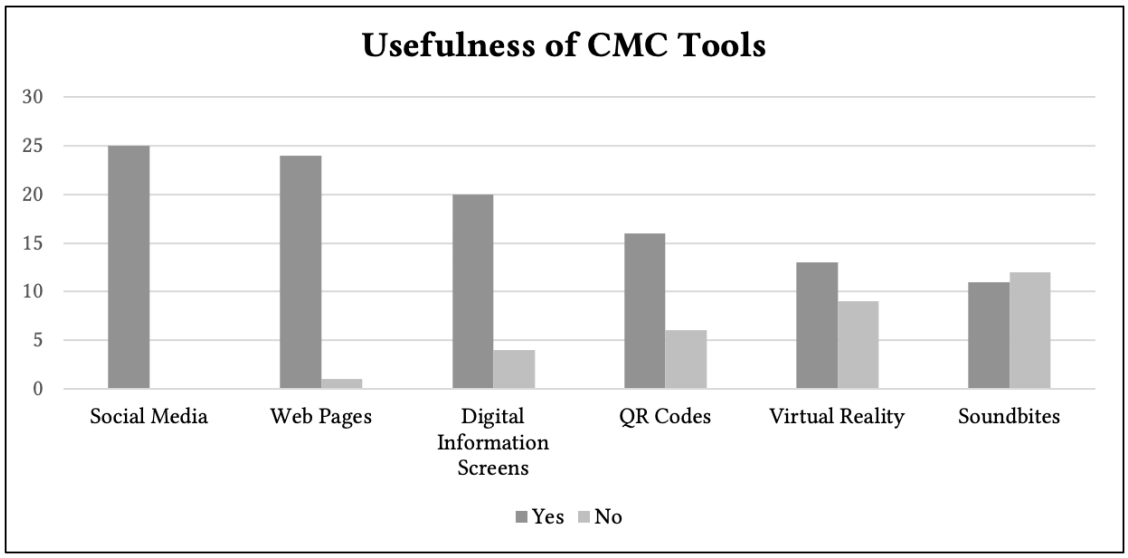

Fig. 2. Questionnaire data showing participant perceptions about the usefulness of Computer-Mediated Communication.

Social networking sites (SNS)

We unpacked social media further to establish which sites were used the most, commencing with general access. When questioned about engaging with the botanic garden's SNS, just over half of the respondents indicated they did not engage. Of those who did (Fig. 3), it seems that engagement via social media is weak, particularly for Instagram, TikTok and YouTube. However, from the content analysis (Table 1), it soon became apparent that the gardens did not have accounts for TikTok and YouTube, nor a formal account for Instagram; therefore, the lack of engagement was unsurprising. The questionnaire reported a larger number of participants accessing Facebook, Twitter and WhatsApp, yet a particular frontrunner remained elusive. From the content analysis, the largest audience was via Facebook, but the informal Instagram account had slightly higher postings. The data suggest some overlap between the content on the two platforms, yet there was little evidence of ESD postings. We could not access a WhatsApp group, so no further information could be obtained surrounding this platform. LinkedIn, Google News and Tumblr were identified within the qualitative responses as spaces for occasional engagement. However, the garden does not appear to use these platforms formally, particularly surrounding ESD. Instead, some individual members disseminated garden-related information via their personal accounts.

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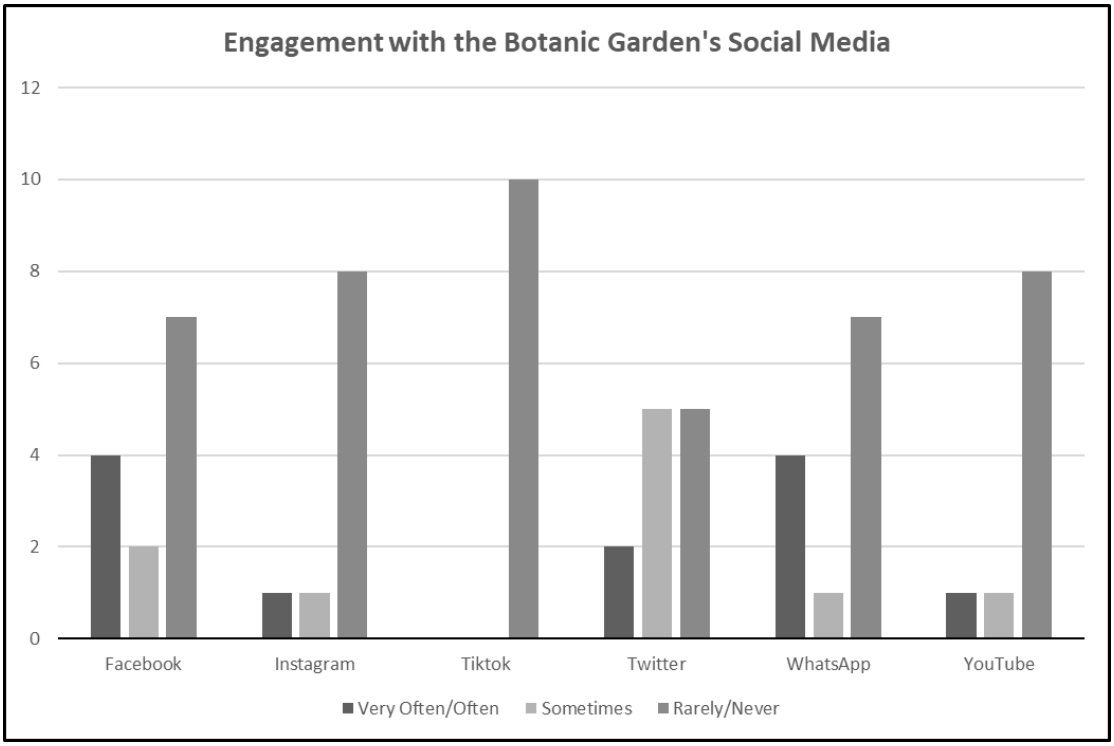

Fig. 3. Questionnaire data showing participant engagement with the various social media platforms related to the botanic garden.

Table 1: Content analysis data of various social networking sites.

Platform	**Account**	**Number of followers**	**No of Postings**	**Content**
Facebook	Formal	Almost 3000	13	Gardens-based arts and culture events Local project information Videos about the garden Weather-related closures Wider organisational events Other
Instagram	Informal	Less than 1000	14	Gardens-based arts and culture events Image of flowers/plants/trees (no narrative)

				Images: flowers/plants/trees (with narrative) Local and national project information
TikTok	No account	N/A	N/A	N/A
Twitter	Formal	Less than 1000	0 (the last posting appeared in 2020)	N/A
WhatsApp	N/A	N/A	N/A	N/A
YouTube	No account	N/A	N/A	N/A

Overall, 78% of the participating voluntary and paid staff thought the garden used social media well to inform the public about sustainability. However, one open response emphasised the need for more coordinated posts across the platforms; it noted their struggle in locating the botanic garden on Instagram (perhaps due to the informal account) alongside Twitter's limitations in giving in-depth information. Despite this, the qualitative data highlighted several strengths. For example, the mix of information shared through images and information, including event notifications—according to one participant, this demonstrates the authenticity of the garden's work. Furthermore, positive views of postings surrounded the garden's connection to the (local) city. That said, the content analysis did not reflect these strengths concerning ESD.

Some offered suggestions to strengthen ESD across the garden's different media platforms. These included:

- A need for a dedicated role where “resources are allocated” to “build a programme of posts linked to key themes and activities taking place within the garden across the whole year”
- “Developing stories that connect with live projects and ongoing sustainable work in the garden and across the [organisation] grounds”
- “More advice on what people can do as individuals”
- From a local perspective, it “would be good to see more about local sustainability—both how the Botanics works on this and things you can do locally to live more sustainably”.

Continuing the sense of the local community, one highlighted the potential for a "better connection with academia" to act "as a local and regional exemplar to promote ongoing initiatives and research programmes". Finally, another noted the potential of utilising the platforms to share general sustainability information, giving examples of "traditional materials used in horticulture such as peat", "alternative power" […] and "water collecting and saving" methods.

Web page usage

The key findings of the web page content analysis highlighted the embedded nature of the garden's web page within the larger organisation's website. They included features such as the homepage, an "about the gardens" page, news, visitor information, event listings and education. The education section contained information about the garden's onsite projects alongside those further afield. Although these projects are not directly related to ESD, some narratives were given in the periodic newsletters highlighting wildlife news within the garden. While the information was clearly presented, the ESD content appeared limited.

Turning to the questionnaire, only three respondents indicated using the garden's web page often. For most, web page visits were an occasional undertaking, and six respondents indicated they had never used it. When questioned about the purpose of their visits, the responses (Fig. 4) mainly focused on events and garden information such as opening times. Three responses reported seeking information on sustainability, whilst other areas included conservation, horticulture, research and education. Yet, the content analysis showed a lack of information regarding these themes.

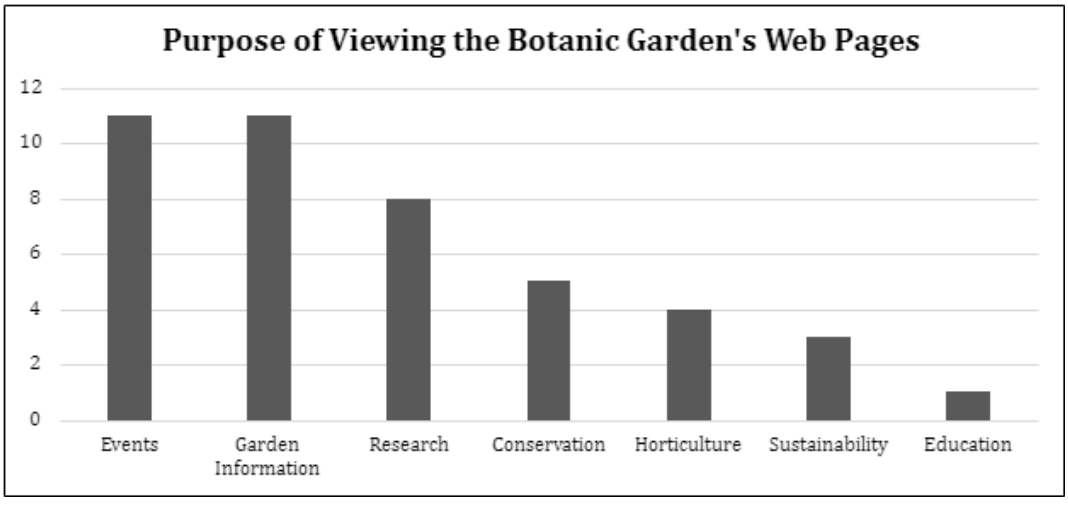

Fig 4. Questionnaire data showing the purpose of the participants' botanic garden web page viewings.

One individual commented, “There's a lot of great stuff on there, and the overall design seems nice and uncluttered”. While others were less than positive in their comments, for example, “There is room for improvement”, and “[I] can't find information on sustainability on the garden's web page”. Although we need to recognise the garden as part of a larger organisation and the need to align the organisational design and brand, both comments chimed with our analysis. Similarly, one respondent stated:

> “This [the website] is not a strength currently, while initiatives that have begun in 2021 [name of initiatives removed to preserve the garden's identity] are embedded in the web pages, the content is not clear nor easily navigated by a visitor”.

Several recommendations were suggested to enhance the web pages, including “embedding clear messages about sustainability”, promoting broad “climate change challenges”, and “sustainability research”. Focusing on the web page's operational components, a respondent highlighted the need for “a dedicated page with nested levels of knowledge embedded”, including “hyperlinks to work taking place in the garden or elsewhere within [the organisation]”. Others suggested the use of “podcasts” or a “blog style format” rather than “static web pages” and including information about physical visits such as “self-guided trails” alongside showcasing “local case studies”. Regardless of these suggestions, one participant noted that the virtual space would need widely promoting by “making it a more prominent and explicit part of the site”, which chimes with the need for a dedicated page with nested levels.

Beyond SNS and the web pages, many respondents (65 per cent) did not have an awareness of the garden using other CMC tools. Of those who did, QR codes appeared to be the primary mechanism for distributing information. Information from the qualitative data highlighted that QR codes have only recently been trialled (2021) in collaboration with other partners and linked to specific events promoting education for sustainability.

Perceptions of the Botanic Garden's role in leading ESD

All participating voluntary and paid staff reported the importance of the botanic garden in educating on sustainability and environmental issues. Delving further, half of the respondents indicated that the garden uses social media and their website well (53 and 50 per cent, respectively), with other technologies appearing under-utilised, with 85 per cent not using this well or only 'somewhat'. Thus suggesting further opportunities to educate the community on sustainability issues through CMC.

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Referring to Fig. 5, sharing internal event information was a strength, with 68 per cent of respondents reporting this as being done well or very well, yet this reduced to less than half when sharing external event information. Sharing ideas on sustainability was viewed positively by 58 per cent of the respondents. Still, when questioned about the garden providing tips for improving sustainability, the data flipped, with 58 per cent identifying this as a weakness. Enhancing knowledge through videos was viewed negatively by 80 per cent of the participants. The data was split even when improving knowledge through images was considered. Similar outcomes were reported for improving knowledge through well-researched posts, with 56 per cent noting this feature positively. Once again, the overall perception of the gardens making sustainable education easy and convenient did not show a substantial strength, with 53 per cent reporting this positively. These results align with the content analysis findings of limited information surrounding ESD.

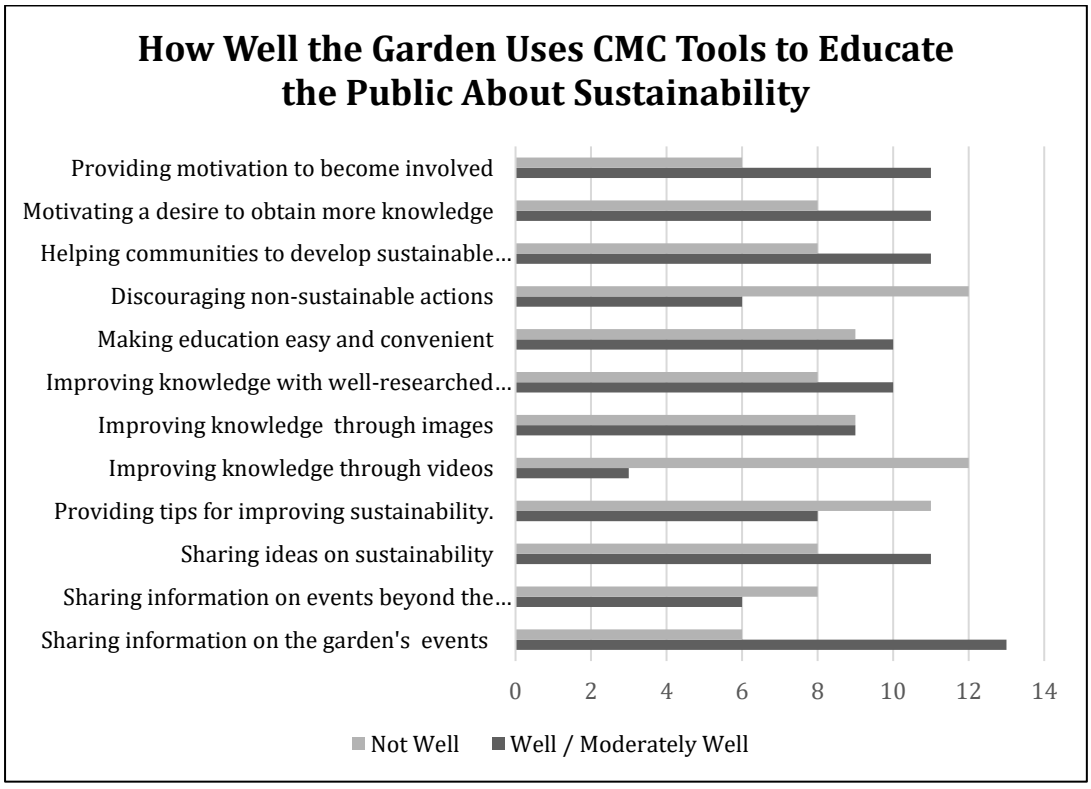

Fig. 5. Questionnaire data showing the participants' perceptions of how well the garden uses CMC tools to educate the public about sustainability

When asked about the garden's use of CMC as a source of motivation to learn more about sustainability or to be involved in sustainability activities, the results (Fig. 6) were weighted in a favourable direction, with 58 and 65 per cent (respectively) reporting this to be well or moderately well.

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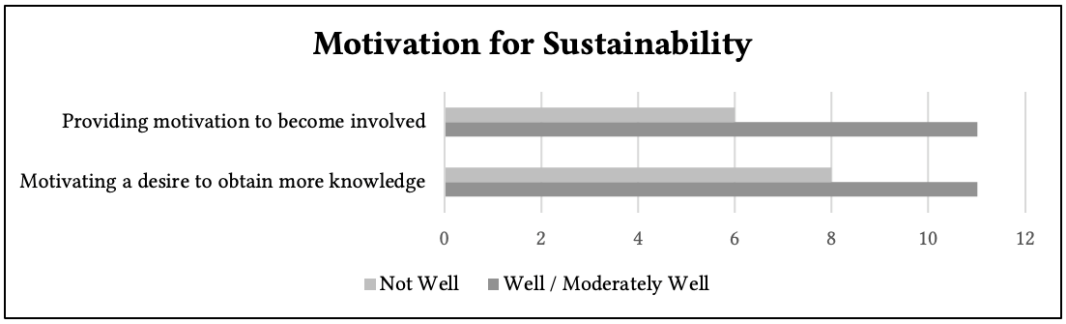

Fig. 6. Questionnaire data showing participant perception of the garden's use of CMC as a source of motivation relating to sustainability.

Finally, we asked the participants for their perspectives on how well the garden uses CMC tools to discourage non-sustainable actions and help communities develop sustainable activities (Fig. 7). Regarding discouraging non-sustainable actions, 67 per cent responded that this was not a feature that the Botanic Garden did well with 42 per cent of participants responding “not well” when focusing on helping communities to develop sustainable practices. The evidence suggests there is a need for some improvement to drive pro-sustainable activities.

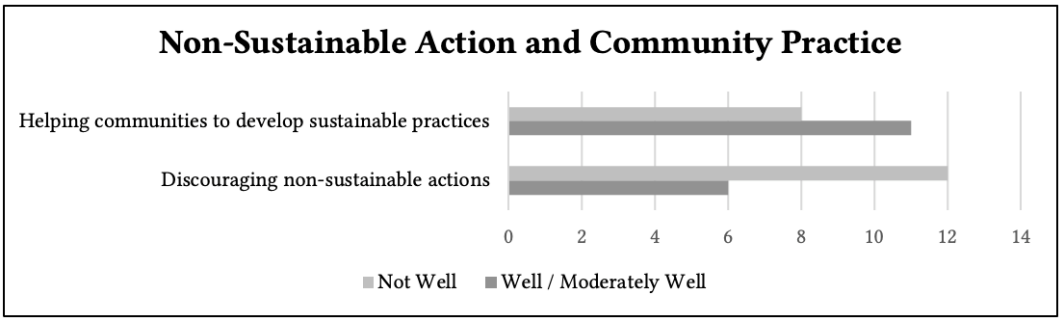

Fig. 7. Questionnaire data showing participant perceptions concerning sustainable and non-sustainable actions.

DISCUSSION

Within the context of a botanic garden underpinned by social leadership (SL), this mixed methods study set out to learn more about how SL offered us a model that illuminated insights into the extent and how a botanic garden uses CMC to lead education for ESD. Education is a catalyst for change toward building a more sustainable future (UNESCO, 2017; Blessinger *et al*., 2018), and as we have highlighted, educating others on sustainability is a fundamental role of botanic gardens (Romano,

2008). Although our findings have drawn primarily from the questionnaire data with the paid and voluntary staff as the sample, the target audience of the general public should be kept in mind when considering the outcomes and enhancing ESD for the end-user. Our findings align with Albarenda-Tiana *et al. (2018)* and Bolmsten and Kitada (2020) concerning the importance of ESD, alongside the desire of users to learn more. To enable this across various contexts, using CMC is an approach that can help ESD beyond physical boundaries.

The curation, co-creation, and dissemination of information through CMC tools can engage large communities and encourage action by educating individuals, groups, and organisations on sustainability understanding and practices that might otherwise have remained closed to them. The aim of SNS usage should be to deliver and engage end-users in evidence-based information streams (Simionescu *et al*., 2020). Whilst our data shows the importance of the botanic garden using CMC (specifically social media and web pages), the content associated with ESD requires some strengthening, particularly in increasing user knowledge. Limited use and engagement were also evident depending on the platform used. For example, participants appeared to connect primarily through Facebook and Twitter; LinkedIn was also mentioned. In short, to stimulate the garden's visibility on their commitment to ESD and "strengthen social influences" on sustainability, well-crafted and engaging postings on complementary CMC tools that are "tailored to the populations" require careful consideration (Ballew *et al*., 2015: 10638). However, whilst staff technological know-how and subject knowledge must be considered (Le *et al*., 2022), our findings demonstrated barriers beyond these, such as human and financial resources, alongside the broader organisational constraints.

An additional finding surrounds the financial and digital tensions that manifested through the budgetary limitations and the perception that CMC platforms of the larger organisation must be used if ESD to a larger audience is to be enhanced through such mediums. These conditions require creative problem-solving, innovative solutions, and opportunistic activities through intrapreneurial approaches. Yashin-Shaw (2018: 1) defines an intrapreneur as "the act of thinking and behaving like an entrepreneur while working within a large organisation" and includes characteristics such as creativity, collaboration, determination, growth-oriented, opportunistic, resourceful, and trend spotters. Cultivating intrapreneurial thinking and action will enable innovative improvements despite organisational constraints (Martiarena, 2013) and allow the botanic garden to be a knowledge-sharing organisation further afield, i.e., beyond the physical boundary of the garden walls.

The critical strands of community, communication, and digital technology of SL have provided us with a valuable lens to underpin this research. Through curation and sharing a narrative to build a reputation, SL drives change by engaging and connecting diverse individuals and communities (Stodd,

2016; Saunderson, 2018). To navigate this change, energy and commitment are required to achieve the common purpose (Guglielmo and Palsule, 2014). Whilst we are not questioning the energy and dedication of the garden's team in a general sense, the data indicates the limitedness of these features when associated with ESD through CMC. Therefore, returning to Stodd's (2016: 33) statement, "without the technology, you can't be a Social Leader", our data suggests that this requires some extension. To be influential leaders in the social age, working to increase community-centred sustainability ventures and sharing clear and consistent narratives through digital technologies are essential. The botanic garden has an opportunity to use SNS and their web pages effectively to portray the approach adopted by the garden regarding sustainability management to enhance ESD.

CONCLUSION

ESD is essential for addressing global sustainability challenges. CMC offers non-formal educational spaces that enable individuals and communities to act in ways without compromising the needs of future generations. Organisations must actively and consistently facilitate knowledge exchange to make good use of digital technology and add value to these spaces.

The context of this case study was a botanic garden situated within a larger organisation—a university; this containing factor appeared to reduce the garden's opportunities to make the most of CMC to become leaders in ESD. Yet, if large organisations are serious about sustainability, the operational constraints of subunits, such as the botanic garden, need to be addressed, allowing for greater autonomy. Increased autonomy would amplify knowledge and idea propagation and enhance action across diverse networks not predesigned or imposed by organisational structures. Further exploration of sustainability education through CMC could be usefully explored across independent botanic gardens (i.e., not constrained by the practices of a larger organisation) to further understand their role in leading ESD and the subsequent impact of this, alongside obtaining the views of younger audiences.

Overall, the extent and methods by which the botanic garden uses CMC paint a blurry picture because of the limited SNS activity. Whilst the participants viewed some aspects of the garden's use of CMC positively, they also offered recommendations to strengthen weaker areas. We can draw from the data that there is a will and desire for the team to increase usage, enhance community engagement, and disseminate information. Overall, this study makes two contributions to knowledge. First, it highlights CMC as a potentially valuable tool for the botanic garden to communicate, engage and educate about environmental ESD beyond the garden walls. Second, we show that there is a will and desire for the botanic garden to utilise such educational mechanisms. The limitations of this study's scale— such as drawing from voluntary and paid staff and the lack of younger participants mean we cannot draw broader inferences. However, our participants offer a valuable lens to draw from as they

may have a greater insight into the inner workings of the garden and can comment on areas which end-users may not be aware of, for example, financial constraints. Although we have not set out to statistically test nor prove a phenomenon, we have highlighted meaningful conclusions about the perceptions of ESD and user experiences of CMC to expand knowledge and drive sustainability activity.

Recommendations for further research:

- While this study has focused on a single botanic garden from the viewpoints of both paid and volunteer staff, future research should encompass end-users' perspectives while broadening the sample to include a more extensive range of botanic gardens and their respective audiences.

Recommendations for practice

- Identify opportunities for adapting organisational templates to declutter the digital spaces and reorganise them to suit the needs of the garden's community. For example, establish a formal social media presence to share sustainability knowledge and updates. Also, to promote local projects and ways to enhance individual sustainability practices. Ideally, the garden would self-manage the spaces rather than being controlled by the larger organisation.
- Use SL as a lens to drive ESD forward by establishing a reputation through digital technology and creating a straightforward narrative with the community at its heart.
- Increase the connection with academia by working with and sharing insights from academics across the region and inviting scholars to share research via the garden's CMC tools.
- Remain consistent with the monthly newsletters, but perhaps take the format of a blog-style approach; obtaining contributions from guest authors and curators would also benefit.
- Whilst a botanic garden could hire a marketeer, this would be costly. Although financial, personnel, and organisational constraints are evident in our findings, these are not unusual, and the team should adopt intrapreneurial spirits to identify ways to overcome some of these problems. For example, drawing from volunteers or students (perhaps offering internships or placement opportunities) to help build and deliver a programme of thematic postings and operationalise the garden's ESD vision.

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A BOTANIC GARDEN AS A POTENTIAL SOCIAL LEADER IN EDUCATION FOR SUSTAINABLE DEVELOPMENT THROUGH COMPUTER-MEDIATED COMMUNICATION

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ABSTRACT

When many are experiencing the impact of human disconnect with the natural environment, botanic gardens are well-positioned to contribute to reconnection through sustainability education. Globally, whilst many botanic gardens highlight the impact of human endeavours on the natural world, we question the use of computer-mediated communications (CMC) to enhance knowledge sharing and encourage pro-sustainability actions across communities. Through the lens of social

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leadership and undertaking a mixed methods study, we explore the potential for one UK-based university botanic garden to lead on education for sustainability with the broader community using CMC. The findings highlight the desire of the staff and volunteers to increase the usage of CMC tools to enhance community engagement and disseminate information. Findings also indicate a need for greater autonomy and an intrapreneurial mindset to amplify knowledge and strengthen action across diverse networks that are not predesigned or imposed by organisational constructs.

Keywords: sustainability, education, digital technology, social leadership, botanic gardens, intrapreneurship.

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INTRODUCTION

Sustainable development has grown as a concept since its inclusion in the Brundtland Report (Brundtland Commission, 1987), where it was defined as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (p.15). More recently, the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017) highlighted a central focus on integrating sustainability into education as a catalyst for change, arguing that there has never been greater momentum for change than now. More than ever, sustainability education is necessary for everyone if we are to minimise human-related planetary destruction (Zelenika *et al*., 2018; UNESCO, 2020). As the realities of global climate change are becoming increasingly observable, education for sustainable development (ESD) permits everyone to critically review how the world is and visualise how the world might be in the future (The Quality Assurance Agency for Higher Education and Advance HE, 2021).

With over 3,000 botanic gardens (Romano, 2008) and, globally, an estimated 240 million physical visits per year (Zelenika *et al*., 2018), botanic gardens are well-placed to enhance ESD. Beyond the physical visits, there is an opportunity to extend ESD to a much larger audience by using computer-mediated communication (CMC) tools. As Romiszowski and Mason (1996) outlined, CMC elucidates how individuals share information through digital technology and can play a supportive role in facilitating conversational discourse (Ahern *et al., 1992)*. Such tools include social networking sites (SNS), for example, Facebook, X (formally Twitter), LinkedIn and Instagram. Note, due to the date of the data collection being completed before the rebranding from Twitter to X (Counts and Levine, 2023), we maintain the name Twitter throughout the paper. Through a small-scale case study of one botanic garden, we question to what extent and how a botanic garden uses CMC to lead ESD.

LITERATURE REVIEW

Education for sustainable development

The turning point for ESD was during the 1992 Rio de Janeiro Earth Summit, when the UN escalated Agenda 21, recognising the role of education as a necessity if we are to progress towards a sustainable future (United Nations, 1992). Complementing this, at the World Conference on Education for Sustainable Development, ESD was defined as "an approach to teaching and learning based on the ideals and principles that underlie sustainability" UNESCO (2009: 8). The blueprint for ESD is located within the United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), alongside its inclusion in landmark agreements, namely, the

UN Framework Convention on Climate Change (UNFCC) and Convention on Biodiversity (United Nations, 2015; Maruna *et al.*, 2018). Essentially, ESD points to the practice of teaching for sustainability (Grosseck *et al.*, 2019) regardless of the discipline, sector or field. As a result, it is crucial to recognise that educating for sustainable development requires diverse learning and teaching approaches to be accessible to all.

With the evermore pressing global concerns such as climate change and large-scale ecological and environmental degradation, sustainability is a topic that we all need to understand (Simionescu *et al*., 2020) if we are to respond to these issues as a global collective. Yet, according to Zelenika *et al*. (2018), promoting public engagement to encourage individual action continues to be challenging for institutions, organisations and governments. Still, the authors acknowledge using innovative methods to promote sustainable understanding and practices. Regardless of the learning format, ESD aims to change the approach to sustainability education by incorporating values, principles and successful practices into learning (Elmassah *et al*., 2021). For this reason, ESD is an educational change agenda (The Quality Assurance Agency for Higher Education and Advance HE, 2021).
One of the 17 SDGs in its own right, integrated, inclusive, quality education underpins all other SDGs as well. For example, promoting integrated water resource management, ocean sustainability, protection of biodiversity, mitigating and adapting to climate change, advancing sustainable cities and deepening social inclusion. Within UNESCO's (2017: 6) report,

> "*Education is both a goal in itself and a means for attaining all the other SDGs. It is not only an integral part of sustainable development but also a key enabler for it. That is why education represents an essential strategy in the pursuit of the SDGs.*"

Accordingly, education is a powerful means to develop a more sustainable future (Blessinger *et al*., 2018); it is a foundation for acting upon all sustainability goals constituting the environmental, economic and social realms for sustainable development (Albarenda-Tiana *et al*., 2018; Bolmsten and Kitada, 2020). With this view, ESD is a dominant force for a prosperous future as continuous, quality education enables individuals and communities to flourish through increased knowledge and skills development (David and Ibrahim, 2020). ESD supports people in identifying and addressing sustainability-threatening problems (UNESCO, 2008), enabling adaptive and responsive action to our ever-changing realities, and facilitating transformation to alternative planetary futures (Sharma and Kelly, 2014). If education is the inclusive and integrated keystone in tackling global issues, then we must consider education beyond formal education systems. Using CMC may provide a valuable medium for ESD to establish learning across the broad spectrum.

Botanic gardens

Whilst the focus for botanic gardens has typically centred on horticulture and taxonomy developments, more recently, emphasis surrounds addressing the broader *ex-situ* sustainability and conservation challenges alongside public education (Wyse Jackson and Sutherland, 2000; Donaldson, 2009; Williams *et al*., 2015; Frediani, forthcoming). As noted by Zelenika *et al*. (2018), institutions such as botanic gardens, whilst holding documented collections of living plants for scientific research and plant conservation, 'there is a tremendous, yet untapped opportunity for gardens to re-connect communities with the natural world' (p.1582). Also, as Williams *et al*. (2015) highlighted, they constitute meaningful educational contexts and are working to increase audiences. From this, it is evident that education should be viewed as a principal function of botanic gardens (He and Chen, 2012; Gao and Weibang, 2018; Faraji and Karimi, 2020). In essence, ESD is a primary objective for botanic gardens (Willison, 2006).

Educational initiatives within botanic gardens register different forms. These include coordinating workshops, guided tours (Kneebone, 2006; Jensen, 2014), community outreach (Krishnan *et al*., 2019), adult education and certification programs, internships, family activities, children's summer camps, and field trips as part of school programs and teacher training (BGCI, 2010; Krishnan and Novy, 2016). Additionally, Faraji and Karimi (2020) report that community-based research and education collaborations provide meaningful opportunities for botanic gardens and nature-based organisations to contribute to sustainability education directly. Against this backdrop, and as a result of their multifaceted wealth of resources (Willison, 2006: 8), botanic gardens have a responsibility concerning ESD and challenging the public to live sustainably with others, including their relationship with the non-human world (Huckle, 1996: 35).

In addition to the environmental aspects, botanic gardens also hold responsibility for various economic (Benfield, 2013; Connell and Page, 2014; Flôres Limberger *et al*., 2014) and sociocultural elements (Connell, 2005; Ward *et al*., 2010; Frediani, forthcoming). As previously indicated, many of these elements are located within the SDGs, such as Responsible Consumption and Production, Good Health and Wellbeing, and Zero Hunger (United Nations, no date). Thus, the research underlines the value and importance of botanic gardens as an educational catalyst (Moskwa and Crilley, 2012; Catahan, 2018), going beyond horticulture. Indeed, Willison (2006) and Sellmann (2014) document that by providing information and sharing expertise to support the development of ESD programmes, particularly in the local environment, botanic gardens offer appropriate learning spaces. In turn, this aids in helping individuals and communities to make informed decisions about

sustainability issues that may impact life, now or in the future; therefore, botanic gardens need to remain at the forefront of ESD.

Computer-mediated communication

A way for botanic gardens to remain at the forefront of education for sustainable development is to use CMC. CMC describes how people disseminate information to others using digital technology (Romiszowski and Mason, 1996) and can assist in conversational discourse (Ahern *et al*., 1992) between 'groups, or individuals separated by time and space' (Marani *et al*., 2020: 97). Whilst we are not suggesting that digital interaction replaces the direct contact of physical visits, where connecting with nature as a sensory experience takes place, there is a space to share ESD knowledge through CMC. The internet has no doubt revolutionised learning and offers powerful opportunities to utilise technology for educational purposes inside and outside of the formal classroom (Wang *et al*., 2022). Using CMC promotes self-directed learning (Asfar and Zainuddin, 2015), public awareness of environmental subjects such as climate change (Mavrodieva *et al*., 2019), and allows individuals and organisations to appear more visible (Treem *et al*., 2020). However, keeping abreast of CMC applications is crucial as these change over time in tandem with the development of new social norms and technology platforms (Treem et al., 2020). A popular application of CMC is disseminating information through SNS. Recognising this and the intensive use of social media by young people, alongside their interest in the sustainability and climate issues affecting the world (Thigpen and Tyson, 2021), has been one of the reasons behind our consideration of the use of this media. Moreover, the general use of social media across all age groups has increased, driven in part by this becoming the way of communication (Petricini, 2022), and this is seen as an important mechanism by which to share information on sustainability.

When developing digital content for internet distribution, creators must establish an imagined audience to guide online behaviour. The development of such an audience can consider behaviours displayed by a real audience, the creators' skills in developing socially acceptable content and the motivation to engage with social media content (Litt, 2012). The quality of digital interactions can vary depending on the platform used (Oz *et al*., 2018) and the skill set of those developing content. For successful use of CMC, organisations must consider i) the motivation that staff have to engage with specific media, ii) the knowledge that staff have in a given subject area, and iii) their overall skill in using technology (Le *et al*., 2022). Furthermore, many end-users can be classified as lurkers, where they will read the content but not engage with it (Cranefield *et al*., 2015). This passive online

behaviour can be related to users' unwillingness to create a social investment in future content from a given source (Ellison *et al*., 2020).

CMCs, such as SNS and websites, have become significant for organising various human activities, including economic, social and political interactions (Asadullah *et al*., 2018). Whilst the use of CMCs is an opportunity to provide content developed to raise awareness and understanding through connectivity with their audience, studies investigating their impact on informing the public of sustainability endeavours remain limited. Moreover, our exploration of the literature suggests a gap when positioning the research in the context of botanic gardens.

Social leadership

In this study, we do not consider 'leading' as an individual endeavour. Instead, we aim to understand 'leadership' in the field of ESD as a collective, knowledgeable community. Here, we draw from Guglielmo and Palsule (2014), who define a community as a group of individuals with a shared passion. Progressing from the industrial age, we require leadership that detaches from hierarchical power structures and advances knowledge and digital eras into the social age. The social era requires leadership forged through, among other things, communities, connections, networks, collaboration and communication (Stodd, 2016) and individuals being prosumers who are engaged, proactive contributors (Guglielmo and Palsule, 2014: xiv). All of these are central to social leadership (SL), a stance that underpins our research.

Leadership through an SL lens removes itself from many common concepts in leadership texts, such as leader-centric personalities and decision-making. Social leaders are altruistic (Saunderson, 2018) and drive change by constructing, connecting and engaging the power of diverse and inclusive communities where reputable meaning is co-created, curated and shared through narratives (Stodd, 2016; Saunderson, 2018). Social leaders orchestrate adaptive change across various groups and communities (Porteous, 2013: 524) and release geographical shackles (Guglielmo and Palsule, 2014). The power of SL builds upon discovery (Porteous, 2013), transparency, trust, integrity and collective ventures (Stodd, 2016); it is founded on content and reputation rather than ‘simple positional authority” (ibid., p.8).

Effective use of CMC can drive high levels of engagement and connection. In turn, through sharing co-constructed narratives to educate and empower the audience, not only does CMC help to build reputation and momentum, but according to Stodd (2016), it also brings about social change and, subsequently, environmental change. While we realise that not everyone has access to digital

technology or wishes to utilise it, its use does mean that cross-boundary dialogic communication is enabled synchronously and asynchronously across a broad audience. Accordingly, digital technology is central to SL (Biro, 2013), with Stodd (2016: 33) reporting, "without the technology, you can't be a Social Leader".

Bearing in mind the complex nature of botanic gardens in terms of their continuously evolving social and environmental roles and the communities they serve, SL is a valuable lens to explore the use of CMC in leading ESD. Social leaders balance the complexities between formal and informal organisational structures. Therefore, it is particularly relevant to the context of the botanic garden situated within the larger organisation of a university.

In summary, the existing body of literature presents persuasive evidence of botanic gardens' role in advancing ESD, offering a unique and advantageous opportunity to integrate the different SDG fields (Leal Filho *et al*., 2019; Michael *et al*., 2020). The utilisation of CMC not only offers innovative avenues for botanic gardens to disseminate their expertise in ESD but also serves as a powerful catalyst in enhancing public awareness and fostering self-directed learning. As a result, we explore how one UK-based university botanic garden utilises opportunities to lead environmental ESD through CMCs and underpin our work with SL.

METHODOLOGY

In response to our research questions - (i) 'To what extent does a botanic garden use CMC to lead ESD?' and (ii) 'How does a botanic garden use CMC to lead ESD?', we adopted a case study methodology. Case studies allow researchers to penetrate multiple realities and unique portrayals of situations (Lincoln and Guba, 1985) whilst recognising the complexities and numerous variables in operation within any given case (Cohen *et al*., 2018). A case study is preferred when the research questions surrounding a contemporary social phenomenon are 'how' or 'why' (Yin, 2014). By way of such an approach and "bounding the case" (Yin, 2014: 33) within a social boundary (Gerring, 2017), this research aimed to explore the use of CMC in leading environmental ESD through an SL perspective within one botanic garden.

Context

The study was conducted in a UK university botanic garden, Sequoia Botanic Garden (pseudonym). The over 50-year-old garden is located on almost ten hectares in an affluent area of a coastal city. With a team of 32 paid and voluntary staff and three students, the garden accommodates over 80,000 visitors annually and works closely with multiple partners across the city and neighbouring regions. The garden hosts many activities, such as educational visitors, nature-based art exhibitions

and theatre groups. As part of a larger organisation, this brings additional complexities to the garden's operational and strategic activities.

Like many botanic gardens, the site has seen the demise of botany and the rise of life (plant) sciences with a key focus on the impacts of climate change, population increases and conservation efforts. We purposefully selected the site as the garden is located within a wider organisation—a university—and this potentially increased the constraints and opportunities for ESD, therefore providing us with a deeper understanding of the impacts and possibilities. Moreover, the garden makes an ideal context to explore the leading of environmental ESD using CMC tools because of the curator's unique and specific focus on environmental and ecological sustainability as a management approach and its role as a sustainable development research and outreach hub.

Research design

We employed a complementary mixed methods approach (Bazeley, 2018; Poth, 2018), drawing from content analysis and questionnaires. By collecting data and integrating the findings, we obtained a deeper understanding of the phenomenon by weaving two data types from different sources based on common themes.

Following the piloting for each data type, we collected data from the following sources:

1. *Content analysis*: A sample of social media platforms (such as Twitter, Instagram and Facebook) and the garden's web pages were selected for scrutiny and analysis through quantitative data (such as the number of followers and engagement) and qualitative content. Using the questionnaire themes as a starting point, we obtained and analysed data for three months (January to March 2022).
2. Questionnaire: The use of questionnaires enabled participant anonymity, which allowed more honesty (Blair *et al*., 2014). Using Jisc (no date) online survey platform offered an opportunity for volunteers and staff from the garden to anonymously share their insights on the garden's use of CMC to promote ESD. We obtained institutional ethical permission, and all respondents provided consent as part of the questionnaire design. We prepared a 23-item questionnaire with a series of short sections on:
    - General views on sustainability
    - Use of technology
    - Use of and views on social media
    - Views on the botanic garden's social, web pages, and other technologies.

Applying mixed methods, we elicited quantitative data in the form of yes/no or rating scale responses to provide a numerical description of participant opinion. Further, each section also allowed an opportunity for qualitative responses by providing additional space for participants to expand their answers to give greater insight. It also included four open-response questions surrounding the garden's strengths, weaknesses and recommendations for using CMC tools for ESD.

For this research, we have drawn from two independently generated data sources. We used descriptive analysis for the quantitative data. Cohen *et al*. (2018) note that descriptive analysis often uses frequencies and percentages and visual presentation showing the relationships between the variables. The questionnaire themes were then utilised to drive the qualitative data analysis. An oscillating approach was applied to the data analysis through a back-and-forth movement between the questionnaire's quantitative descriptive statistics and qualitative thematic analysis (Beresford-Dey, 2020). The findings for the content analysis were then integrated. Throughout this phase, we used Bazeley's (2018: 282) reflective questions to aid the analysis:

- What have we learned?
- What do we know?
- How do all of the pieces of evidence fit together?
- Is there a story to tell?

Recruitment and sample

Taking a voluntary participation approach, participants were invited to complete the questionnaire via an email invitation, which the garden administrator shared across the garden's paid and voluntary staffing team. Whilst we recognise that the perspectives of different stakeholders, including the end-users of the garden, would be beneficial, we have targeted the staffing team in the first instance as they have specific knowledge of the garden working within the realms of the university alongside the garden's aims and vision. The sample consisted of 25 volunteers and paid staff, resulting in a 78 per cent response rate. None of the participants indicated being under thirty years old, twenty-two were between the ages of thirty and sixty-five, three identified as sixty-five or over, and two-thirds of the sample were male.

FINDINGS

The data from the 23-item questionnaire and the content analysis provided details surrounding the delivery of environmental sustainability at the botanic garden through CMC and how the

participants perceived this. This section explores five themes drawn from the twenty-five participants, as reported above.

The topic of sustainability

All participants considered sustainability an important topic (Fig. 1). Also, 84 per cent of the respondents reported understanding the concept of sustainability well or very well, with some stating their professional and/or academic expertise. For example, having previously studied for a Master's degree in sustainability, working in the field and lecturing land-based studies. Regardless, with almost all respondents considering this an important subject, there was still a willingness to learn more about the subject matter. One participant highlighted the need to "learn more from experts". Others indicated the need to know more about the positive and negative impact of action alongside cost-effective sustainability, particularly because the botanic garden was "tempered by financial challenges".

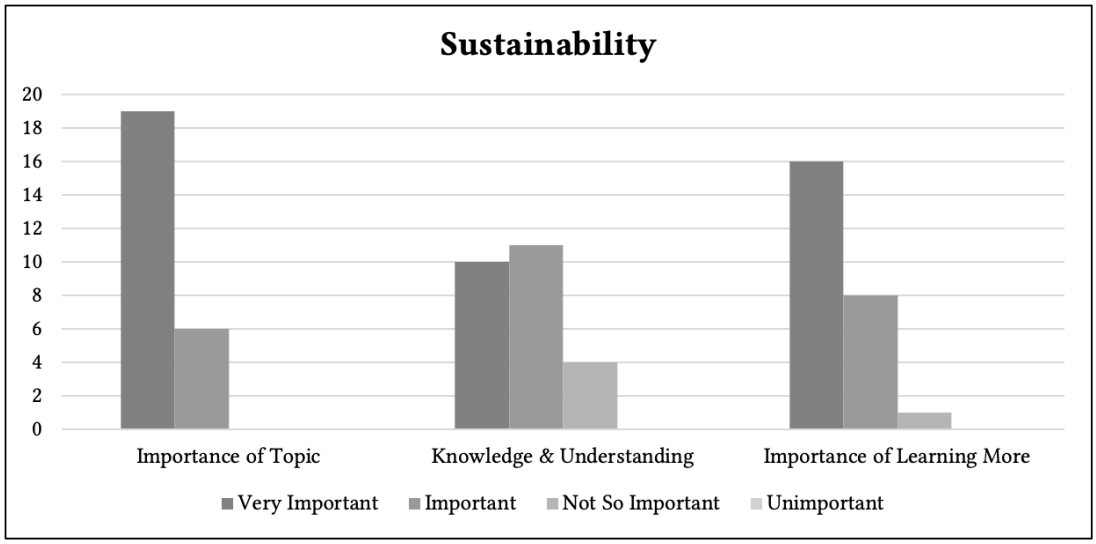

Fig. 1. Questionnaire data showing participant perceptions about sustainability.

Sustainability and CMC tools

Next, we explored the usefulness of CMC tools in sharing information on sustainability (Fig. 2). All participating voluntary and paid staff considered social media platforms helpful; the majority also reported web pages as valuable. Five respondents who indicated not utilising CMC tools highlighted various reasons, for example, lack of access to personal technology, lack of know-how, perceived as time-consuming, disengaging content and lack of information. One respondent commented that although they "look things up" when needed, they had not considered doing so concerning

sustainability. Whilst it is crucial to consider individuals who do not have technological tools or know-how, for those who do, the provision of environmental sustainability information requires a proactive approach from the botanic garden's team to enhance user engagement by sharing valuable and current content through instant and simple methods—such as, through regular e-newsletters and various social networking sites. Unfortunately, none of the participants provided any insight as to why they thought CMC tools were useful.

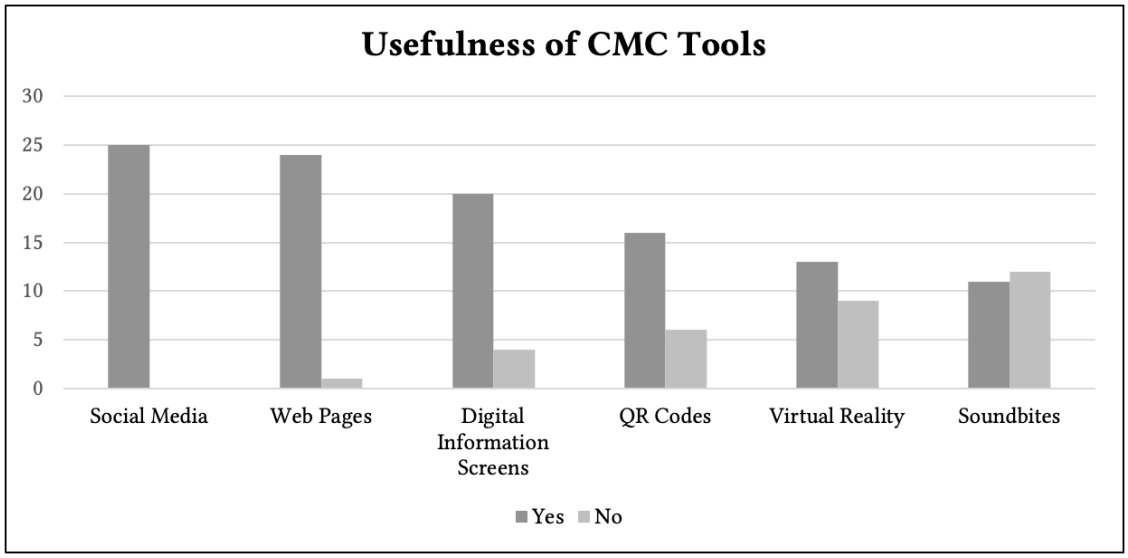

Fig. 2. Questionnaire data showing participant perceptions about the usefulness of Computer-Mediated Communication.

Social networking sites (SNS)

We unpacked social media further to establish which sites were used the most, commencing with general access. When questioned about engaging with the botanic garden's SNS, just over half of the respondents indicated they did not engage. Of those who did (Fig. 3), it seems that engagement via social media is weak, particularly for Instagram, TikTok and YouTube. However, from the content analysis (Table 1), it soon became apparent that the gardens did not have accounts for TikTok and YouTube, nor a formal account for Instagram; therefore, the lack of engagement was unsurprising. The questionnaire reported a larger number of participants accessing Facebook, Twitter and WhatsApp, yet a particular frontrunner remained elusive. From the content analysis, the largest audience was via Facebook, but the informal Instagram account had slightly higher postings. The data suggest some overlap between the content on the two platforms, yet there was little evidence of ESD postings. We could not access a WhatsApp group, so no further information could be obtained surrounding this platform. LinkedIn, Google News and Tumblr were identified within the

qualitative responses as spaces for occasional engagement. However, the garden does not appear to use these platforms formally, particularly surrounding ESD. Instead, some individual members disseminated garden-related information via their personal accounts.

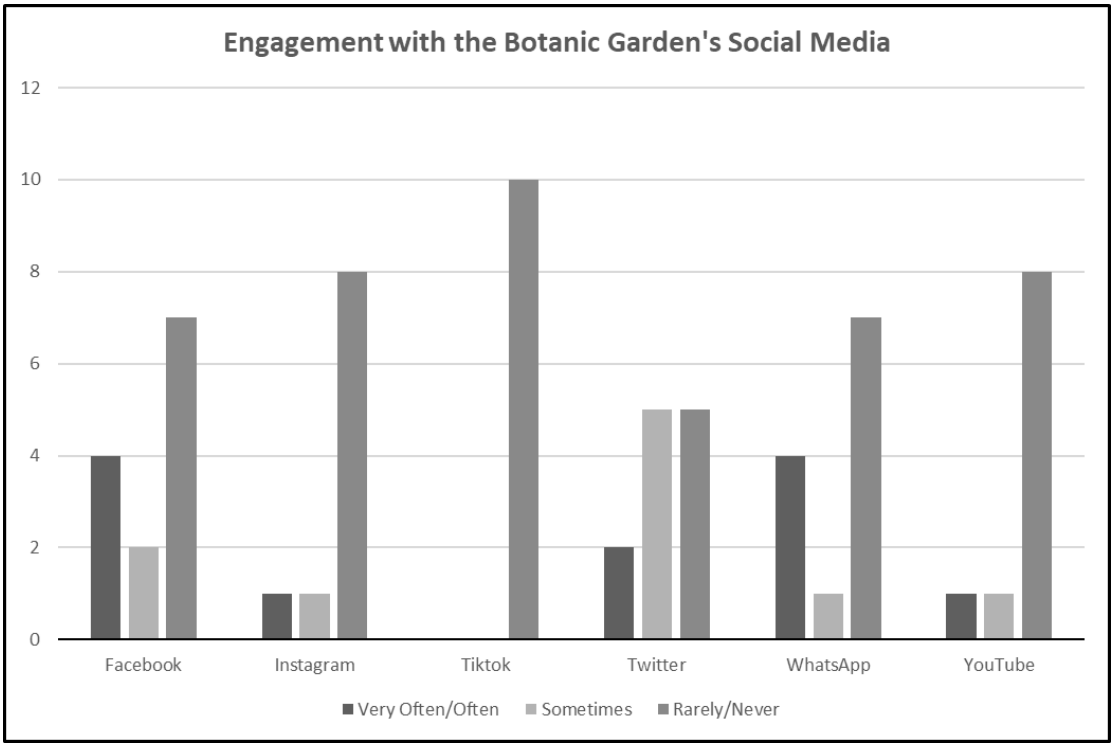

Fig. 3. Questionnaire data showing participant engagement with the various social media platforms related to the botanic garden.

Table 1: Content analysis data of various social networking sites.

Platform	**Account**	**Number of followers**	**No of Postings**	**Content**
Facebook	Formal	Almost 3000	13	Gardens-based arts and culture events Local project information Videos about the garden Weather-related closures Wider organisational events Other
Instagram	Informal	Less than 1000	14	Gardens-based arts and culture events

				Image of flowers/plants/trees (no narrative) Images: flowers/plants/trees (with narrative) Local and national project information
TikTok	No account	N/A	N/A	N/A
Twitter	Formal	Less than 1000	0 (the last posting appeared in 2020)	N/A
WhatsApp	N/A	N/A	N/A	N/A
YouTube	No account	N/A	N/A	N/A

Overall, 78% of the participating voluntary and paid staff thought the garden used social media well to inform the public about sustainability. However, one open response emphasised the need for more coordinated posts across the platforms; it noted their struggle in locating the botanic garden on Instagram (perhaps due to the informal account) alongside Twitter's limitations in giving in-depth information. Despite this, the qualitative data highlighted several strengths. For example, the mix of information shared through images and information, including event notifications—according to one participant, this demonstrates the authenticity of the garden's work. Furthermore, positive views of postings surrounded the garden's connection to the (local) city. That said, the content analysis did not reflect these strengths concerning ESD.

Some offered suggestions to strengthen ESD across the garden's different media platforms. These included:

- A need for a dedicated role where “resources are allocated” to “build a programme of posts linked to key themes and activities taking place within the garden across the whole year”
- “Developing stories that connect with live projects and ongoing sustainable work in the garden and across the [organisation] grounds”
- “More advice on what people can do as individuals”

- From a local perspective, it "would be good to see more about local sustainability—both how the Botanics works on this and things you can do locally to live more sustainably".

Continuing the sense of the local community, one highlighted the potential for a "better connection with academia" to act "as a local and regional exemplar to promote ongoing initiatives and research programmes". Finally, another noted the potential of utilising the platforms to share general sustainability information, giving examples of "traditional materials used in horticulture such as peat", "alternative power" […] and "water collecting and saving" methods.

Web page usage

The key findings of the web page content analysis highlighted the embedded nature of the garden's web page within the larger organisation's website. They included features such as the homepage, an "about the gardens" page, news, visitor information, event listings and education. The education section contained information about the garden's onsite projects alongside those further afield. Although these projects are not directly related to ESD, some narratives were given in the periodic newsletters highlighting wildlife news within the garden. While the information was clearly presented, the ESD content appeared limited.

Turning to the questionnaire, only three respondents indicated using the garden's web page often. For most, web page visits were an occasional undertaking, and six respondents indicated they had never used it. When questioned about the purpose of their visits, the responses (Fig. 4) mainly focused on events and garden information such as opening times. Three responses reported seeking information on sustainability, whilst other areas included conservation, horticulture, research and education. Yet, the content analysis showed a lack of information regarding these themes.

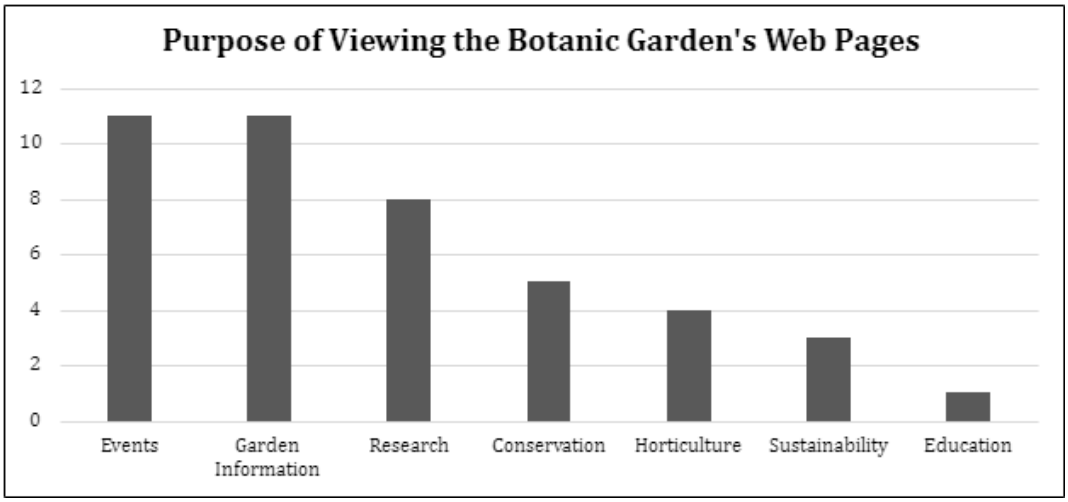

Fig 4. Questionnaire data showing the purpose of the participants' botanic garden web page viewings.

One individual commented, “There's a lot of great stuff on there, and the overall design seems nice and uncluttered”. While others were less than positive in their comments, for example, “There is room for improvement”, and “[I] can't find information on sustainability on the garden's web page”. Although we need to recognise the garden as part of a larger organisation and the need to align the organisational design and brand, both comments chimed with our analysis. Similarly, one respondent stated:

> “This [the website] is not a strength currently, while initiatives that have begun in 2021 [name of initiatives removed to preserve the garden's identity] are embedded in the web pages, the content is not clear nor easily navigated by a visitor”.

Several recommendations were suggested to enhance the web pages, including “embedding clear messages about sustainability”, promoting broad “climate change challenges”, and “sustainability research”. Focusing on the web page's operational components, a respondent highlighted the need for “a dedicated page with nested levels of knowledge embedded”, including “hyperlinks to work taking place in the garden or elsewhere within [the organisation]”. Others suggested the use of “podcasts” or a “blog style format” rather than “static web pages” and including information about physical visits such as “self-guided trails” alongside showcasing “local case studies”. Regardless of these suggestions, one participant noted that the virtual space would need widely promoting by “making it a more prominent and explicit part of the site”, which chimes with the need for a dedicated page with nested levels.

Beyond SNS and the web pages, many respondents (65 per cent) did not have an awareness of the garden using other CMC tools. Of those who did, QR codes appeared to be the primary mechanism for distributing information. Information from the qualitative data highlighted that QR codes have only recently been trialled (2021) in collaboration with other partners and linked to specific events promoting education for sustainability.

Perceptions of the Botanic Garden's role in leading ESD

All participating voluntary and paid staff reported the importance of the botanic garden in educating on sustainability and environmental issues. Delving further, half of the respondents indicated that the garden uses social media and their website well (53 and 50 per cent, respectively), with other

technologies appearing under-utilised, with 85 per cent not using this well or only 'somewhat'. Thus suggesting further opportunities to educate the community on sustainability issues through CMC.

Referring to Fig. 5, sharing internal event information was a strength, with 68 per cent of respondents reporting this as being done well or very well, yet this reduced to less than half when sharing external event information. Sharing ideas on sustainability was viewed positively by 58 per cent of the respondents. Still, when questioned about the garden providing tips for improving sustainability, the data flipped, with 58 per cent identifying this as a weakness. Enhancing knowledge through videos was viewed negatively by 80 per cent of the participants. The data was split even when improving knowledge through images was considered. Similar outcomes were reported for improving knowledge through well-researched posts, with 56 per cent noting this feature positively. Once again, the overall perception of the gardens making sustainable education easy and convenient did not show a substantial strength, with 53 per cent reporting this positively. These results align with the content analysis findings of limited information surrounding ESD.

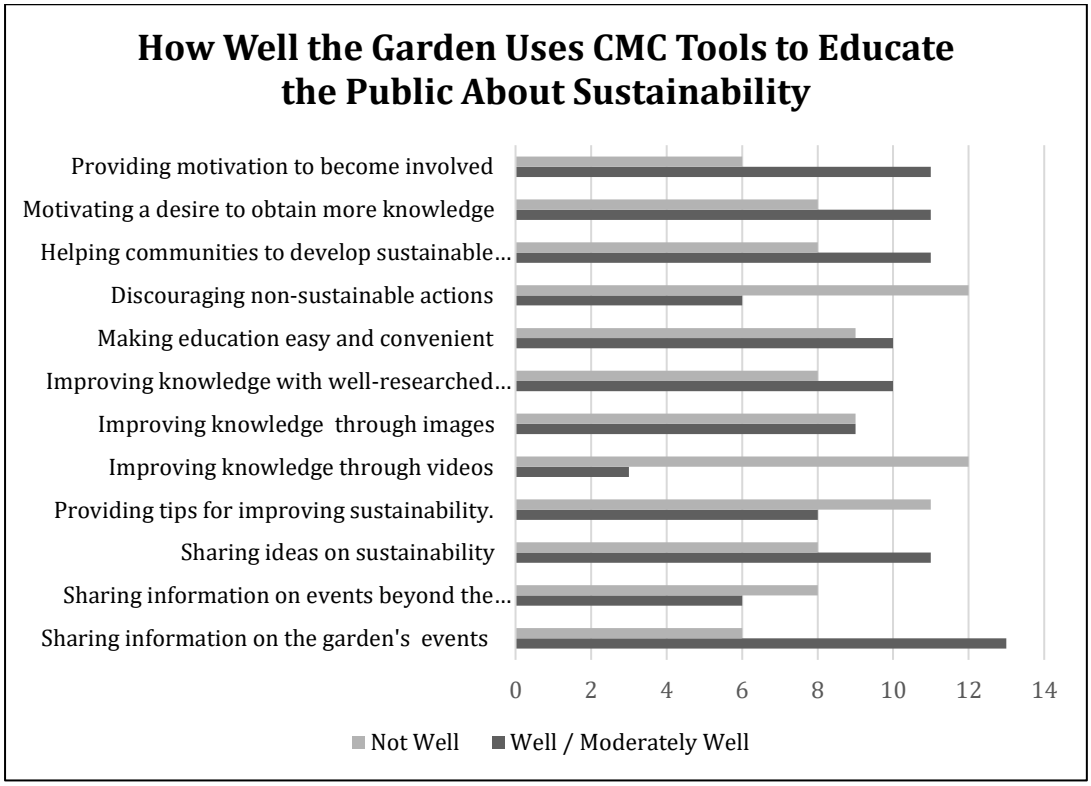

Fig. 5. Questionnaire data showing the participants' perceptions of how well the garden uses CMC tools to educate the public about sustainability

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When asked about the garden's use of CMC as a source of motivation to learn more about sustainability or to be involved in sustainability activities, the results (Fig. 6) were weighted in a favourable direction, with 58 and 65 per cent (respectively) reporting this to be well or moderately well.

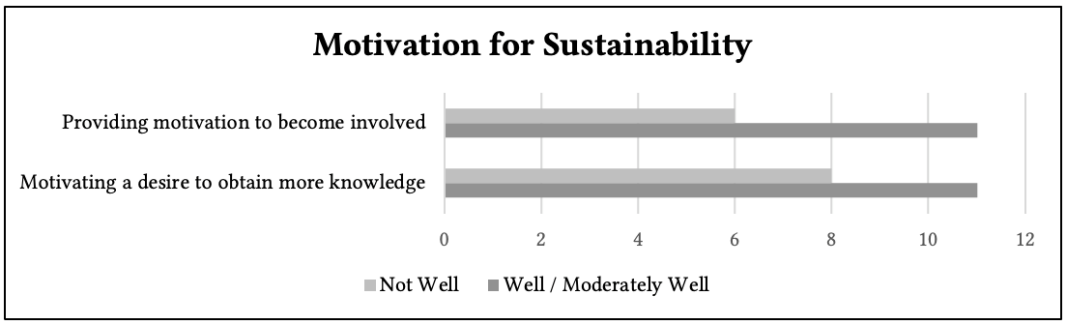

Fig. 6. Questionnaire data showing participant perception of the garden's use of CMC as a source of motivation relating to sustainability.

Finally, we asked the participants for their perspectives on how well the garden uses CMC tools to discourage non-sustainable actions and help communities develop sustainable activities (Fig. 7). Regarding discouraging non-sustainable actions, 67 per cent responded that this was not a feature that the Botanic Garden did well with 42 per cent of participants responding “not well” when focusing on helping communities to develop sustainable practices. The evidence suggests there is a need for some improvement to drive pro-sustainable activities.

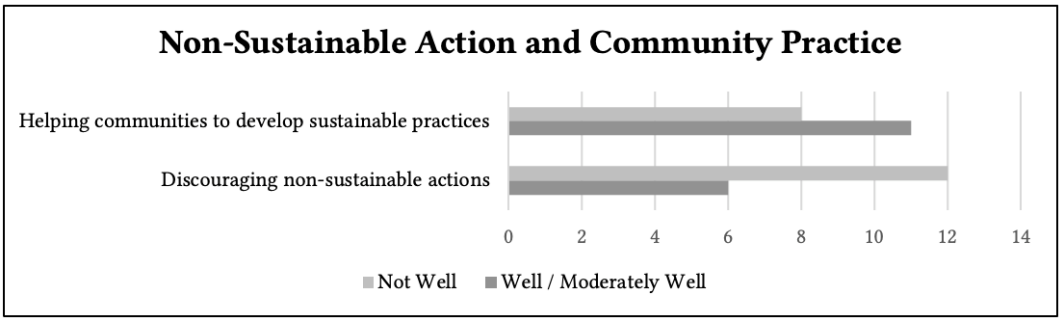

Fig. 7. Questionnaire data showing participant perceptions concerning sustainable and non-sustainable actions.

DISCUSSION

Within the context of a botanic garden underpinned by social leadership (SL), this mixed methods study set out to learn more about how SL offered us a model that illuminated insights into the extent and how a botanic garden uses CMC to lead education for ESD. Education is a catalyst for change toward building a more sustainable future (UNESCO, 2017; Blessinger *et al.*, 2018), and as we have

highlighted, educating others on sustainability is a fundamental role of botanic gardens (Romano, 2008). Although our findings have drawn primarily from the questionnaire data with the paid and voluntary staff as the sample, the target audience of the general public should be kept in mind when considering the outcomes and enhancing ESD for the end-user. Our findings align with Albarenda-Tiana *et al. (2018)* and Bolmsten and Kitada (2020) concerning the importance of ESD, alongside the desire of users to learn more. To enable this across various contexts, using CMC is an approach that can help ESD beyond physical boundaries.

The curation, co-creation, and dissemination of information through CMC tools can engage large communities and encourage action by educating individuals, groups, and organisations on sustainability understanding and practices that might otherwise have remained closed to them. The aim of SNS usage should be to deliver and engage end-users in evidence-based information streams (Simionescu *et al*., 2020). Whilst our data shows the importance of the botanic garden using CMC (specifically social media and web pages), the content associated with ESD requires some strengthening, particularly in increasing user knowledge. Limited use and engagement were also evident depending on the platform used. For example, participants appeared to connect primarily through Facebook and Twitter; LinkedIn was also mentioned. In short, to stimulate the garden's visibility on their commitment to ESD and "strengthen social influences" on sustainability, well-crafted and engaging postings on complementary CMC tools that are "tailored to the populations" require careful consideration (Ballew *et al*., 2015: 10638). However, whilst staff technological know-how and subject knowledge must be considered (Le *et al*., 2022), our findings demonstrated barriers beyond these, such as human and financial resources, alongside the broader organisational constraints.

An additional finding surrounds the financial and digital tensions that manifested through the budgetary limitations and the perception that CMC platforms of the larger organisation must be used if ESD to a larger audience is to be enhanced through such mediums. These conditions require creative problem-solving, innovative solutions, and opportunistic activities through intrapreneurial approaches. Yashin-Shaw (2018: 1) defines an intrapreneur as "the act of thinking and behaving like an entrepreneur while working within a large organisation" and includes characteristics such as creativity, collaboration, determination, growth-oriented, opportunistic, resourceful, and trend spotters. Cultivating intrapreneurial thinking and action will enable innovative improvements despite organisational constraints (Martiarena, 2013) and allow the botanic garden to be a knowledge-sharing organisation further afield, i.e., beyond the physical boundary of the garden walls.

The critical strands of community, communication, and digital technology of SL have provided us with a valuable lens to underpin this research. Through curation and sharing a narrative to build a reputation, SL drives change by engaging and connecting diverse individuals and communities (Stodd, 2016; Saunderson, 2018). To navigate this change, energy and commitment are required to achieve the common purpose (Guglielmo and Palsule, 2014). Whilst we are not questioning the energy and dedication of the garden's team in a general sense, the data indicates the limitedness of these features when associated with ESD through CMC. Therefore, returning to Stodd's (2016: 33) statement, "without the technology, you can't be a Social Leader", our data suggests that this requires some extension. To be influential leaders in the social age, working to increase community-centred sustainability ventures and sharing clear and consistent narratives through digital technologies are essential. The botanic garden has an opportunity to use SNS and their web pages effectively to portray the approach adopted by the garden regarding sustainability management to enhance ESD.

CONCLUSION

ESD is essential for addressing global sustainability challenges. CMC offers non-formal educational spaces that enable individuals and communities to act in ways without compromising the needs of future generations. Organisations must actively and consistently facilitate knowledge exchange to make good use of digital technology and add value to these spaces.

The context of this case study was a botanic garden situated within a larger organisation—a university; this containing factor appeared to reduce the garden's opportunities to make the most of CMC to become leaders in ESD. Yet, if large organisations are serious about sustainability, the operational constraints of subunits, such as the botanic garden, need to be addressed, allowing for greater autonomy. Increased autonomy would amplify knowledge and idea propagation and enhance action across diverse networks not predesigned or imposed by organisational structures. Further exploration of sustainability education through CMC could be usefully explored across independent botanic gardens (i.e., not constrained by the practices of a larger organisation) to further understand their role in leading ESD and the subsequent impact of this, alongside obtaining the views of younger audiences.

Overall, the extent and methods by which the botanic garden uses CMC paint a blurry picture because of the limited SNS activity. Whilst the participants viewed some aspects of the garden's use of CMC positively, they also offered recommendations to strengthen weaker areas. We can draw from the data that there is a will and desire for the team to increase usage, enhance community engagement, and disseminate information. Overall, this study makes two contributions to

knowledge. First, it highlights CMC as a potentially valuable tool for the botanic garden to communicate, engage and educate about environmental ESD beyond the garden walls. Second, we show that there is a will and desire for the botanic garden to utilise such educational mechanisms. The limitations of this study's scale— such as drawing from voluntary and paid staff and the lack of younger participants mean we cannot draw broader inferences. However, our participants offer a valuable lens to draw from as they may have a greater insight into the inner workings of the garden and can comment on areas which end-users may not be aware of, for example, financial constraints. Although we have not set out to statistically test nor prove a phenomenon, we have highlighted meaningful conclusions about the perceptions of ESD and user experiences of CMC to expand knowledge and drive sustainability activity.

Recommendations for further research:

- While this study has focused on a single botanic garden from the viewpoints of both paid and volunteer staff, future research should encompass end-users' perspectives while broadening the sample to include a more extensive range of botanic gardens and their respective audiences.

Recommendations for practice

- Identify opportunities for adapting organisational templates to declutter the digital spaces and reorganise them to suit the needs of the garden's community. For example, establish a formal social media presence to share sustainability knowledge and updates. Also, to promote local projects and ways to enhance individual sustainability practices. Ideally, the garden would self-manage the spaces rather than being controlled by the larger organisation.
- Use SL as a lens to drive ESD forward by establishing a reputation through digital technology and creating a straightforward narrative with the community at its heart.
- Increase the connection with academia by working with and sharing insights from academics across the region and inviting scholars to share research via the garden's CMC tools.
- Remain consistent with the monthly newsletters, but perhaps take the format of a blog-style approach; obtaining contributions from guest authors and curators would also benefit.
- Whilst a botanic garden could hire a marketeer, this would be costly. Although financial, personnel, and organisational constraints are evident in our findings, these are not unusual, and the team should adopt intrapreneurial spirits to identify ways to overcome some of these problems. For example, drawing from volunteers or students (perhaps offering

internships or placement opportunities) to help build and deliver a programme of thematic postings and operationalise the garden's ESD vision.

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