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Experiential and authentic learning in a Living Lab: the role of a campus-based Living Lab as a teaching and learning environment

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Abstract

Living Labs provide stakeholders with authentic and spontaneous environments in which innovations and technologies can be developed. This paper highlights the use of Living Labs as an educational teaching and learning environment. We give four current examples of practice and present a conceptual framework for pedagogic design and development of experiential learning activities and assessment in a Living Lab environment. Examples are based around current higher education undergraduate and postgraduate taught assessments and activities. We highlight how Living Labs, particularly campus-based examples, are an excellent opportunity for education providers to provide realistic experiences for students that promote empowerment, inclusivity and sustainability where activities and results can be spontaneous. Learning in a Living Lab environment provides the opportunities for students to develop applied skills, work in a transdisciplinary manner and co-create and collaborate on data sets. These activities are associated with potential increases in student attainment and receive positive student feedback. Living Labs introduce opportunities for interdisciplinarity, transdisciplinarity and cross-cultural working and provide an excellent base for education for sustainability.

Keywords: Living Lab; authentic assessment; active learning; experiential learning.

Introduction

Living Labs are a reasonably recent concept first coined in the 2000s (Markopoulos and Rauterberg, 2000) and are traditionally set up and used as research environments. There are multiple definitions used in the literature, typically corresponding to the definition given by Hossain et al. (2019) who state that "a living lab is a physical or virtual space in which to solve societal challenges, especially for urban areas, by bringing together various stakeholders for collaboration and collective ideation". Because Living Labs are a recent concept, examples of deviation from a research focus are rare. Some examples of the educational value of Living Labs have been explored (Callaghan and Herselman, 2015; Mazutti et al., 2020).

Learning environments are linked to the behaviours of those within them, including the way we communicate and engage (Leander et al., 2010). The spaces used for the presented case studies are examples of learning environments outside of the traditional classroom (Leander et al., 2010; Healy et al., 2015; Psaros, 2022). Our experience of teaching within a Living Lab environment suggests that students tend to be engaged, inquisitive and more receptive to using mistakes as a learning opportunity than when in a “traditional” classroom setting. Abegglen et al. (2019) introduce the idea of teaching in the “third space”, a place in the curriculum where things start to fall into place for learners, and where learners might even re-evaluate their academic goals – many of the aspects reported here resonate with this concept. Learners in the Living Lab experience empowering, spontaneous and authentic activities.

This case study comes from Keele University, a campus-based institution situated within the Midlands of the UK. We outline several higher education teaching, learning and assessment activities from a range of disciplines, which use the Universities' 2.5 km^2 rural campus as a multifaceted Living Laboratory. Many activities students currently undertake are part of research and/or industry projects or are parts of campus deliberately developed as a learning environment. Keele University campus is host to academic, residential and commercial holdings; it has forests, fields, lakes, roads and sports facilities. The campus is also home to a renewable energy site that can produce up to 50% of the campus electricity demand. In short, it is a perfect analogue for a small town, with approximately 17,000 people in residence during semester. The campus therefore provides opportunities for a variety of educational experiences. Wider research activities are also included here for education, and indeed, they are one of the most accessible learning environments on campus. These educational activities rely upon elements from the Living Lab which would be present if they were part of a learning environment or not; this includes subject-specific research, industrial partnerships and research, plus campus estates or buildings with particular purposes.

The campus Living Lab can provide an accessible location for learning and its use is potentially a more sustainable alternative to many other field-based teaching environments. It is hoped that the reporting of these activities and their framing within pedagogic theory might encourage others to experiment further with their Living Labs as educational assets. The environmental (potential lower CO_2 footprint) and monetary benefits of campus-based Living Labs for educational activities may also be attractive for other higher education institutions (HEIs), and could play an important role in programmes in terms of their economic efficiency and responsible environmental footprints.

This paper represents the thoughts, experiences and reflections of the authors who have designed, developed and ran various activities and assessments within a Living Lab setting, across a range of disciplines. It is through reflective practice that we have established the presented framework.

Living Labs background

A Living Lab allows innovations to be experienced and studied in an environment where people, the environment, services, ideas and actions are manifesting in a natural and organic manner. Activities occur in real time (Hossain et al., 2019), with experiments and studies exposed to multiple variables that would be impossible to simulate in a traditional laboratory setting. Multiple stakeholders are involved, and the dynamics of the research environment allow research to be influenced by users in order to create new ways of working and/or deploying the technologies, concepts or ideas they are testing. Bergvall-Kåreborn et al. (2009b, pg.1) summarise the Living Lab as "...an environment in which people and technology are gathered and in which the everyday context and user needs stimulate and challenge both research and development, since authorities and citizens take active part in the innovation process".

A Living Lab is essentially a partnership built between stakeholders, often public-private relationships (Bergvall-Kåreborn et al., 2009a), where companies, organisations, authorities, public-groups and the general public can work together to create an environment in which new concepts, services, technologies or policy can be tested and developed. A precondition is that it is situated in a real-world context (Bergvall-Kåreborn et al., 2009a). From this shared real-world, details of the innovation under scrutiny can be assessed, but, unlike a sterile or controlled lab environment, the results often transcend discipline boundaries and can be spontaneous and unexpected. Innovations can be tested for business case validity at the same time as function efficiency or social impact. This system means that the general public, and real-word infrastructure, play an active role in developing the innovative process. Living Labs have been viewed as different things by different authors; this is unsurprising when each Living Lab is likely to be constructed from different perspectives with contrasting stakeholders, innovations and intentions. This makes a Living Lab a hard to define concept, although there is an emerging consensus as discussed by Hossain et al. (2019). Living Labs have been virtualized or used as a type of environment (Ballon et al., 2005; Schaffers et al*.,* 2007), a methodology (Niitamo et al*.,* 2006) and as a system for enabling research (Bergvall-Kåreborn and Ståhlbröst, 2009). Liedtke et al., (2012) propose several research areas for the development of sustainable technology innovations within a Living Lab. Several studies have looked at collecting the various methods and approaches (Mulder et al., 2007) or at producing concept designs for Living Lab implementation (Bergvall-Kåreborn et al., 2009a). CoreLab (2007) suggest five principles in relation to Living Lab methodologies: (1) Continuity, (2) Openness, (3) Realism, (4) Empowerment of users and, (5) Spontaneity.

Because of the holistic nature of Living Labs, sustainability issues and “Grand Challenges” have increasingly become the focus of University based Living Labs (König and Evans, 2013; Robinson et al., 2013; Trencher et al., 2013; Evans et al., 2015). These sustainability approaches are designed to make use of the cross-disciplinary nature of institutes and often work with university estates, procurement or external consultants to provide projects within the Living Lab setting (Evans et al., 2015).

Living Labs as a Learning Environment

The Living Lab environment has a proven track record of producing valuable user-centric and technological/product information, see the European Network of Living Labs (EnoLL, 2020) for some examples. At Keele, this has attracted large amounts of funding, particularly related to our goal of becoming carbon neutral by 2030. The Smart Energy Network Demonstrator (SEND) links and monitors real-time energy use on campus (Fan et al, 2022); the on-campus Low Carbon Energy Generation Park (LCEG), created in partnership with Engie (now Equans), developed 12,500 solar panels, two wind turbines and a battery storage facility (Isaac, 2019; Fogwill et al., 2020; Fan et al., 2022); and the on-campus HyDeploy Project (Wakefield and Kassem, 2020) was the first ever demonstration of hydrogen as a fuel source in residential homes, with the infrastructure now providing the potential future opportunity to generate green hydrogen on site. All of this, in addition to the environmental aspects of campus, provides the ideal opportunity for research-led teaching right on our doorstep, linking the low-carbon agenda to wider interdisciplinary studies in social science, ecology and geosciences.

The user-centric, collaborative, authentic aspects of Living Labs share many similarities with the pedagogic concepts of active learning (Prince, 2004; Settles, 2011; Freeman et al., 2014) and authentic assessment (Wiggins, 1998; Hart, 1994; Darling-Hammond and

Snyder, 2000; Gulikers et al., 2004). The benefits of students undertaking authentic assessment, such as that provided by an extensive campus environment, and interacting with real world examples and data, is well documented and closely linked to enhanced student engagement and employability (Bosco and Ferns, 2014; Senior et al., 2014). Cumming and Maxwell (1999) suggest four key elements to authentic assessment:

- performance and performance assessment.
- situated learning and situated assessment.
- complexity of expertise and problem-based assessment.
- competence and competence-based assessments.

The Living Lab provides an environment where these elements can all be met whilst the social-, economic-, product- or concept-based focus of the experiment/test is not compromised by the participation or actions of the students. Indeed, the students can provide an additional stakeholder group or co-operate with a present stakeholder group (by collecting data, for example). Furthermore, an additional benefit which can be part of Living Lab-based education is how activities can expose students to thinking, processes and skills that they may not normally be exposed to within a discipline-specific, traditional curriculum, allowing them to make connections across different parts of the curriculum and the spaces they learn in (Cousin, 2010). The Living Lab not only allows interdisciplinary working (such as geoscience, ecology and social science tangibly integrated) but lends itself moreover to effective transdisciplinary working, in that knowledge and understanding are produced in contexts of application (for a discussion of the various understandings of disciplinary prefixes such as multi-, inter- and trans- see Osborne, 2015).

Tackling complex authentic problems requires a specific approach to teaching, learning and assessment. Practical problem-solving skills, which include collaboration, team-based, active and experiential learning, are key to encouraging deeper learning required in order to develop the skills and competencies necessary to solve the problem (Kek and Huijser, 2011; Espey, 2018). A deep learning approach fosters the ability for students to build on previous knowledge, to draw on experience, to bring together disparate information and organise into a coherent whole, to identify relationships, to form hypotheses and ultimately enhance conceptual understanding (Biggs, 1996; Ramsden, 1992). Aligning assessment and teaching methods through the construction of related learning objectives (Biggs, 1996) allows for critical thinking skills to be embedded throughout teaching. Studies by Brodie (2009) and Yuan et. al., (2008) conclude that higher level critical thinking skills are found in students who have experienced problem-based learning environments.

Examples given here of student activities at Keele University Living Lab are building on existing components or activities and highlight the breadth of opportunity for education. The benefits of staff and students participating in a Living Lab setting include insightful feedback to processes and products; a level of expectation for procedures and experiences to be authentic; fresh perspectives and outlooks on projects each year; and the potential for certain stakeholders to influence, educate or expose potential future consumers or employees. Campus activities also test new methodologies to be approved or for research to be conducted – activities benefit from students and staff as stakeholders in the same way that any partner company might do. Each case study outlines activity undertaken, logistics involved, processes used, and how the activity sits within a Living Lab.

Living Labs as a Learning Environment Framework

When designing activities within a Living Lab it is apparent that each activity (with completely different learning outcomes, skills and methods, assessed or not) shared several aspects that made them different to other outdoor sessions; namely, the purpose and interaction of the Living Lab itself. The design framework we present/used is divided into six strands (see Table 1). The first four are provided to ensure teaching and learning activities within a Living Lab environment are fully considered, practical and beneficial to students. The fifth outlines the importance of embedding Living Lab learning activities into the wider curriculum and providing students with proper preparation and support in the learning activities they will be undertaking, with the sixth showing some technical challenges and benefits gained.

Table 1. The general framework used to develop learning activities within the Living Lab.

Living Labs as a Learning Environment concepts	**Contribution to the student experience and the learning environment**
Guiding Strategy	What is the purpose of the Living Lab which is to be used as the basis for this activity? Does the activity compromise this? Most importantly, are the pedagogical benefits of learning in a Living Lab setting being considered? Pedagogical innovations must be included as an educational innovation, and not as an innovative tool for the sake of using that tool. Assessments in Living Labs should provide authentic experiences which allow for spontaneity and openness in purpose and resulting information gathered.
Interactions	What are the teachers and students going to do? Who or what will they be interacting with and is this a passive process or an active process? Do you need permission for the work to be undertaken or are there ethical considerations to be made? Health and safety of the activities must be considered, for the participants but also other stakeholders and the environments they are working in.
Experiences	What activities will the students undertake and what are the links between the activities and the intended learning outcome? Are there logistical considerations with equipment or with getting to the intended area of work? The skills, competence and aptitude of the student cohort need aligning with the activity, prerequisites and prior learning should be mapped to the proposed activity.

Processes	How will students gather data? Who owns these data and what will be done with the data once the students have used it? Are the students going to feedback into the Living Lab exercise or passively interact, gaining skills and experiences but not becoming active stakeholders?
Embedding Living Labs within the curriculum and providing support for learning activities	Very few educational activities work in isolation. Most are best suited to a blended approach where a mixed modality of teaching delivery is provided. This might include asynchronous or synchronous delivery of materials in a variety of environments (both in-situ and digitally). Nearly all authentic activities will require some form of preparation, including training with equipment, contextualisation of the activity (including the consideration for and development of virtual/digital materials), introduction of key concepts and theory, and provision of fundamental health and safety information, all of which provides a foundation upon which learners can build.

Case studies

The case studies explored below are all in-curricula and associated with assessment. Table 2 provides an outline of the relationship between case studies and the activities' wider placement within the Living Lab at Keele University. The relationship between case studies and the Living Lab Principles are referenced throughout the case study descriptions: LLP1 = Continuity; LLP2 = Openness; LLP3 Realism; LLP4 = Empowerment; LLP5 = Spontaneity.

Table 2. A list of the 4 case studies in this study, with respective assessment status indicated. Each case study is also placed into the context of the wider campus and Living Lab.

Case Study	Assessed?	Wider relationship with the Keele Living Lab
1: Environmental Baseline Study	Yes	Continued monitoring of environmental change on campus, including ecological and biodiversity resulting from the installation of a renewable energy park (solar panel arrays and wind turbines).
2: Simulated Crime Scene Investigation	Yes	Development of non-invasive crime scene investigation methods through time, working with police forces and informing national protocols.
3: Greening Business: employability and sustainability	Yes	Various activities, sustainability policy and processes across campus. Student work has led to/informed changing practice and policy.
4. Covid-19 Fieldwork and development of new on-campus field-courses	Yes	Fieldwork activities investigating the glacial history of the campus and monitoring of environmental factors. The renewable energy site provides a unique field site in which to study micro-climates and their effects on above- and below-ground biodiversity.

Case study 1: Environmental Baseline Survey

An Environmental Baseline Survey (EBS) Module was created in 2006 and aimed to increase employability, field and research skills of L5 (second year, undergraduate degree) FHEQ Level (UK Government, 2020) students. The module was developed in collaboration with MJCA Environmental Consultancy, to ensure students gained key skills required for graduate jobs (LLP3) in the environmental and geoscience sector (Robinson and Digges la Touche, 2007). The module uses the Keele University campus as a Living

Lab to undertake student-led, experiential, active learning and to provide an authentic experience of collecting, analysing and presenting data (LLP3, LLP4, LLP5). The module also builds upon existing skills developed during L4 (first year, undergraduate degree) (LLP2).

Working in groups, students are set the brief that they are acting as Environmental Consultants and must undertake an EBS on soils, habitats and hydrology surrounding Keele lakes on campus (LLP3). Every week for 8 weeks the students spend 3 hours collecting and analysing specific data to write up as an industry standard EBS report (LLP1). Each class begins with a short briefing session, outlining aims and objectives of the activity and some background information, for example, risk assessments, maps and methodologies. Students then go into the Living Lab to watch a demonstration of techniques and equipment. Teaching staff also spend time asking questions to students to get them to think critically about how best to sample, to realise study limitations and think about the number of samples to be representative. By revisiting and building on existing knowledge in introductory sessions, promoting discussion and reflection in the field and having emphasis on active learning, the sessions foster deep, reflective learning in an authentic environment (LLP4) (Bloom and Krathwohl, 1956; Ryan and Deci 2000; Light and Cox 2001; Russell et al*.* 2004).

Students gain experience of a range of techniques, including water chemistry sampling and analysis, groundwater discharge readings using dilution gauging, soil sediment analysis, and surveying techniques to produce geomorphological maps. The students also make use of the Keele Meteorological station that is part of the UK's weather station network, which collects data hourly, to make interpretations of water chemistry, discharge, groundwater and soil data (LLP4). Students also compare results to data collated over the last 4 years by past students to analyse trends (LLP1, LLP2). Using the extensive woodland and grassland environment, skills in habitat survey methods are also included. This follows the Joint Nature Conservancy Council (2010) Phase 1 Habitat classification system, currently a key component of Environmental Impact Assessments within the UK planning system (Joint Nature Conservancy Council, 2010). Students also reflect on what impact Keele's Low Carbon Energy Generation Park will have on site soils, hydrology and biodiversity they are studying (LLP1, LLP4). The Living Lab provides an opportunity to collect ecological data within the framework of an environmental baseline assessment, providing an authentic understanding of the role that ecological data can play in protecting biodiverse sites within the planning system.

The EBS is assessed through a group-led, industry standard, Environmental Baseline Report and must collate, present and analyse all groups' data to produce a professional report, in order to replicate likely requirements of working as an environmental consultant, geoscientist, or in any analytical career.

Figure 1. Elements of Keele University campus used as part of the Living Lab where students collect samples and data as part of an Environmental Baseline Survey: images of river sampling (left), soil sampling (top right) and Keele lake sampling (bottom right).

Case study 2: Simulated Crime Scene Investigations

Created on campus in 2008, in collaboration between academics and the Keele University Estates team, a simulated multiple-buried victim crime scene was created within a secure area, with ethical approval given by the University and by the Department for Environment, Food and Rural Affairs, UK (DEFRA).

For geophysics-based L5 or L6 undergraduate modules, outdoor practical classes involve a student group-led, problem-based scenario, with each group taking on the role of a ground forensic search team (LLP3). Groups are tasked with non-intrusively investigating a specified search area to locate, and characterise if possible, simulated clandestine burials of murder victim(s) (Figure. 2), for a hypothetical intrusive investigation team to confirm the presence/absence of victims at locations specified by the students (LLP5). This style of problem-based, active, outdoor practical learning has been proven to accelerate learning and understanding and greatly enhance students' employability skills (see Murphy and Pringle, 2007; Pringle et al., 2010). The forensic search angle has also proven useful to enthuse and keep students engaged on the task at hand.

Students are provided the opportunity to design a robust forensic search strategy by choosing their own search methods/equipment based on the theory they have covered (LLP2, LLP4). Each group then collect the multi-disciplinary site data in a time-limited period on the campus site, before subsequently processing and integrating datasets back in the lab, to produce a technical group report with recommendations on which area(s) to intrusively investigate, as would be the case when doing this in a real-world context. Supervisors have direct experience of this and are on hand to discuss and solve any problems as they come up, but it is emphasised that this is a student exercise and so they are free to make (and hopefully correct) their own mistakes (LLP5). Many of these graduates go on to related commercial careers using the skills learnt here, especially within the geotechnical and applied geophysics site investigation industry. Student marks for this formative assessment averaged +7% for L5 Geoscience BSc undergraduates and +5% for L6 Forensic Science BSc undergraduates above their respective module averages.

Student evaluations at the end of the module also rated the outdoor Living Lab sessions consistently higher than both the module content and assessments. Evaluation quotes were almost universally positive, including one L5 student in the 2020-2021 cohort saying that “practicals allowed independent thought and organisation” and “practical session interesting and fun to carry out” as well as “I was glad we were able to do the outdoor practical, it was fun and useful”. Another L5 student wrote “the practical element of the forensics part of this module was really good and helped me to understand the equipment we were using in order to write a better report”. There were some negative comments including “would have liked a practice field exercise before the assessed one”, which has been partly mitigated as a virtual Living Lab practical has been generated to give students a pre-practical familiarisation with requirements, the study area and equipment.

Figure 2. Keele University undergraduate students collecting near-surface geophysical data over the simulated crime scene site on campus. Students conduct the activity using the same methodologies and equipment (including clothing, as seen in the image) that a geoforensics search team would use in active search.

The site has also been used for over 10 years as a collaborative research environment between students and staff (LLP1). This has been included as formative assessment, as part of their under- or post-graduate courses, as research projects, or indeed as non-credit bearing collaborative research projects. Student project-led examples that have been published in international-journals include: (1) determining if magnetic surveys could detect buried victims (Juerges et al. 2010), (2) looking at seasonal factors affecting forensic geophysics surveys (Jervis and Pringle, 2014), (3) analysing soil water from such graves (Dick and Pringle, 2018) and (4) the long-term geophysical monitoring of the site (Pringle et al. 2016, 2020). Research outcomes have directly led into refining UK and international Police search strategies, allowing them to compare live missing person and unsolved cold case data to controlled data (e.g. Pringle and Jervis, 2010) and even test their search strategies (LLP1, LLP2, LLP3, LLP4, LLP5).

Case study 3: Greening Business: employability and sustainability

Since 2008, Keele University has run ‘Greening Business: employability and sustainability’ as a flipped-classroom module for L4 students (Robinson, 2009). With a strong emphasis on fostering skills required to drive forward positive environmental change within their future workplace (LLP3, LLP4), the module has a core transformative agenda which allows students to consider their own perspectives, attitudes and values in the context of their relationship with the business world. As the sustainability agenda continues to gather pace internationally, especially with regards to climate change and net zero carbon targets, the role that businesses and large organisations play in helping to achieve global Sustainable Development Goals (United Nations, 2015) becomes ever more important to address. Equipping students with the skills and understanding to engage successfully with complex, multi-disciplinary, real-world sustainability problems is a key aim of this module and this provides a genuine and fundamental link to the Living Lab learning environment at Keele University.

All of us act as stakeholders within the business world, whether we are aware of it or not, and this ‘stakeholder lens’ becomes a powerful tool for encouraging students to explore the barriers and opportunities for improved sustainability performance within this sector (LLP3).

Students design, develop and conduct a sustainability project on campus (this can cover environmental, societal, or economic aspects of any area of operations, from catering, infrastructure, wellbeing, transport, etc.). They then present their project to a panel of relevant stakeholders in video format, followed by a question-and-answer session (LLP2, LLP4). Past findings have been used to develop initiatives on campus, illustrating this is an authentic form of assessment and that the University is genuinely interested in findings. The projects are set within a loose structure within which students are responsible for: organising group roles and drawing up action plans; identifying and interviewing professionals who can assist them with their enquiries (e.g. environmental manager, estates or catering staff); gathering baseline data about the issue they are investigating (all of which are situated around activities that happen normally as part of campus operations); and linking issues to existing, over-arching corporate strategies, relatable targets or visionary statements. They also develop a storyboard, film and edit relevant footage, develop the narrative, and present findings to the assessment panel.

The purpose of running educational projects within a Living Lab is to create the atmosphere for collaborative learning where learners co-construct their own knowledge, ultimately generating new sustainability knowledge. Other skills are also evident, including team-working, critical thinking, negotiation, listening, communication, presentation skills, awareness of ethical and value-based motives, a wider understanding of global citizenship, and reflection. This module provides the ideal opportunity for students to work within an interdisciplinary environment, which encourages discussion from different perspectives and places of understanding, modelling the real-world environment that they may find themselves working (described as the principle of Empowerment of Users by CoreLab, 2007).

Case study 4: Covid19 fieldwork and development of new on-campus field-courses

The emergence of the Covid-19 pandemic during the 2020/2021 academic year forced a rethink concerning possible locations which undergraduate field-courses could be safely delivered and the manner in which outdoor activities could be conducted (e.g. Leonard et al., 2022). The campus provided multiple opportunities to investigate geographical and environmental topics (LLP3), reducing the need for travel and providing alternatives to residential fieldtrips which could not be undertaken at that time. Home to two different lake systems, small rivers, different blocks of woodland and acres of grassland, the campus itself became the fieldtrip host (LLP1, LLP3, LLP4).

Climate change is a core teaching and learning theme within our teaching, and the University campus provided the opportunity to explore past environmental change linked to previous glacial events (Figure. 3), as well as contemporary issues such as forms of renewable energy generation. Situated on the geographical edge of the last glacial maximum of the British Irish Ice Sheet, the campus provided students with the opportunity to explore glacial geomorphology and sedimentology first-hand using a mixture of Geographic Information System (GIS) mapping techniques and inland field sections (LLP3, LLP5). Clast shape and roundness counts were used to investigate the transport pathways of the stones found in the field. The presence of a new on-campus renewable energy installation had revealed numerous glacial erratic clasts within superficial sediments, and were used as a known dataset with which to compare those found across the rest of the campus. Students had visited the renewable energy construction site when trenches were exposed for archaeological investigations, but this fieldtrip provided an opportunity to revisit it during installation of the solar panels themselves – a fitting link to the modern element of the climate change theme (LLP1, LLP2, LLP3). The campus was also used to explore wider implicit and explicit sustainability messaging (Djordjevic and Cotton, 2011), using self-guided materials to identify and classify different messages seen on site, including the role that the 'hidden curriculum' plays on campus (Orr, 1993).

Figure 3: Keele University students investigating glacial sediments as part of an on-campus fieldtrip during the Covid-19 pandemic.

During the height of the pandemic, the School of Life Sciences delivered a 5-day on-campus field-course for L4 and L5 Biology students which covered a range of skills. This included pollinator, grassland and freshwater surveys, small mammal trapping (with appropriate licenses and ethical approval in place) and species identification. The renewables provided the ideal location to investigate microclimates, with floral surveys forming the core activity in this location. As a result of this Covid-19 rethink, an annual grassland survey of the renewables site has been built into the core curriculum programme for L5 biology students and a hybrid on-campus/off-campus field-course is likely in the future, making the most of the ecological diversity provided on campus (LLP1).

Other examples of activities conducted within the campus based living lab include (and are certainly not limited to): teaching students how to operate and fly drones; surveying techniques, studying pollinating insects and small mammals and assessing energy ratings of buildings on campus.

Discussion: Living Labs as a learning environment concept design

The concept design for Living Labs as a Learning Environment activity ultimately relies on two factors: 1) activities, projects and infrastructure available to the educational developer, and 2) an intended learning outcome of the proposed task. Other elements to consider include logistics, costs (if any), ethical implications of using the Living Lab as a learning environment, and safety issues. The broad design of a Living Lab as learning environments activity needs to cover interactions, experiences, processes and a guiding strategy. These activities can be planned much like other assessments (see Wiggins, 1998), where student well-being, preparedness and learning outcomes are understood and acted upon.

The broad conceptual framework we designed and used (Table 1) was made to ensure that the learning activities benefitted both the educational aims of the activity as well as the Living Lab itself. The case studies provided show how the framework ensures that the Living Lab principles are embraced, and in a manner that benefits learners (and teachers). The case studies we present here indicate the breadth of the types of activities that could be conducted in such a learning environment. We recognise that there will be activities not suitable to certain Living Labs. The case studies are generally focused on the authentic use of a certain piece of equipment in order to give students experience of techniques and a sense of autonomy and ownership over their own learning. Students commonly comment on how much they enjoy using the equipment/running experiments themselves and alumni often emphasise how useful such activities were for them as they transitioned into the work environment. Some of the best sessions we have run in the Living Lab are those which have gone a little wrong – either a piece of equipment not working, conditions (i.e. weather) changing for the worst, or where data generated has been completely unexpected – these situations lead to excellent moments of staff-student collaboration. As staff using the Living Lab we feel that this mode of learning leads to much greater engagement with the topic/content being developed; each session can be different and there are many learning moments for us too. These activities have also led to staff-student collaboration on academic publications and changes to policy and practice by various stakeholders across the Living Lab, which ultimately highlights the various benefits of this type of learning environment, the authentic experiences, empowerment and ownership, and spontaneity in particular. Our students' work has ultimately changed procurement processes, driven biodiversity campaigns, contributed to academic/applied methods and knowledge development and provided an additional (and engaged) stakeholder group to our campus based Living Lab.

In case study 2 (simulated crime scene investigations) we included a comparison between student attainment in this module against other modules they study at the time. Whilst we do not suggest this is conclusive evidence that authentic activities and assessments in a campus based setting result in better student attainment, we suggest that, along with other student and staff feedback, it makes for a convincing argument that these activities are beneficial to students. From the other case studies presented it is more difficult to suggest if attainment is better, as these are all part of modules that contain other components. However, from these we can certainly say that the actions completed by students have led to realistic experiences, a sense of ownership and achievement (particularly for students where their work has resulted in university policy/practice change or further dissemination of their work) and the improvement of students' abilities to solve complex problems.

Using Living Labs does increase the time and effort required in the planning and set up of higher education teaching, learning activities and assessments. New learning environments and their safety issues must be considered and student participation carefully considered including such questions as: are the students suitable stakeholders? Does their participation change any processes or ethical considerations of the Living Lab experiment? The concept design we used (see Table 1) provides a structured foundation which ensures high-quality assessment and/or activity planning within a Living Lab environment. Such frameworks provide useful guides for development whilst highlighting technical, logistical and practical considerations of what might be achievable and appropriate.

A Living Lab on campus may go some way to address inclusivity and diversity issues within applied environmental, geography and geoscience courses that have been highlighted recently (e.g. Gilley et al., 2015; Chiarella and Vurro, 2020; Giles et al., 2020 Dowey et al., 2021). Offering authentic and meaningful alternatives to fieldwork could reduce prohibitive residential course costs where HEIs charge their students, and requirements for robust and expensive student field gear and equipment. If students and/or staff do not enjoy or are unable to attend long periods away from their university or home base or have family or care obligations etc., a campus Living Lab ensures students do not get inferior ‘paper based’ learning, that is often literature review or essay style alternatives, and can participate in authentic experiential activities.

Conclusion

Living Labs and campus-based activities can be used to provide authentic learning and teaching experiences for higher education students. The outdoor and/or out of the traditional classroom environment is excellent for getting students to use field equipment and allowing them to work in an environment where spontaneity and the opportunity for things to go wrong, or not as planned, as well as solving these issues, is showcased as a very important learning experience. Learning within Living Labs gives students interdisciplinary experiences and allows application of information disseminated by other teaching and learning methods within the curriculum. Activities should be framed by: 1) a Guiding Strategy of *why* a Living Lab is appropriate; 2) clearly outlined interactions (with people or things) including health and safety consideration; 3) a clear idea of the experiences, intended learning outcomes and activities to be undertaken; 4) an idea of processes such as how student derived data will be collected and if it will be used in the Living Lab; and 5) a clear scaffold of supporting material preparing students for activities within the Living Lab. Making use of campus environments also helps to ensure course intended learning outcomes are met, whilst potentially reducing carbon footprints. These activities may be more inclusive for students either not wishing, or unable, to attend residential field-courses. Living Lab activities also result in student-led innovations implemented across the place of study, heightening student empowerment and including students as stakeholders of the environment in which they learn.

Author contribution

The drawing together of the co-authors experience and teaching activities into a framework and corresponding manuscript was conceived by Steven L Rogers. All authors have contributed to case studies herewith and have all contributed to the drafting of the manuscript.

The authors declare that they have no conflict of interest.

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