RESEARCH ARTICLE:

Undergraduate Inquiry-Based Research to Promote Sustainable Development Goal 11 (Sustainable Cities and Communities)

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Abstract

The global sustainability agenda provides the opportunity for higher education institutions to mainstream the Sustainable Development Goals into their programmes to contribute towards achieving these goals. Using an inquiry-based research approach, underpinned by constructivism, this study aimed to determine how research concepts and research skills can be integrated effectively into a first-year module through inquiry-based learning. First-year students at a South African university were assigned research tasks to analyse journal articles and compile a summative project based on observations in urban ecosystems. Using a mixed-methods approach, data were collected via online, structured questionnaires, reflective practice schedules and semi-structured interviews. Data were analysed quantitatively using descriptive statistics and supported by qualitative analysis of open-ended responses. Some of the findings included main skills developed, communication and social skills, main challenges experienced, finding a study site, and working with a partner; the research task was relevant to career and society, and enhanced understanding of the module content. The integration of research at undergraduate level fostered environmental stewardship, positive career aspirations, motivation to pursue further research, and promoted problem-solving to real-world problems. It is recommended that universities support more undergraduate programmes to adopt inquiry-based learning within authentic research tasks.

Keywords: *undergraduate research; inquiry-based learning; sustainable cities; SDG11; education*

Introduction

The sustainability agenda is driven by the 17 Sustainable Development Goals (SDGs), conceived in 2015, when 193 global nations came together to address global challenges. This common agenda aims to achieve universal peace, eradicate poverty, reduce harm to the environment and to safeguard human wellbeing. Fundamental to the achievement of these goals by 2030 is a collaborative effort from all stakeholders through partnerships (UN 2021b, 2021c). The 2030 Agenda is being mainstreamed into policies and programmes internationally. Achieving the SDGs is the collective responsibility of all sectors of society, including government, businesses, civil society, and local communities. To this end, universities and other higher education institutions can play a significant role in integrating "Education for the SDGs" (ESDGs) into their teaching, learning and research agendas to drive the sustainability agenda (SDSN, 2020). Through these endeavours, the higher education sector has the potential to produce graduates equipped with the appropriate skills and knowledge, focused on finding solutions to address the sustainability crisis that humanity is currently faced with. ESDGs also addresses Goal 4, "Ensure inclusive and equitable quality education and promote lifelong learning and opportunities" (UN, 2021b). Target 4.7 specifically focuses on ensuring that learners are equipped with the skills and knowledge to encourage and support sustainable development and sustainable lifestyles. Teaching the SDGs creates a mindset of stewardship and highlights the holistic approach of recognising the relatedness between environment, society, and economy.

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The sustainability crisis is quite evident in cities globally, due to the immense pressure exerted by expanding urban populations which are growing at an alarming rate (UN, 2021a). It is therefore necessary to make cities more liveable, while ensuring that people and nature can live harmoniously together. SDG 11 "Sustainable cities and communities" pledges to "make cities and human settlements inclusive, safe, resilient and sustainable" (ProjectEveryone, 2021). The natural components of cities are often overlooked by society, and their true value is not considered adequately (Gulati and Scholtz, 2020). Cities are in themselves ecosystems, where the human component plays a significant role as part of the biota. As 'intellectually advanced' biota, humans have the potential to add value through preservation and protection of the natural components in cities. This can be facilitated through academic endeavours. Universities in South Africa offer undergraduate qualifications in environmental sustainability, which have the potential to equip students with the ability to find innovative solutions to many societal problems related to sustainability.

Incorporation of research concepts and skills in undergraduate modules, using inquiry-based teaching and learning, can encourage critical thinking and problem-solving (Corwin *et al*., 2015; Pedaste *et al.,* 2015). This has immense possibilities to facilitate the translation of science into action and, ultimately, to reach broader society, through graduates' work as practitioners in horticulture and conservation. Undergraduate research experiences have the dual purpose of developing skills and knowledge to foster innovation and critical thinking, which makes graduates more employable, whilst sharpening their problem-solving skills (Rodenbusch *et al.,* 2016). This also motivates students to pursue postgraduate qualifications to seek practical solutions to complex problems faced in urban environments, as they are equipped with the basic understanding of research (Lopatto, 2007). The motivation for this project included preparation for postgraduate studies, preparation for the workplace and facilitating entrepreneurship/innovative thinking and creating an in-depth understanding that makes content relevant to students' prospective careers and societal needs. This study aimed to determine how research concepts and research skills can be effectively integrated into a first-year module through inquiry-based learning.

Undergraduate students often have limited exposure to research knowledge and skills, which may pose challenges when students embark on postgraduate studies and when entering the workplace. Introducing these skills at undergraduate level may make students more employable and more adaptable in challenging situations, as they may possess more critical and innovative thinking skills. Inquiry-based learning, through research concepts and research projects, is likely to support SDG 11. The promotion of sustainable living in cities and assessing the interaction of living and non-living components of urban environments within the context of sustainability have the potential to develop problem-solving skills.

Protecting Urban Ecosystems through Undergraduate Research

Humans derive many benefits from nature, which is of critical importance in built-up urban areas. Ecosystem services (ES) are the benefits people derive from ecosystems, while Ecological Infrastructure (EI) is the equivalent of built infrastructure that is provided by natural systems (Cumming *et al.,* 2017; Childers *et al.,* 2019). EI includes rivers, wetlands, catchments, coastal dunes, green open spaces in built-up areas, and natural habitats. It is critical that we conserve EI to ensure that society continues to receive the benefits thereof, such as water purification, carbon sequestration, groundwater recharge, improvement in soil quality and flood attenuation, amongst others (Angelstam *et al.,* 2017). EI also contributes to employment, community livelihoods and economic development. Anthropogenic activities contribute substantially to the degradation of EI. There are many urban areas experiencing pressures from development and a growing population. Cities comprise largely built infrastructure, designed and implemented by humans, which has resulted in large-scale modification of the original landscape (Gulati and Scholtz, 2020). The remnants of natural vegetation or the landscaped green spaces are crucial to

enhancing the role that nature must play in built up areas (Childers *et al*., 2019). Urban ecosystems are significant in providing the EI necessary to contribute to resiliency to withstand the impacts of uncertain events such as those linked to climate change, natural disasters, and extreme weather events. It is therefore critical that we protect urban ecosystems and green spaces to continue to provide important functions for society to benefit, and contribute to the health and well-being of humans, especially in built up areas such as cities.

Urban ecosystems provide an ideal 'natural laboratory' for undergraduate students to practise inquiry-based research through projects, where various research concepts and research skills can be implemented. Various studies have documented the value and benefits of undergraduate research (Wei and Woodin, 2011; Hanauer and Dolan, 2014; Corwin *et al*., 2015). Incorporating research in undergraduate modules engages students in addressing problems of relevance to the scientific community, as well as problems of significance to broader society (Emery *et al.,* 2019). This engagement of students in problem solving plays a critical role in enhancing skills related to planning and executing projects and basing arguments and decisions on evidence. Such a skills set provides the next generation of scientists, practitioners and decision-makers with the tools to manage problems and challenges effectively in a complex world (Dolan, 2017).

Scientific research conducted early in one's higher education experience, encourages students to address scientific and societal problems. This facilitates the successful progression from undergraduate to postgraduate studies, which contributes to knowledge production, and seeking solutions to economic and societal challenges (Lopatto, 2007). This practice also enables a more diverse and inclusive group to access academic opportunities (Dolan, 2017; Corwin *et al.,* 2018). Course-based Undergraduate Research Experiences(CUREs) provide the opportunity for a larger number of students to be exposed to research skills and the implementation of such skills, as opposed to the traditional one-on-one supervision, where research is reserved exclusively for a select few (Dolan, 2017). Resources and facilities are often limited at universities. CUREs provides a practical option to address this issue, by allowing more students access to research via activities which are adapted to meet these needs (Hanauer and Dolan, 2014). This has a much greater impact in terms of the reach of such practices. More students benefit from this experience in terms of their career development, as it bridges the gap between their academic knowledge and requirements in the workplace (Lai, 2018).

The purpose of the ecology module, which is the focus of this study, is to enable students to understand the dynamic interactions in ecosystems and to incorporate this knowledge into their practice of horticulture and landscaping. The learning objectives of this module included knowledge and an understanding of the different elements of ecosystems and natural resources and their interactions, and the organisation of ecological entities and the dynamics of the natural environment. Graduate attributes that relate to the skills and understanding essential for possible career paths related to this programme include a demonstration of the following:

- The ability to work in an individual or team setting.
- The ability to identify the relationships between the various components of ecosystems, and humans' relationship to nature, and relate these to sustainable horticultural practices.
- Entrenching environmental considerations in the workplace and in general, as citizens to achieve sustainability.
- The knowledge of environmental issues in relation to local and global contexts.

The development of these skills and attributes is aimed at producing graduates who are global citizens with an ethos of environmental stewardship, with a focus on innovative problem solving, providing a foundation for students to progress from this first-year module to the subsequent years.

Depth of Knowledge through Inquiry-Based Learning

To encourage links between theory and practice in urban ecological conservation, an inquiry-based approach can be used to introduce research concepts and scientific skills in the teaching and learning of applied ecology. According to Pedaste *et al.* (2015), "Inquiry-based learning can be defined as a process of discovering new causal relations, with the learner formulating hypotheses and testing them by conducting experiments and/or making observations." Structured inquiry included in research projects encourages students to ask further questions, investigate, discover, and seek explanations for themselves, instead of someone providing answers for them (Brew and Jewell, 2012; Killen, 2015; Walkington, 2015). However, Healey and Jenkins (2018) point out that there is a difference in undergraduate research approaches. One focus is on original research with a contribution to the body of knowledge and another on learning research skills through research. The authors further distinguish four overlapping dimensions related to student engagement in research, namely research-led (current disciplinary research), research-oriented (development of research skills), research-based (undertaking research) and research-tutored (discussions on current research).

The approach to undergraduate research in the study reported in this paper encompassed two overlapping dimensions, namely research-oriented and research-based without an emphasis on original research. In the pedagogy of inquiry-based learning, learning takes place in a phased manner. There are two broad approaches to inquiry-based pedagogy: the inductive (empirical or data-driven) and the deductive (theory or hypothesis-driven). Constantinou, *et al*., (2018), in reviewing literature, indicate that the inductive approach is interpreted as a 'bottom-up' approach where, through observation and involvement, learners can construct their own knowledge. Brew (2018) suggests that one of the ways to incorporate research and inquiry into courses is to get students to actively collect data, whether it is on site or through secondary sources. However, Willison (2018) points out that guidance to the student is necessary in research skills development (such as data collection skills) and that this guidance and development are not a linear process, but cyclic and reiterative. The inductive approach evolved and is commonly referred as an inquiry-based science approach (Rocard, 2007). How these approaches are applied may differ, based on the research problem. Inquiry-based undergraduate research reflects what scientists do, the type of investigations undertaken, and requires of students to be accountable for their scientific work. This enables growth in terms of development of scientific skills, reasoning and personal growth (Edelman and Edelman, 2017).

A constructivist lens underpinned this study. Constructivism is neither a method nor a singular idea; there are variations in interpretation, but also common tenets that are visible in the range of constructivist views (Shively, 2015). The premise of constructivism is that knowledge is constructed and reconstructed through deliberate, progressive deepening of meaning and understanding through valid linking of experiences, new knowledge and existing knowledge, and involves active learner participation (Peters *et al*., 2003; Killen, 2015; Dennick, 2016). Constantinou *et al.* (2018) caution that inquiry learning is not a synonym for constructivism, although constructivist tenets are evident. For students to construct knowledge and meaning through research, they would require some basic skills, e.g., data collection, data analysis and literacy skills to analyse research articles. In constructivist learning contexts, the instructor has a valuable role in planning the activities and supporting the learner (Killen, 2015). Killen (2015) supports the importance of developing basic research skills in students for inquiry-based learning. Based on a study done in Australia, Willison and Buisman-Pijlman (2016) report that it is important for instructional criteria to be made explicit in research skill development. The construction of knowledge through inquiry learning using a research approach hinges on basic research skills development, clarity of instructions and on support or mentorship provided by the academic instructor.

Inquiry-based research is well suited to urban ecological studies due to the availability of material in an urban setting, where students can make observations and relate these to theory, making deductions and recommendations. Similar research undertaken in conservation and environmental science (Flowers *et al.,* 2016; Edelman and Edelman, 2017) yielded good results in terms of the development of research skills and other skills, such as stakeholder interaction, teamwork, science communication and collaboration at different levels. These studies also indicate that scaffolding of information facilitates a phased approach to building research skills and knowledge, which builds confidence in students as they master skills and knowledge at each phase. Ultimately this contributed to students completing undergraduate research tasks successfully, as they were able to apply research concepts to assigned tasks. They also demonstrated knowledge of identifying the different elements of nature and their interactions, which addressed some of the learning objectives of the module. The undergraduate research experience has the potential to benefit graduates in the workplace, in academia and in the contribution to society.

Methodology

The Durban University of Technology (DUT) is in Durban, a city along the east coast of South Africa. This study formed part of a larger institutional project at DUT through the Supporting Undergraduate Research Excellence (SURE) project, which aims to integrate research into undergraduate programmes. This study used a mixed-methods research paradigm, making use of both quantitative and qualitative information in data gathering and analysis. Data collection included structured questionnaires, containing both open and closed questions, semi-structured interviews, reflective practice schedules, and visual representations (photography included in the final written project reports submitted by students). The last data set (visual representations) was excluded from the data analysis in this paper to limit the length of the paper and due to the time required for analysis. All students were given the opportunity to respond voluntarily to online questionnaires. Questionnaires were posted via an online platform. Further probing was used to explore participants' reasons and motivations for their responses to structured or semi-structured questions via interviews.

Given the challenges of the Covid-19 pandemic, virtual means were the primary strategy to gather data via interviews (Audio-visual via MS Teams). All students were invited to participate in the interviews on a voluntary basis. Due to non-response to this request, students were selected randomly and those who were willing to participate were interviewed. After conducting interviews with five students, saturation had been reached based on the responses. The closed questions in the questionnaire and reflective practice schedules were quantitatively analysed and presented as descriptive statistics. The open questions in the questionnaire, interviews and reflective practice schedules were coded in Microsoft Excel 2016 and analysed quantitatively. The results were further explained with qualitative content analysis. The participants for this study were from the Faculty of Applied Sciences at the DUT. The students were registered for a diploma programme with the focus on Sustainable Horticulture and Landscaping. The selected group included 78 students registered for the ecology module. This is a compulsory second-semester module, at first-year level, within a three-year diploma. Ethical protocols were followed as required by the Ethics Approval Committee of the university.

Two key tasks assigned to the students were engagement with a research article, and a summative project requiring observation and application of research concepts and course content to the real world. The lecturer responsible for the module is a PhD candidate specialising in ecology, with many years of experience in the environmental management industry and local government, as well as more than 12 years of higher education teaching experience. The lecturer composed the assignment and project and assessed these tasks. A PhD candidate, with tutoring experience, was engaged to facilitate tutorials, with the aim of guidance on research concepts. The lecturer briefed the tutor on content to be included in the tutorials. While the semester,

support tutorials were provided to orientate students in terms of research concepts to analyse journal article contents, and to guide them in completing the assignment based on a journal article. The aim of guided reference to journal publications was to facilitate the students' engagement with journal articles while understanding how journal articles are structured in relation to different research concepts. Tutorials were provided weekly by the Research Tutor over six weeks. Each week, a new research concept was dealt with in detail (Week 1: the abstract; Week 2: Introduction; Week 3: Aims and objectives and how to identify these in research publications; Week 4: Methodology; Week 5: Results and Week 6: Discussion and conclusion). The importance of referencing was incorporated into the introductory tutorial, as this is also covered by library tutorials offered by the university. The main task for this cohort of students was a summative project focusing on urban ecology. They were required to make observations in an urban ecosystem, noting plant and animal adaptations to the built environment and urban setting, and relate it to content covered in the module. The final project submission required of students to compile a report with photographic evidence and a written account of the methodology and observations, and to link this to theoretical content relevant to the module.

Results

The results are presented according to the following student responses, viz. reflection on the components of the research tasks, skills development associated with the research task, relevance of the task to career and society, challenges experienced, and views on what could be done differently if the task were repeated.

Reflection on components of the research tasks

Of a total of 78 first-year students registered for the ecology module, 56% (44) respondents participated in the online questionnaire. The number of responses for the rating of specific aspects generated some variation in the number of responses per question. Students were instructed to assign one rating on a scale from 1 to 5, but students assigned more than one rating per criteria. This was based on the task that involved several tutorials to introduce students to journal articles and how to use them effectively. Following this, students had to rate the importance of the different research components (Figure 1). The highest number of responses was received for research component 'conclusion' (53.3%), rated as very important, followed by 'research question' (50%) and 'data analysis' (48.9%) as very important, and 'sharing findings' (46.7%) rated as very important. The research component that received the highest rating for critically important was for 'field observations' (34.1%). Collectively, the rating of very important and critically important for each of the research components received the following responses: 'research question' (79.5%); 'data analysis' (75.6%); 'sharing findings' (73.4%); 'conclusion' (73.3%); 'field observations' (72.7%); literature review' (47.8%); and 'methodology' (47.7%). The highest collective responses for rating irrelevant or not important were received for the concept 'literature review' (15.2%).

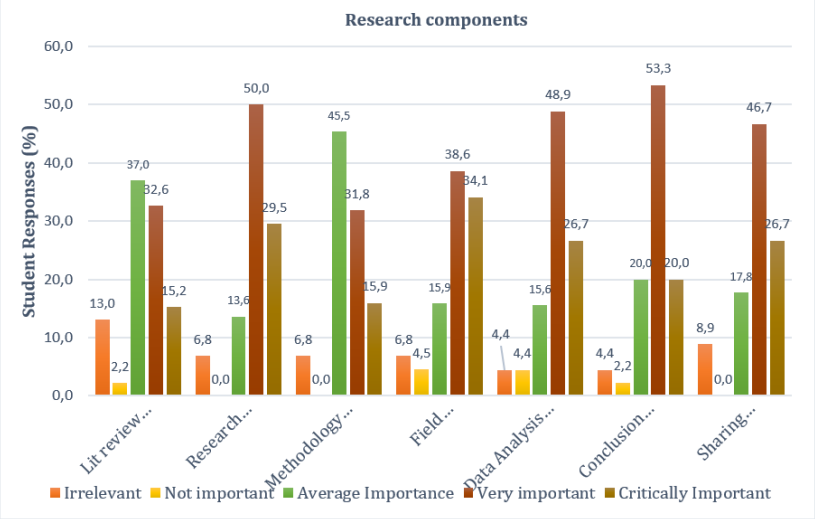

Figure 1: Student responses to the question: In reflecting on your research experience, rate the importance of the following components in the research assignment/project undertaken. Provide a rating from 1-5. (5 = critically important; 4 = very important; 3 = average importance; 2 = not important; 1 = irrelevant)

Skills development associated with the research task

Figure 2 shows the student responses received from the questionnaire responses relating to skills developed during the project. Responses indicated that 'social skills' and 'communication skills' were *significantly developed*, with 47.9% responses rating 'social skills' as *significantly developed* and 46% rating 'communication skills' as significantly developed. In the rating category of *noticeable development*, 'scientific skills' and 'scientific reporting' received more responses at 44.9% and 40.8%, respectively. When considering the collective positive skills development rating categories of noticeable development and significant development, the collective responses for these for each skill set was over 50%, indicating a positive response in general. The responses for these two collective rating categories were: 'Observation' – 83.4%; 'Social' – 83.3%; 'Communication' – 80%; 'Analytical' – 78%; 'Scientific reporting' – 75.5%; 'Scientific' – 74.9%; 'Recording Data' – 71.1%; 'Technical' – 51%.

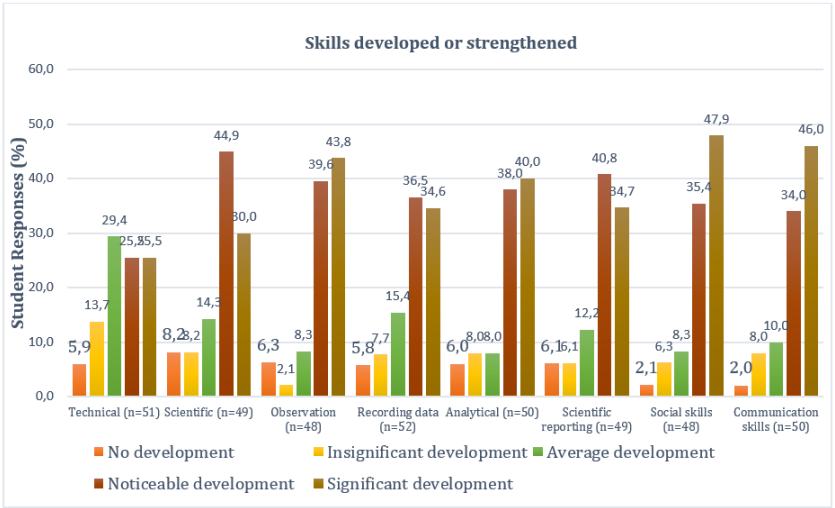

Figure 2: Student responses to the question: Which skills do you think were developed or strengthened during the project? Provide a rating from 1–5. (5 = significant development; 4 = noticeable development; 3 = average development; 2 = insignificant development; 1 = no development)

Student responses from the interviews related to the significance of the research skills developed with a focus both on professional or social skills, as well as research and scientific thinking skills.

For example, one student responded that they advanced in "communication". Another student specified that they, "*had a partner, so …. were able to do more research and communicate well*". Two respondents cited that they had significantly gained in the skills relating to "observation" and "investigation". As a follow-up to the question requiring skills development to be rated, students were asked to state which skills were the most important to their career and why, and which skills were the most important to society and the reason for stating this. Figure 3 shows the results obtained from questionnaire responses. Most of the responses pertaining to career importance and societal importance indicated that social and communication skills were the most important, with social skills being more important for society, with 40.9% of the responses indicating this. Communication was selected as the most important skill for respondents' careers at 36.4% of responses indicating such value. 13.6% of the responses relating to career importance indicated that observation was important for career relevance. The results indicated that students viewed communication and social skills of significant importance, and this was developed through the project.

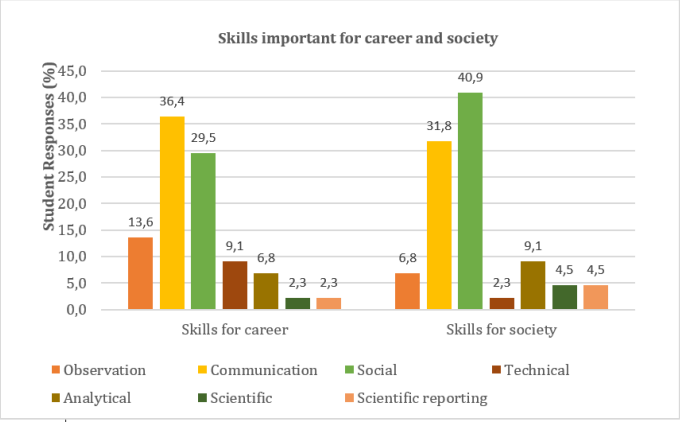

Figure 3: Responses to the question regarding the importance of the different skills developed during the project to students' future career and society (n=44).

Relevance of the research task to content, career, and student experience

In the questionnaire students were required to respond to the relevance of the research task. These were open-ended questions.

Relevance to future career received the following main responses:

- Improved general ecological knowledge – 41%
- Better skills developed through the research to benefit the career – 32%

Relevance to the overall student experience generated responses which:

- Expanded the students' knowledge as indicated by responses such as "*It is relevant because it enlightened me about urban ecosystems*"; *"I now understand urban ecosystems better"*; "*I think that this research project was relevant because it helped me to understand what an ecosystem is and the importance of ecosystems to day-to-day activities*".
- Fostered stewardship towards nature, with some responses indicating specific engagement: "*Encouraged me to protect and keep the ecosystem healthy so we are going to have a better economy*"; "*What I am supposed to do to make my country, or my town a better place*".

The questionnaire response to the research experience making content learned in the module more understandable received a 98% positive response. The interview also probed this focal area by questioning the relevance of the research task to make module content more understandable. Students' responses were very positive and included: "*during lectures we talk about nature and the project is based on nature*"; "*I find more information like the biotic and abiotic*"; "[*it] really*

helped me because now I have a good understanding of the negative impacts of the humans". These responses relate directly to the purpose of this module ('to enable students to understand the dynamic interactions in ecosystems and to incorporate this into their practices …') The link between theory and the real-life practice unfolded through this research experience.

Challenges experienced

According to the questionnaire responses, students indicated the following key challenges when engaging with the task, as listed below. These were grouped into common issues as follows:

- None: 22.7%
- Finding an appropriate site: 22.7%
- Difficulties working in pairs: 15.9%
- Understanding the task: 9.1%
- Covid posing challenges to meet with partner: 2.3% (1 response)

Figure 4 below represents the results obtained from the reflective practice schedules, reporting on key challenges experienced when carrying out the research task. The key challenge was finding an appropriate site to conduct their observations. This is noted as a challenge; however, it must also be noted that principles of constructivism identify the learners as active participants in the learning process (Killen, 2015). This would have involved cognitive activity of using their experiences, comparing, and eventually deciding on the appropriate site. The second major challenges were understanding the requirements of the task and working with a partner. These were important challenges to develop better communication skills, to obtain further guidance, and to find solutions to difficulties of working with a partner. To a lesser degree, financial constraints were challenges. These were related to travel costs in getting to a suitable site. Those challenges categorised as 'other' in Figure 4 were the result of respondents not answering the question directly, or the response was off topic. Some of these challenges address the learning outcomes and graduate attributes relating to working in a team or group, knowledge of ecological systems, and the relationships between the ecological components, as the latter would have been crucial in identifying a suitable site.

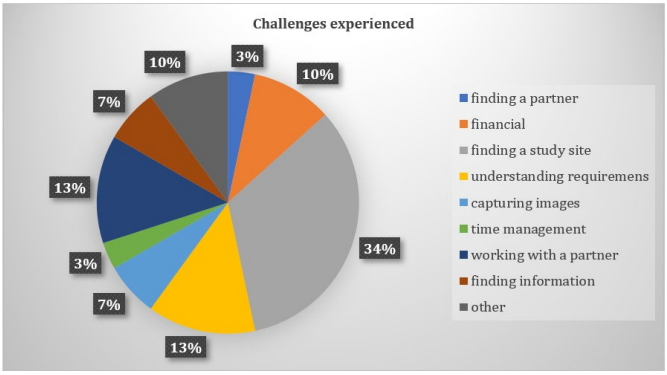

Figure 4: Responses from the reflective practice schedules indicating challenges experienced during the summative research project(n=30).

Some of the responses from the interview relating to challenges included:

> "*Finding an ecosystem*"; "*sometimes a partner is difficult*"; "*the problem is what comes when you have to interpret it (findings/observations) and write it down*".

Responses from the questionnaire:

- "*It was not easy to find an area or place that was good for our projects, but we manage to get an area that we think is better and that has enough information for our projects.*"

- "*Having to understand that I have no control over the environment may still affect the quality of my pictures and the observation of the field, and the features that co-exist with the natural features (ecosystem). We (meaning partners) may still disagree on certain things such as time and work division.*"

Improvements to consider for future research tasks

Reflection is valuable to the learning process where a situation can be analysed with a view to moving forward (Wain, 2017). Further, reflection can develop critical skills to transform or break away from practices, which could become routine (Ali, 2020). The module purpose includes an understanding of dynamic interactions between elements of the ecosystem to ensure that this is incorporated into the practices of horticulture and landscaping. Reflection has the potential to add value to an adaptive management cycle to improve practices in the workplace and general individual development.

The following were the significant responses from the questionnaires, indicating what students would do differently if the task were repeated in another setting:

- Provide more information to produce their final report: 25%
- Better time management: 13.6%
- General improvement in how the task is done: 11.4%
- No change: 4.5%
- Work alone: 2.3% (1 response)

The two major categories of future improvements in reflective practice items were accessing information and time management, as indicated in Figure 5. These are significant in terms of research. Accessing information through literature and primary sources is important in understanding contexts, which in the assigned tasks pertained to the ecological site. Secondly, management of time is dependent on the nature of research undertaken. The latter is significant in the research process, as contexts can change. The students' ability to identify time management as a future improvement strategy contributes to the holistic development of the student, implying that the student accepts accountability for being more realistic in future tasks of this nature.

In responding to the question of the support provided during the research task, to assist and guide students, a positive response of 89% was received. Interview responses supported this by the following responses:

- "*Yes, I found the tutorials helped in doing the project.*"
- "*It was very, very helpful from the beginning until the last day of the project. It made me understand a lot.*"
- "*There was enough support. I can say it has helped.*"

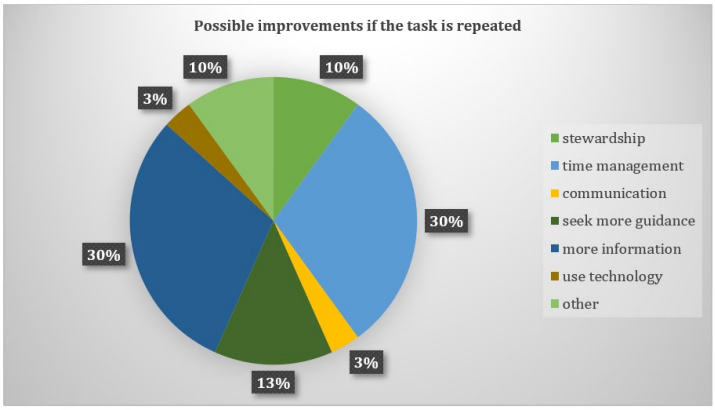

Figure 5: Responses from the reflective practice schedules indicating possible improvements in the future if the summative research project is repeated (n=30).

Discussion

It is a realistic expectation that working towards achieving the SDGs may not be realised completely. Yet, higher education institutions have a crucial role to play in facilitating the process of embedding the SDGs in the content delivered to produce graduates who value the intent behind the SDGs (Leal Filho *et al.,* 2021). Ideally, this would ultimately translate into graduates who are able to take this forward into the workplace and community or social engagement. With the challenges facing cities, inquiry-based learning is well suited to equipping students who are future engaged citizens ready to participate in seeking and providing innovative ideas to address such challenges, while promoting ESDGs. Instructional approaches that incorporate SDG11 into undergraduate education can provide an appropriate motivator for students who can go on to encourage sustainable urbanization and economic development, while reducing negative impacts on the environment. Through the tasks assigned to students in this study, they were acutely aware of the different components in urban ecosystems, focusing on the interactions between these components and relating these to research concepts, research processes and research reporting. This also engaged students with their surroundings in a new way, which related to the content taught in the ecology module. It is important to introduce research at undergraduate level so that students have insight into the research process and research culture, which would prepare them for more opportunities on completion of their qualification (McGill *et al.,* 2021).

Constantinou *et al*., (2018) have flagged constraints in inquiry-based learning as well as opportunities. Amongst the constraints flagged were recipe-type inquiry activities, the instructional support for students, the challenges students may face in the assigned activities, and the instructor preparation. Amongst the opportunities flagged were students' scientific practices and inquiry skills and students' metacognition. These constraints and opportunities were used to determine the research activity assigned to the first-year undergraduate class. The research task assigned in this study was an authentic task and not a simple recipe-type inquiry activity. Authentic learning in relation to sustainable development is about real contexts, threats, problems, and the seeking of solutions, and it involves active, hands-on education (Dreyer and Loubser, 2016). In this sense, the research task itself was dynamic rather than contrived. Student responses verified the value added in terms of learning and in terms of the impact of the task on them. Many positive experiences reported by students were indicated by phrases such as

- "*It was valuable, and a lot was learned*";
- "*Fun and informative*"; "*I have a good impression about this research as it made me understand ecology more*";
- "*The research was not hard, I enjoyed going to the park and taking pictures*";
- "*It was good even though I faced some challenges*".

This resonates with the statement by Callaghan *et al.* (2021) that COVID-19 has offered "a unique opportunity to engage driven students in open-ended learning". Further, the type of task assigned was borne out of a need for students to engage with the environment, but also due to the online mode of teaching and learning during the COVID-19 pandemic. When continuous assessment replaced examinations written in examination halls, this posed an opportunity for students to venture outside and make observations using research concepts and processes. They were able to interact with their surroundings within the context of material covered in the module and expressed an understanding of the relevance of the research task to the module content, prospective careers, and a holistic student experience.

Constructivist approaches provide opportunities for students to be active, confident and to identify gaps in their knowledge, understanding and the way the meaning was constructed (Peters *et al.,* 2003). Reflection is one of the deliberate ways of identifying gaps in meaning making. Reflection on the research experience provided the opportunity for students to assess how the research process had helped them grow, identify problems through observations and propose solutions (Lopatto, 2007), as indicated by the following response, "*It took us out of our*

comfort zone and we learnt new things about the site we chose." Some of the responses also indicated a connection with nature and stewardship as a potential value that could contribute to social transformation and effect progress towards the SDGs. Some of these included, "*We need [to] keep urban ecosystem[s] protected*"; "Natural conservation is [a] much more important[t] thing to practice keeping our nature alive", and *"[I] know what I will have to change in the future*". These comments indicate the personal growth in how students viewed their surroundings and their renewed appreciation for the environment. This is the characteristic of constructivist teaching and learning approaches, where students make meaning through relevant activities. Their reflection on the research process and experience has the potential to circumvent possible difficulties and may initiate problem-solving (Pedaste *et al.,* 2015)

A constructivist approach involves an active learner and is therefore learner centred (Shively, 2015). However, constructivist approaches in active meaning making involve cognitive skills linked to other domains such as the social domain. Skills development explored in this study produced findings showing that effective results were obtained through the tasks relating to undergraduate research. Skills development was a key benefit derived from engaging in the task, as outlined in the purpose, learning outcomes and graduate attributes of the module, and as mentioned in the introduction. Students responded most positively to the development of social and communication skills, perceived as important for career development and societal benefit (SDSN, 2020). These are significantly important skills, as they help students to navigate challenges associated with conflict and difficult interactions. Promoting ESDGs through inquiry-based learning will enhance the abilities and knowledge of students as future practitioners, leaders and decision-makers within the context of the SDGs (Leal Filho *et al.,* 2021). The metacognitive activity of reflecting on the research task was also a valuable one. It raised students' awareness of social and scientific challenges and how they can move forward in such research tasks in future. According to Corwin *et al.* (2018), students who are exposed to undergraduate research experiences acquire improved research skills, become more confident in undertaking research, expand their knowledge and have clearer ideas regarding their career choices.

Challenges faced by students could be categorised as constraining factors. Some of these were beyond the control of the instructor or students. For example, a student expressed,

> "*The challenges were that the area belongs to someone and will not be easy to gain access to the area, it will be a long process trying to get the area in our hands so that we can use or manage the area in a sustainable way*."

However, upon reflection, the tutor could have discussed possible challenges with students and possible ways to navigate these challenges within the context of the task. In general, the challenges experienced by students helped them to navigate difficulties and seek solutions. This was evident when considering the main challenges of finding a study site and working with a partner. The final successful accomplishment of the research task was evidence of dealing successfully with the difficulties experienced. Some students indicated that it was difficult to work with a partner at first, which indicates that they worked through that challenging situation. The response by students indicating that the main skills developed during the research experience were communication and social skills may be linked to the problem-solving involved in dealing with the challenges of difficult partners or finding a study site, as this would have required working together and negotiating how to resolve these challenges.

Instructional and learning support provided by a tutor contributed to the success of the undergraduate research project, as indicated by positive student responses. The engagement of a tutor is not a norm for this module due to financial constraints. This was possibly due to project funding. Student support was not a constraining factor in this study. Students received support from a tutor who briefed students over several weeks, pacing through the various components of research implementation to allow for a better understanding of these components, and which

facilitated the application of research concepts in the project. Continued support and interaction with students likely promoted students' independence in inquiry learning (Attard *et al.,* 2021). While instructional strategies are included, instructor preparation was not fully explored in this study due to the focus on students' learning. Yet a deliberate reflective process may be useful in the future to explore whether instructor or tutor preparation was a constraint. However, results do indicate that the fact that the instructor specifically employed a postgraduate student, and thus an experienced peer researcher as a tutor to support the students, was a positive decision.

Conclusion and Recommendations

To achieve a more sustainable future, especially in cities where human impact is prolific, higher education institutions have the potential to deploy instructional strategies and content to help equip students to address many global challenges. This can be accomplished by higher education institutions customising the undergraduate programmes they offer to incorporate the application of research concepts (Agirreazkuenaga, 2019). Through implementing an undergraduate research project from the first year of study, and progressively increasing the level and depth of research content to direct problem solving and innovative ideas over time, future graduates will be prepared to respond to local societal needs, and more progress can be achieved towards the SDGs. The SDGs are more likely to be realised through active participation, understanding of contexts, and proposing solutions to challenges. In this study, it can be concluded that inquiry-based learning and research tasks in undergraduate programmes have enhanced the students' skills, understanding of contexts, and encouraged active participation. The numerous positive responses of the students indicate favourable effectiveness of the approach on undergraduate students. In the context of the SURE project, the researchers recommend that more instructors be supported in implementing inquiry-based learning by offering students authentic research tasks, as well as being provided with guidance on the design of tasks.

Gaps exist that need further exploration, viz. more intensive support for students during all phases of the inquiry approach and the formative, rather than summative implementation of metacognitive processes formatively in the research tasks, rather than only at the end of the task. This is likely to help students negotiate challenges as the task progresses. Further research on components of metacognition and reflection, which are tenets of a constructivist approach, will strengthen the body of knowledge of incorporation of research tasks in undergraduate programmes. Lecturer or instructor reflection of the tasks, and the role played by the instructor and tutor has the potential for adaptive management to improve on undergraduate research teaching and learning.

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