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The Role of Community-Engaged Learning in Engineering Education for Sustainable Development

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Abstract: This paper presents the positive experience of facilitating over 300 community-engaged engineering projects at an Irish higher-education institution. The projects are framed by a research orientation, a commitment to civic engagement, and building university–community partnerships, city–university partnerships, and partnerships with other official agencies, so that community users can provide real learning problems and contexts for students and researchers and benefit from the results. The paper highlights how well the outlined approach fits with the ideas of engaged scholarship and civic professionalism, and facilitates sustainable development. Students recognise the long-term value of engaging with community partners, understanding their future role in the community as engineers, reinforcing the idea that their work can respond directly to real needs in the community, while promoting the sustainability agenda at the same time. The approach presented in this study will not only enable the development of future models for embedding sustainability in engineering programs, but will also equip future engineers with transferable skills to ensure that sustainable development goes beyond university courses and is practiced every day.

Keywords: community-engaged learning; sustainable development; engineering education

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1. Introduction

1.1. Sustainable Development and Engineering Education

Sustainable development is the overarching paradigm of the United Nations [1]. Sustainable development 'meets the needs of the present without compromising the ability of future generations to meet their own needs' [2]. The 2030 Agenda for Sustainable Development was adopted in 2015 by United Nations member states and provides a plan for action for people, planet, and prosperity, both now and into the future [3]. At the centre of the Agenda are 17 Sustainable Development Goals (SDGs) to eradicate poverty and hunger, improve health and education, reduce inequality, ensure peace and justice, and stimulate economic growth, while tackling the challenges of climate change and biodiversity loss.

In May 2019, the United Kingdom and the Republic of Ireland became the first two countries in the world to declare climate and biodiversity emergencies. Since then, 15 countries and the European Union have made climate-emergency declarations (as of July 2021) [4].

By declaring a climate emergency, these governments recognised human-induced climate change and the massive threat posed by the loss of biodiversity, and committed to an immediate and ambitious science-based action to limit global warming to 1.5 °C and avoid massive biodiversity loss [5].

Engineers play a significant role in shaping the world around us. Through their engineering education, application of knowledge, leadership, communication skills and ethical practice, engineers are:

- Specialists, who solve problems;
- Integrators, who operate and manage across boundaries and with different stakeholders;
- Change agents, who provide creativity, initiative, innovation and leadership.

The application of engineering in response to large-scale problems, such as those brought on by climate change requires a comprehensive and systematic approach [6]. Considering the impact of engineering achievements to date, it could be argued that engineering has had one of the biggest influences on the climate crisis, but also the biggest opportunity to help transition to a more resilient society [7]. Since the majority of greenhouse gas emissions come from industries that are enabled by engineers, Lawlor and Morley (2017) [8] called on professional engineering institutions to develop declarations for engineers addressing climate change.

Engineers Ireland is a professional body for engineers in Ireland, representing 25,500 members. In early 2020, Engineers Ireland added their voice to other professional engineering organisations around the world [9–11], by declaring a climate and biodiversity emergency and defining a sustainability framework [12]. Furthermore, engineering industry organisations are also recognising climate and biodiversity emergency by committing to changes in their practice [13].

Education and collaborative partnerships are central to the implementation of sustainable development. Quality education and Partnerships for the Goals form two of the SDGs (SDG 4 and 17), but relate to the entire sustainable development agenda. According to Malala Yousafzai, the education activist and Nobel Prize laureate, 'All the SDGs come down to education...' [14]. SDG 4 focuses on 'ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all' [15]. The core competencies required, alongside traditional learning outcomes, for achieving SDGs include [16]:

- Envisioning;
- Critical thinking and reflection;
- Systemic thinking;
- Building partnerships;
- Participation in decision-making;
- Ensuring that the engineering students who obtain these competencies contribute to a more sustainable future.

Higher-education institutions have been instrumental in transforming society by educating decision-makers, leaders, entrepreneurs and academics [17]. Universities are expected to produce graduates who can develop innovative and creative solutions to the world's most complex problems, and need to include sustainability concepts in their curricula [18].

Previous studies explored the principles and practices of sustainable development in university curricula [19–21], green campus initiatives [22], and university leadership and governance [23]. Moreover, the scientific output associated with the sustainable development goals and their integration with universities has also been mapped [24]. However, there are still many obstacles to the inclusion of sustainable development in universities, both through research and teaching curricula and though the holistic integration of sustainability in university systems [25].

Rampasso et al. [26] analysed the difficulties associated with the inclusion of sustainability in engineering education. The study showed that technical training in engineering education, with a focus on optimising solutions from an economic perspective, is not enough. Courses integrating sustainable development need to place more emphasis on the social aspects of sustainability [27]. Apart from their core engineering knowledge, students need integrated socio-contextual knowledge to evaluate designs for sustainability and demonstrate its positive social benefits [28]. Furthermore, engineering students must

be better prepared in relation to the environmental aspects of sustainability [29], as it is imperative that professional engineers take into account the environmental impact of their designs, such as the proper use of water, materials and energy, the emission of polluting gases and the disposal of waste. According to Felgueiras et al. [30]: 'new engineering professionals need to have not only a set of deep capabilities in a specific area, but also more comprehensive proficiencies that allow them to understand how to integrate their particular system into a wider functional system'.

1.2. Community-Engaged Learning

As well as the need to integrate sustainable development into engineering degree programmes to provide them with the means to meet the challenges of the 21st century, there is a critical need to provide engineering students with a deeper understanding of the general concepts and principles of engineering [31–34]. The Royal Academy of Engineering [31] highlighted the need for 'university courses to provide more experience in applying theoretical understanding to real problems'. It was shown previously [27] that students can achieve better learning outcomes when more community-oriented and constructive-learning approaches are applied. These types of approaches also increase students' knowledge of sustainable development.

Several accrediting bodies for engineering qualifications have developed outcome-based criteria for evaluating programmes. Similarly, a number of engineering regulatory bodies have developed, or are in the process of developing, competency-based standards for registration. Educational and professional accords for the mutual recognition of qualifications and registration have developed statements of graduate attributes and professional competency profiles. These accords are the Washington, Sydney and Dublin Accords, which are the international agreements providing for the mutual recognition of programme-based accreditation for professional engineers, engineering technologists and engineering technicians, respectively. In relation to graduates understanding the role of engineering and technology in society [35]:

- The Washington Accord programme provides 'comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability'.
- The Sydney Accord programme provides 'comprehension of the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability'.
- The Dublin Accord programme provides 'knowledge of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts'.

Community-engaged learning and teaching are academic approaches that seek to engage and accredit students, within the curriculum, for working in partnership with civic and civil-society organisations to act on local societal challenges [36]. Working in collaboration with community organisations enables students to use and enhance skills, competencies and knowledge in a real-world capacity, which leads to an enlarged and more fulfilling educational experience [37]. Through community-engaged engineering projects, students can: (i) develop the ability to identify, formulate and solve engineering problems in their field of study in a real-world context; (ii) select and apply relevant methods from established engineering practice by critically using appropriate sources of information to pursue detailed investigations and research on technical issues in their field of study; (iii) recognise the importance of non-technical societal, health and safety, environmental and economic constraints; and (iv) develop the ability to effectively communicate information, ideas, problems and solutions with the engineering community and society at large. In fact, community-engaged engineering projects can help fulfil all seven of the programme outcomes required by Engineers Ireland, which is the education standard required for the registration of Chartered Engineers in Ireland [38]:

- Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.
- The ability to identify, formulate, analyse and solve complex engineering problems.
- The ability to perform the detailed design of a novel system, component or process using analysis and the interpretation of relevant data.
- The ability to design and conduct experiments and to apply a range of standard and specialised research (or equivalent) tools and techniques of enquiry.
- An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.
- The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning.
- The ability to communicate effectively on complex engineering activities with the engineering community and with society at large.

Previous studies have shown the impact of project-based learning in engineering education [39], students' perceptions of the effectiveness of online-project-based learning in engineering [40] and the creation of communities of practice for industry-based projects [41]. However, more research is needed to establish the most effective way of embedding sustainability into undergraduate courses, including in engineering, and encourage authentic student engagement [18].

1.3. Community-Engaged Building Engineering Projects

The University of Galway formally committed to civic engagement in 2001, through the establishment of the Community Knowledge Initiative [42], to work on mainstreaming community engaged learning within the curriculum across the institution. To date, the majority of undergraduate and postgraduate degree programmes in the School of Engineering have embedded community-engaged learning, which allows students to work with and in local and international communities, as well as in multidisciplinary groups, as part of their academic courses [43]. Goggins [43] showed how community-engaged learning and teaching in engineering education at the University of Galway (formally known as the National University of Ireland Galway) can be intergraded at levels ranging from undergraduate to post-graduate modules, as well as how this can be a lens through which the global dimension of engineering is integrated into the curriculum.

Furthermore, the University of Galway recognises that the future of humanity is threatened by unsustainable interactions between society, the economy and the environment: 'Building on the work of the Community and University Sustainability Partnership and its approach to Learn-Live-Lead sustainability across the university mission, the University of Galway will embed sustainability in its culture, operational policies and governance structures and empower communities to be champions of sustainability' [44].

This paper presents findings and reflections from the authors' 12 years of experience of facilitating over 300 community-engaged building engineering projects for second-year undergraduate (Level 8) civil engineering students in Ireland. The projects are based around the student groups developing solutions for real-world problems identified by civic society organisations. The projects are framed by a research orientation, commitments to civic engagement, building university–community and city–university partnerships and partnerships with other official agencies. This framing means that community users can provide real learning problems for students and that community partners can benefit from the results.

The projects are designed based on the community of enquiry framework [45], which integrates the teacher's presence, cognitive presence and social presence to ensure that students discover, discuss and reflect upon their new learning. The module provides a platform for students, lecturers and community partners to engage, interact and collaborate, because the 'interaction between learners is of great importance to student success' [46]. This is aligned with Bloom's taxonomy [47] and enhances students' learning, particularly in

terms of applying, analysing, evaluating and creating. The approach helps students' deep learning [48] and enables them to develop a wide range of graduate attributes, through [49]:

- Knowing—students utilise the knowledge they gain from other modules;
- Acting—students apply their theoretical knowledge to real-life projects;
- Being—students reflect on their work and engage with their learning.

Finally, the 'students as researchers' pedagogic approach [50] enables students to develop knowledge and understanding while also contributing to broader knowledge in their discipline. This approach allows students to learn from the published literature in engineering and gives them an opportunity to go beyond it by utilising their skills and knowledge to innovate.

Much of the engineering-related research and practice associated with societal responses to climate change falls under civil engineering and environmental engineering [6]. By applying knowledge from the physical sciences and engineering, these disciplines seek innovative ways to design, construct and operate built environments, to prevent and reduce the emission of greenhouse gases and deliver infrastructure that is resilient in the face of the changing climate. Thus, it is imperative that relevant threshold concepts [51] in engineering are considered and that future civil engineers are equipped with the right skills with which to develop innovative and creative solutions to the world's most complex problems, such as climate change. For instance, Pawley et al. [52] and Reed [53] investigated the incorporation of the sustainability and environmental concepts into an engineering curriculum.

Community-engaged building engineering projects develop the core competencies required for achieving the SDGs [16] through:

- Exploring how to achieve change, offering direction and inspiration to take action, taking ownership of visions, processes and outcomes;
- Providing new perspectives and promoting alternative ways of thinking;
- Understanding the nature of feedback;
- Building shared vision among a diverse range of stakeholders, motivating and adding values to initiatives, communicating and exchanging information;
- Decision-making and responsibility for outcomes, an enhanced sense of ownership and commitment, building capacity for self-reliance and self-organisation.

The paper highlights how well the outlined approach fits with the ideas of engaged scholarship [54] and civic professionalism [55]. Students recognise the long-term value of engaging with community partners, understanding their future role in the community as engineers, reinforcing the idea that their work can respond directly to real needs in the community. Furthermore, this paper shows how community-engaged building engineering projects enable a greater understanding of sustainable development among engineering students and partner community organisations. These projects facilitate the development of skills, lateral thinking and knowledge transfer to translate student research into real-life projects to improve quality of life, protect the environment and reduce inequalities (Figure 1).

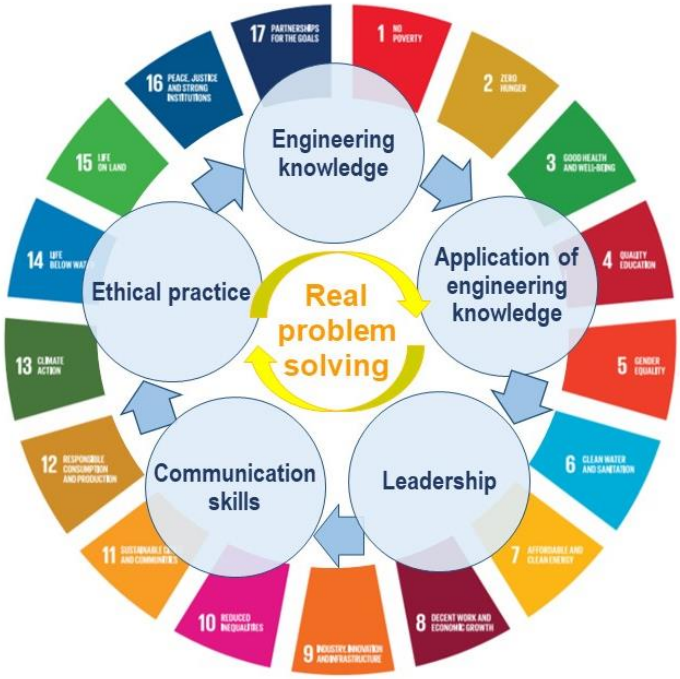

Figure 1. The development of core engineering competencies [38] through United Nations Sustainable Development Goals [15].

2. Methodology

2.1. Community-Engaged Building Engineering Projects

The community-engaged building engineering projects were allocated five European Credit Transfer and Accumulation System (ECTS) credits and started in academic year 2008/2009, as part of the second-year undergraduate 'Principles of Building' module. Since academic year 2020/2021, the 'Community Engaged Building Project' has been an autonomous module in second-year engineering. This module is compulsory for all students in Civil Engineering, Project and Construction Management and Energy Systems Engineering (approximately 60 students per academic year, but up to 120 students have completed projects in a given year). The general learning objectives for the projects include:

- Developing engineering skills through a self-directed project.
- Developing a sense of commitment to local communities by contributing time and expertise to an individual or community group.
- Learning how professional engineers make contributions to their communities.
- Applying the knowledge or skills learned in this module (and others) to a real-world context.
- Producing a technical engineering report.
- Delivering a high-quality oral presentation on a particular subject.

The projects are carried out following a step-by-step methodology that encourages students' engagement and self-evaluation (Figure 2).

At the start of the project, students (working in groups of two or three people) engage with community partners to identify a potential topic and scope for their engineering project. Community partners may include charity organisations, city and county councils, youth organisations, schools and universities, sport clubs, public organisations/offices, etc. Once the students identify a community partner and a project topic, they create learning outcomes of an individual nature for their project and complete and sign a learning agreement with the community partner. Identifying the project and its outcomes and completing and signing an agreement with the community partner increases the students' sense of ownership of their learning and gives them freedom to work on a topic of interest within the broader realm of the module. Many students appreciate the freedom that they are given to specify objectives for their project. However, outcomes of projects must fulfil

a 'real' need of the community partner. In the recent feedback survey, the students stated (Student feedback, 2020):

- 'I liked being given a problem and looking for a solution interdependently, rather than being focused in on finding the correct way to bring about a solution that had already been formulated. Freedom.'
- '[The project] gives creative freedom to the students.'
- 'I liked the practicality of the project and the freedom of choice on which area we could choose to work on.'
- 'I enjoyed the group work and the ability to engage with a community partner in a real world engineering scenario.'

Figure 2. Community-engaged building engineering projects methodology.

Once the agreement with a community partner is signed, students have approximately 7 weeks to complete the project, which includes researching the topic, carrying out engineering design/evaluation and writing up an engineering report. During this time, students are encouraged to attend drop-in clinics run by teaching assistants, who can provide guidance on the project work and assess progress. Technical workshops on project stages, technical writing and presentation skills are also provided as part of the drop-in clinics.

When submitting a project report, students must complete a self-assessment form, where they reflect and assess their project work based on its knowledge base, relevance, impact on society, structure and presentation. Students later receive feedback (from their academic mentors) on their projects based on this self-assessment form. In this way, the students know what is expected of them and can compare their self-assessment of their project with that of the reviewers. This makes students aware of the characteristics of 'good work', encourages them to take responsibility for their own learning and helps them to reflect on themselves as learners [56].

Following the submission of a project report, students present their project results in the form of oral presentations in front of their peers, research students, engineers, a communication expert and community partners. Both the project reports and presentations are assessed based on their technical and presentation/communication merit. Thus, students learn not only how to carry out an engineering project, but also how to communicate it to various stakeholders.

Finally, students (and community partners) are asked to provide feedback on their experience with community-engaged learning.

Crucial elements of the community-engaged projects' set-up include:

- Detailed and structured guidance document for students;

- Structured learning agreement template that must be completed by the students and their community partners at the start of the project;
- Self-assessment form and marking sheet for reviewers;
- The return of marks to the students with feedback within two weeks of submission of the project and before the end of semester;
- Reports being sent to the community partners, who are asked to return feedback to the University.

2.2. Mapping Project Goals against the SDGs

In order to show relevance of the community-engaged building engineering projects to the 2030 Agenda for Sustainable Development, the projects carried out between 2014 and 2021 were mapped against the SDGs. Thirty different projects were undertaken by students in 2021, 30 projects were undertaken in 2020, 18 projects in 2019, 20 projects in 2018, 23 projects in 2017, 24 projects in 2015 and 19 projects in 2014. These projects were individually evaluated for their relevance to all SDGs. This evaluation generated a list of SDGs relating directly to each of the projects. Results of this analysis are presented in Section 3.1.

2.3. Evaluation Survey

Previous research [57] systematically reviewed literature on community engagement in undergraduate engineering education between 1980 and 2019. The study identified a need for additional research focusing on community partners' experience.

Thus, an important part of ensuring that the community-engaged building engineering projects meet the needs of students and community partners are feedback surveys. To date, seven online feedback surveys have been carried out among the community partners (2012, 2013, 2014, 2017, 2019, 2020 and 2021) and six feedback surveys have been carried out among students (2009 and 2011 in class; 2012, 2019, 2020 and 2021 online). This resulted in 62 community partners and 101 students providing qualitative feedback on the projects.

The community partner survey sought feedback on students' engagement with community partners, the usefulness of project report, any positive and negative aspects of the projects' set-up and suggestions for improvement.

The student survey included descriptive questions, such as:

- What did you like about the project and how it was set up?
- What do you gained from completing the project?
- What about how the project is run needs to be improved?
- What suggestions can you offer that would help make this project a more valuable learning experience for you?
- What suggestions can you offer that would help make this project a more valuable experience for your community partner?

3. Results

This section presents how the community-based building engineering projects, carried out in Civil Engineering at the University of Galway between 2014 and 2021, address the 2030 Agenda for Sustainable Development and their relevance to SDGs (content mapping). Furthermore, this section presents the results of surveys (qualitative analysis), carried out among the students and community partners between 2009 and 2021, which sought feedback from the participants on the set-up, structure and components of these engineering projects, invited suggestions for improvement and evaluated the quality of project partnerships and learning outcomes.

3.1. Mapping Project Goals against Sustainable Development

This section presents the results of the content mapping described in Section 2.2.

The community-engaged building engineering projects between 2014 and 2021 related to a number of the SDGs, as shown in Figure 3. Sustainable Cities and Communities

(SDG 11) was associated with the great majority of projects (96%), followed by Good Health and Wellbeing (SDG 3, 58%) and Affordable and Clean Energy (SDG 7, 46%). Industry Innovation and Infrastructure (SDG 9) and Reduced Inequalities (SDG 10) were each associated with approximately 10% of the projects, while Life on Land (SDG 15), Responsible Consumption and Production (SDG 12), Climate Action (SDG13) and No Poverty (SDG1) were directly related to 0.5–3% of the projects. The wide range of projects carried out between 2014 and 2021 included:

- The restoration of a historical mill wheel (2021, in partnership with local historical society)—directly relating to SDG 11, 3, 12;
- The renovation of a 1940s bungalow in order to transform it into a socially inclusive café (2021, in partnership with local social enterprise centre)—directly relating to SDG 11, 10, 7;
- A transitional refugee shelter focused on thermal performance (2021, in partnership with university buildings office)—directly relating to SDG 10, 1;
- The design of student accommodation made of recycled shipping containers (2020, in partnership with the university student union)—directly relating to SDG 11, 9, 3;
- The design of a ventilation strategy for new charity offices (2020, in partnership with the local charity group)—directly relating to SDG 11, 3;
- The design of a board-walk extension (2019, in partnership with the local chamber of commerce)—directly relating to SDG 15, 3;
- An energy and accessibility audit of a sports club (2019, in partnership with the local sports club)—directly relating to SDG 11, 7, 3, 10;
- Electric vehicle feasibility (2019, in partnership with the regional authority)—directly relating to SDG 7, 11;
- The development of a flood defence system in a city (2018, in partnership with the fire and rescue services)—directly relating to SDG 11, 9;
- The development of an awareness campaign for the search-and-rescue services (2018, in partnership with the National Lifeboat Institution)—directly relating to SDG 11, 3, 10;
- A light, heat and fire safety evaluation of a clubhouse (2017, in partnership with a local music band)—directly relating to SDG 11, 7, 3;
- The retrofitting of a charitable organisation's facilities (2017, in partnership with a local charity group)—directly relating to SDG 11, 9;
- The design, structural analysis and cost analysis of bridges in the proposed greenway project (2015, in partnership with the county council)—directly relating to SDG 11, 15, 3;
- An investigation and assessment of the accessibility and fire safety of a theatre (2014, in partnership with a city theatre company)—directly relating to SDG 11, 10, 3.

The community-engaged building engineering projects have been driven by Quality Education (SDG 4) and Partnerships for the Goals (SDG 17), as shown in Figure 4. 'Learning by doing' engineering education enhanced students' learning and engagement, as community partners/users could provide real learning problems and contexts for the students and benefit from the results. Furthermore, the partnerships between the engineering students and the community organisations set out the building blocks of engineering knowledge and skills and the underlying processes—from initial engagement with a community organisation, through communication and leadership, to project and partnership review. These building blocks were necessary to maximise the impact of the community-engaged projects and ensure that these partnerships led to positive changes related to the creation of a more sustainable society, planet and economy.

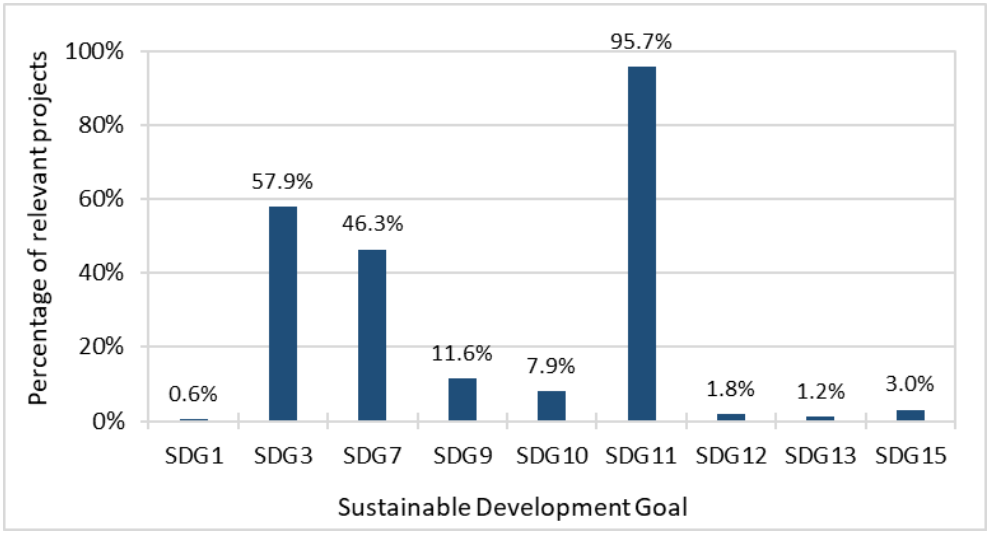

Figure 3. Relevance of community-engaged projects (2014–2021) to SDGs.

Figure 4. The gears of community-engaged building engineering projects.

3.2. Community Partner Feedback

The results of seven feedback surveys (qualitative analysis) carried out among community partners showed that the majority of the students' interactions, communication and cooperation were excellent (average 59%), with an average of 13% of partners expressing room for improvement in this aspect (Figure 5). No community partner felt that the students interacted, communicated or collaborated in a poor manner through the projects. Furthermore, the majority of the community partners found the students' reports very useful (average 54%) and stated that they would carry out the recommendations suggested in the reports (average 86%) (Figure 6).

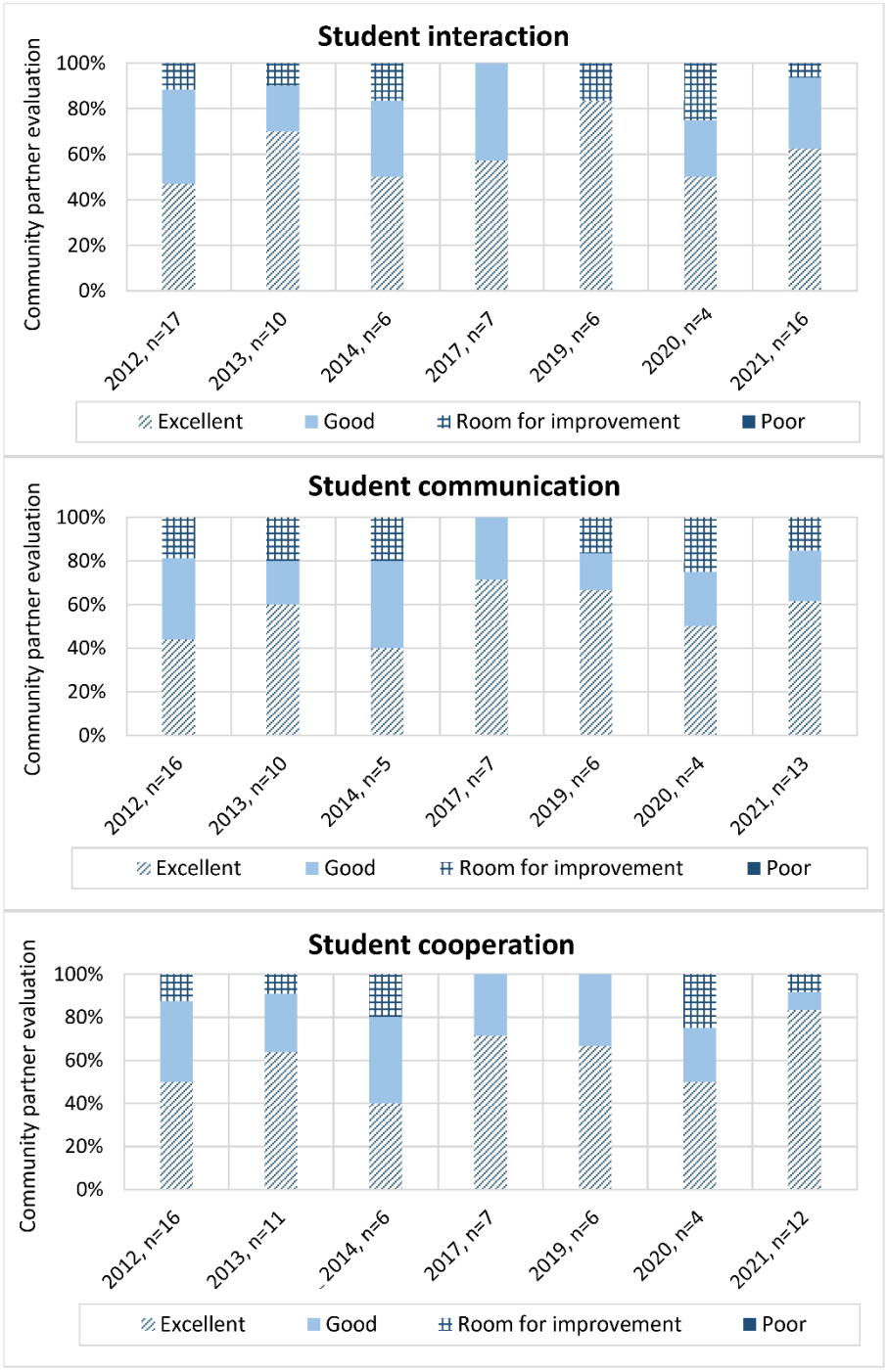

Figure 5. Evaluation by community partners of students' interactions, communication and cooperation.

In terms of the positive aspect of the project set-up, the community partners mentioned:

- 'In a time of economic hardship and challenging times for everyone, this [module] gives a great opportunity for students to get involved in real life projects that will make a difference to the service we provide' (community partner feedback, 2021).
- 'We now have concrete plans to develop our strategy. Being able to show stakeholders a building plan makes things very real, rather than just a concept. Given our limited budgets, we would not be this far advanced without your help' (community partner feedback, 2021).

- 'Fantastic to experience cross disciplinary work and I have the sense that the Engineering students benefitted from visiting and engaging with homeless services' (community partner feedback, 2014).
- 'Makes projects possible that could not be afforded otherwise' (community partner feedback, 2013).
- 'It's great that students can give something back to the community as part of their course, it's a boost for the project and vital real world learning experience for the students' (community partner feedback, 2012).
- 'It was rewarding to work with young people' (community partner feedback, 2012).

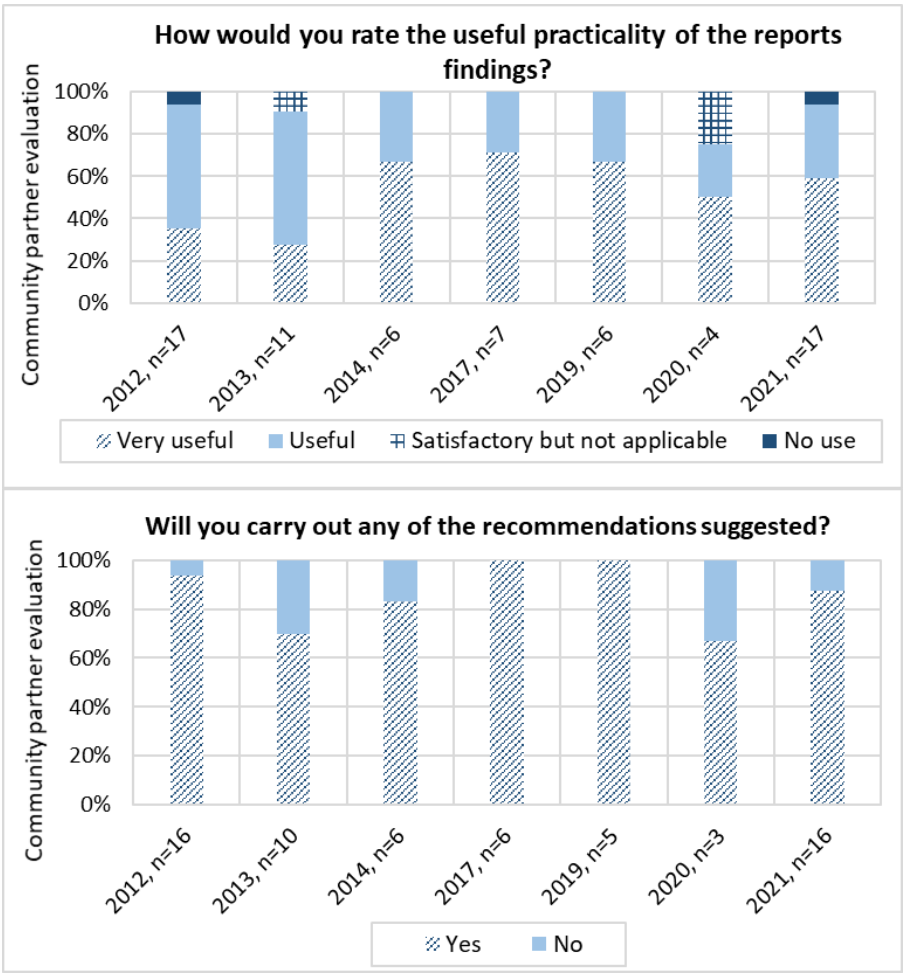

Figure 6. Evaluation by community partners of the usefulness of project reports.

When asked whether they would be interested in working with engineering students from the University of Galway again, as part of a community-engaged project, an average of 93% of community partners responded 'yes', while the remainder were undecided (Figure 7). No community partners claimed that they would not become involved in the projects again.

The community partners also made some suggestions for improvement, including extending the timeframe for the projects, incorporating the community-engaged projects into undergraduate and postgraduate research projects and disseminating and communicating the projects' results to the general public to show how engineering students contribute to the wider community.

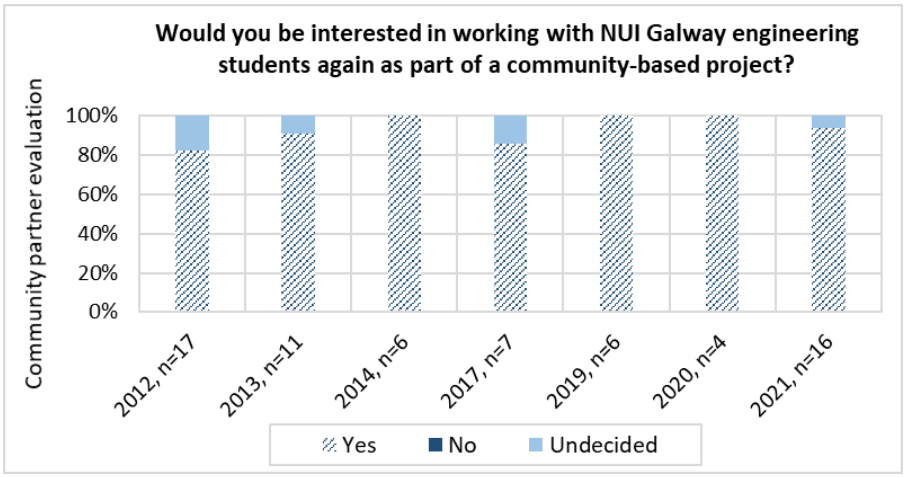

Figure 7. Community partners' interest in being involved in community-engaged projects again in the future.

3.3. Student Feedback

The feedback from the students was very important in the development of the community-engaged projects module in 2009 and has continued to help the module's improvement to date (e.g., inviting community partners to final presentations or increasing ECTS credits for the project from 2 ECTS to 5 ECTS).

In the first year (2009), the projects ran as a pilot, in which it was optional for the students to undertake a community engaged project. After analysing the feedback from the students, it was decided to make it mandatory for all the students in Civil Engineering and Project and Construction Management to complete a community-engaged project in the second year of their degree programme (Energy Systems Engineering students undertook the projects from 2011). In 2011, a grouped student evaluation was carried out, in which the students were asked to complete the survey in groups. Since 2012, the students have been asked to complete an online survey at the end of the module.

During the pilot run of the community-engaged projects, the students felt that they had received enough support from their lecturers and the community partners they worked with. Half of the students who completed the community-engaged projects felt that they had to spend more time working on their projects than if their project had not been community-engaged. It was apparent that the students who completed the community engaged projects were exposed to similar challenges to their professional counterparts. These included difficulties in organising meetings, learning to deal with deadlines and being responsible to clients (in this case, the community partners). It was interesting that feeling responsible to the community partner was described as negative by some students, since they felt under pressure and were forced to work harder in order to produce high-quality projects that met the needs of their community partners. It was, however, a valuable experience for the students for their future careers as engineers.

In the feedback surveys, the students described their experiences with community engaged-learning in the following terms:

- '[I feel I gained a lot] working as a team, looking into a project that we choose without much instruction' (student feedback, 2012).
- 'I feel that I gained more of a social experience from the project than engineering experience' (student feedback, 2012).
- '[I liked the] sense of freedom to an extent, chance to do meaningful work and explore an area of interest' (student feedback, 2019).
- 'I liked the hands-on nature of the project' (student feedback, 2019).
- 'I feel as if I have actually completed an engineering project that will be relevant to my future studies. The teamwork, engineering and presentation skills developed exceeded my expectations' (student feedback, 2019).

- 'I enjoyed getting a look at real world engineering practices. It was very beneficial to see how professionals operate in the real world (outside college). It was set up excellently; we had freedom to choose our own projects and had full control over the project. Letting us do the work ourselves allows both lecturers and community partners to see the quality of work which we are capable of doing' (student feedback, 2021).
- '[I gained] a real insight into the benefits by engaging with a community partner and working together to put a plan in place and execute it' (student feedback, 2021).

4. Discussion

Our society faces many challenges, such as poverty, inequality, climate and environmental degradation, lack of prosperity and insufficient peace and justice, which must be tackled at international, national and local levels to create a better and more sustainable future. Engineers play a significant role in tackling these challenges. Furthermore, considering climate change and biodiversity degradation, engineers are uniquely placed to utilise advanced methods and tools to reduce resource depletion by increasing the efficiency of infrastructure, products and systems during their full life cycle.

Engineering students are more motivated when they can see that their work has an impact on others [58,59]. Introducing community-engaged learning into an engineering degree programme is a very effective way to fulfil the Washington Accord programme requirement to provide a 'comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability' [35].

5. Conclusions

The evidence collected from 12 years of facilitating community-engaged building engineering projects has shown that, by creating community-engaged learning, students' enthusiasm can have a positive impact on communities. Students' energy and enthusiasm can be better utilised by setting assignments as real community projects. Through the projects discussed in this study, the students obtained a sense of pride and satisfaction from the knowledge that their work might have helped the communities. The projects increased the students' sense of ownership of their learning. Furthermore, the projects allowed the students to achieve all of the programme outcomes specified for an accredited engineering degree, while promoting the sustainability agenda at the same time. Finally, the students recognised the long-term value of engaging with community partners, understanding their future role as engineers, reinforcing the idea that their work responds directly to the real needs in the community.

Generally, the community partners found that their interactions and communication with the students was excellent. The technical reports delivered by the students were useful to the community partners, who were interested in carrying out the recommendations. Finally, the vast majority of the community partners were interested in being involved in the projects again in the future.

The qualitative feedback received over the past 12 years, from both the students and the community partners, was extremely valuable in shaping and improving these community-engaged engineering projects. The inclusion of feedback in the module's development led to tailor-made engagement between the lecturers, students and community partners, which enabled the education of engineers as change agents for a more sustainable future.

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