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# Bridging education and action: Student-driven experiential learning in achieving sustainable development goals

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**ABSTRACT**

This project emphasizes experiential learning outside the classroom, as a cornerstone of advancing Sustainable Development Goals, focusing on the reuse of brewing industry by-products- specifically spent grain- as organic fertiliser for winter broad bean cultivation (*Vicia faba*). By integrating hands-on collaboration with local allotment communities, the initiative fostered participatory learning in sustainable agricultural practices, bridging theoretical knowledge with real-world application. While the study explored spent grain's potential to improve plant growth and reduce reliance on synthetic fertilisers, its main contribution lies in demonstrating how student-driven experimentation can drive progress towards circular economies and competency development. Over 14-week period students engaged on university campus-based allotment site trialling spent grain, in growing winter broad bean, sharing observations on plant development and yield outcomes. Though results indicated modest differences in final yield between treated and control groups, the experiential process highlighted spent grain's practical viability as a low-cost resource while empowering participants to adopt and advocate for sustainable waste-reduction strategies. This approach emphasises the crucial role of grassroots education and skill-sharing in scaling eco-friendly practices, aligning with SDG goals focussed on inclusive, lifelong learning and responsible resource use. The findings advocate prioritising experiential frameworks to amplify educational impact.

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## INTRODUCTION

Although global challenges such as climate change, social responsibility, and misinformation are becoming increasingly complex, there is growing concern that students in higher education are not sufficiently developing social responsibility or critical thinking skills—qualities essential for meaningful contributions to society (Mairitsch *et al.*, 2023). Academic programs often emphasize technical proficiency and disciplinary knowledge, yet may overlook the cultivation of ethical awareness, civic engagement, and nuanced analytical abilities (Ali *et al.*, 2021; Richards and Spanjaard, 2025; Gómez and Suárez, 2023). This disconnect manifests as limited opportunities for students to engage with real-world societal issues, resulting in a diminished understanding of their responsibilities as ethical participants within local and global contexts. Moreover, curricula frequently lack comprehensive integration of equity, sustainability, and civic duty, potentially leaving graduates ill-prepared to address systemic injustices or collaborate effectively across diverse perspectives. Many students experience difficulty in critically evaluating information, identifying source biases, and synthesizing interdisciplinary insights, increasing susceptibility to misinformation and superficial analyses. Predominant pedagogical models that prioritise rote memorization over inquiry-based learning can further inhibit creativity, ethical reasoning, and adaptability in ambiguous situations. As a result, graduates may enter professional and civic life underprepared to tackle multifaceted problems, make ethically informed decisions, or advocate for inclusive and sustainable practices. These shortcomings challenge higher education's mandate to cultivate engaged citizens and may contribute to widening societal divisions.

Hence educating students on Sustainable Development Goals (SDGs) is crucial for fostering a holistic understanding of their field's impact on global challenges (Ásványi and Gedeon, 2025). A trending concept is the principle of 'circular economy' that seeks to transform waste into useful resources through biological methods, maximising the use of materials that are often thrown away (Federico Savini, 2023). This not only addresses environmental concerns but also promotes economic sustainability. Biotechnological methods in waste management, such as bioremediation, composting, and biogas production, play a significant role in reducing pollution and conserving resources. These techniques help in the decomposition of organic waste, neutralization of toxic substances, and conversion of waste into energy, contributing to SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action).

In the current study an experiential learning model 'Bio Green' was incorporated into the curriculum to provide practical, hands-on opportunities for students to apply their knowledge in real-world settings. 'Bio Green' is a global initiative to engage and educate learners in Sustainable Development Goals (SDGs) that are crucial for engaging graduates on global challenges and to shape them as responsible life-long learners (Algurén, 2024). By integrating SDG education with experiential learning, students are better equipped to contribute to sustainable development and become innovative leaders in the biotechnology sector (Backman *et al.*, 2018; Blankesteijn *et al.*, 2024; Issa *et al.*, 2025). This holistic approach ensures that they are not only knowledgeable in their field but also socially and environmentally responsible.

Agricultural fertilization systems comprise organic and synthetic types, distinguished by origins and manufacturing. Organic variants utilize biodegradable materials like plant residues and animal byproducts, whereas synthetic fertilizers are industrially produced from finite resources including natural gas and phosphate rock—the latter requiring intensive extraction with growing quality concerns (Cordell and White, 2014). Synthetic formulations deliver targeted NPK nutrients that enhance crop yields, maturation rates, and pest resistance, as evidenced historically. However, their use poses environmental risks through nitrogen leaching causing eutrophication and groundwater contamination (Carneiro *et al.*, 2014), while atmospheric emissions of ammonia and nitrous oxide contribute to air pollution and respiratory hazards. The production-distribution lifecycle further exacerbates carbon emissions and plastic waste accumulation, highlighting critical sustainability trade-offs between agricultural efficiency and ecological preservation (Chojnacka *et al.*, 2019).

Brewing byproducts emerge as nutrient-dense organic fertilizer alternatives, with spent grains containing proteins, sugars, nitrogenous compounds, and a mineral profile encompassing Ca, Co, Cu, Fe, Mg, Mn, P, K, Se, Na, and S (Baiano and Fiore, 2025). This composition positions them as sustainable soil amendments, offering a renewable substitute for synthetic fertilizers (Arantes *et al.*, 2024; Uddin *et al.*, 2025). Building on their demonstrated agricultural potential, this study employed experiential learning methodologies to investigate optimal application conditions, aiming to maximize their viability as ecologically benign nutrient sources in diverse farming systems.

This study sought to evaluate experiential learning model utilizing actual spent grain waste generated by the brewing industry, which is commonly disposed of in landfills but being targeted currently as waste streams demonstrating circularity (Nassary and Nasolwa, 2019; Mainardis *et al.*, 2024). Participants assumed various roles to systematically address the management of this waste and collaboratively lead the project. Contextually this model would address the issue of using inorganic fertilisers and the stability of agricultural practices, using non-renewable resources.

## MATERIALS AND METHODS

### Formation of peer led model

Student cohorts were strategically organized into interdisciplinary teams through a skills-matrix assessment, ensuring balanced expertise across data analysis, communications, recruitment and organizational leadership. Peer leaders were assigned to four domains: data analysis, experimental design (hypothesis-testing rigor), media/advertising (outreach curation), and project management (timeline coordination). Student leads were identified based on their skills and expertise. This peer-led model was designed to enhance collaborative autonomy among student groups while integrating technical and leadership competencies through cyclical feedback and adaptive problem-solving. Recruitment of students on the project was conducted during welcome week and interactive workshops and advertising via social media. Biweekly meetings cultivated cross-domain proficiency, complemented by ethical protocols, and communication strategies. Iterative peer reviews with faculty and stakeholder panels guided refinements to experimental strategy and engaging with peers.

### Experimental plot preparation

A 7.5 × 5 m outdoor plot was partitioned into three rows (~2 m width each), separated by pathways. The left row received soil amendments of brewery spent grain (Neon Raptor Brewing Co.) mixed 1:1 with landscape bark, while the right row served as an unamended control. The central row, initially allocated for synthetic fertilizer testing, was omitted due to supply constraints. Ethanol residues in amended soil were mitigated via a 3–4 week incubation period under tarpaulin cover to concurrently suppress weeds and facilitate volatilization. Experimental boundaries were demarcated with string fencing. Post-incubation, winter broad beans were cultivated in the amended and control rows to assess growth differentials. Amendments were mechanically incorporated into the topsoil prior to the resting phase to optimize nutrient distribution and microbial activation. Simultaneously fifty-seven winter broad bean seeds were germinated in trays and grown to 5–8 cm. Fourteen plants were then transplanted into each of two active rows with even spacing.

### Data collection and analysis

Over a period of approximately 14 weeks, the plants were regularly monitored for phenotypic differences and yield. Plant height was quantified bimonthly to triweekly during the initial three-week period, followed by weekly measurements for eleven subsequent weeks, measured vertically from the soil surface to the apex of the tallest leaf. Irrigation was administered every 48 hours, with personnel assigned to rotating teams of 2–4 individuals to ensure consistent application. Post-measurement, plant height and leaf count data were systematically logged in Microsoft Excel until harvest. The final compiled dataset comprised longitudinal growth metrics and total bean yield (measured by fresh weight) per experimental group.

**Survey to evaluate learner experience on a project**

An anonymous survey was conducted on participants in the project to evaluate their experiences and peer dynamics on this collaborative project. The target population included all the participants who have active engagement in the project. The survey consisted of mixed methods of both closed and open-ended questions. The quantitative evaluation consisted of Likert-scale items (1 = Strongly Disagree, 5 = Strongly Agree). The survey also incorporated qualitative feedback. The data was collected via anonymous online Microsoft forms. Ethical considerations were taken into account by taking informed consent outlining the study's purpose, anonymity, and voluntary participation. A summary of the key findings were reported in this article.

**RESULTS**

The treated group (with added spent grain) consistently outgrew the control by about 1–2 cm during early growth (Fig. 1), ultimately reaching 20.9 cm versus the control's 18.8 cm. The treated group showed steady growth, while the control group's growth was more variable with some sharp increases over three weeks.

In Fig. 2, the treated group began with nearly twice as many leaves as the control group but showed a slight decline over time. The control group steadily increased its leaf count and surpassed the treated group after three weeks.

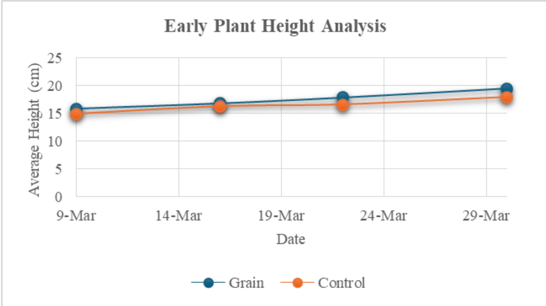


**Fig. 1.** Observed average plant heights (cm) in both the treated and control groups (weeks 0 to 3)

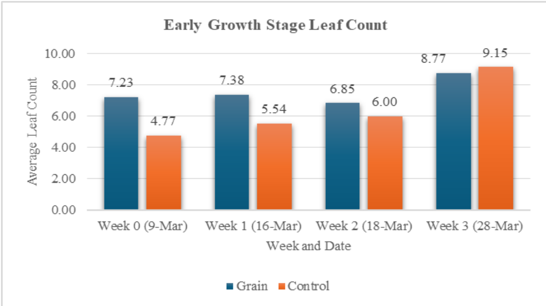


**Fig. 2.** Observed average leaf count in both in both the treated and control groups (weeks 0 to 3).

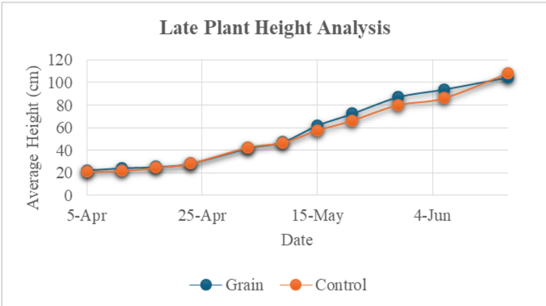


**Fig. 3.** Observed average plant heights (cm) from weeks 4 to 14

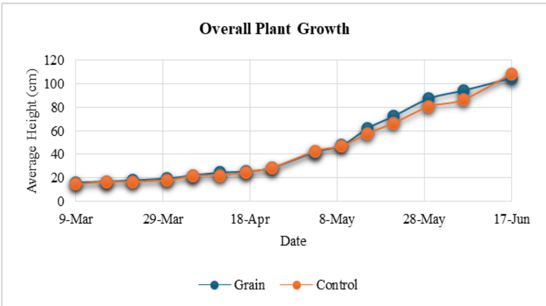


**Fig. 4.** Overall observed average plant heights (cm) over 14 week period

Fig. 3&4 show that both the treated and control groups started at similar heights (22.1 cm vs. 21.4

cm). After minor fluctuations, the treated group showed and increase with an of 6.27 cm through to the end of the late growth stage.

The final average bean yield was 196.75 g per plant for the treated group vs 201.75 g per plant for the control group (Fig. 5).

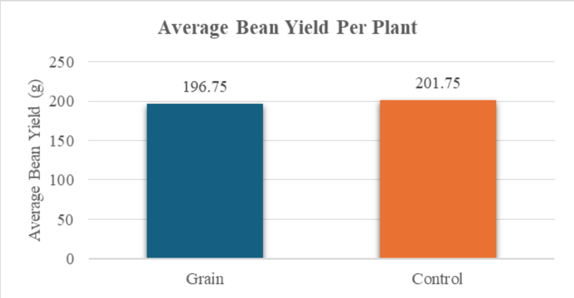


**Fig. 5.** Average final yield of beans (g) harvested from treated and control

### Impact on learner journey

A survey found that 82% of participants had a positive learning experience, 91% felt a stronger campus community, and 77% could apply curriculum knowledge. Additionally, 59% saw improved academic performance, 91% gained global insights, and 85% developed valuable career skills like management, problem-solving, and teamwork. Neutral responses mostly came from new entrants (Fig. 6).

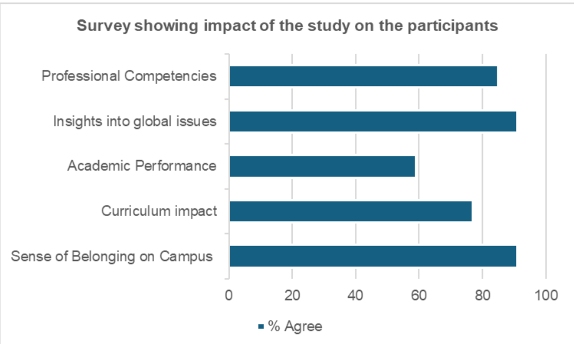


**Fig. 6.** Clustered bar chart illustrating the impact of experiential learning on all participants, including student leads and those involved in the real-time study

### Qualitative evaluation anonymous comments from project participants

'The project has been a fantastic opportunity for me to develop my skills, both in project management and design. I have been able to work with fantastic people and come up with solutions to global issues and waste issues which could potentially leave a long-lasting impact.'

'It was a great project to be part of with an amazing goal in mind. Thank you for the opportunity; we all got to interact with many people and work together towards sustainability.'

'This opportunity helped a lot with team building and communication skills, the focus on sustainability was the highlight of this project and being able to work with different people was very rewarding.'

'Super excited and honoured to be a part of such an amazing and enthralling project.'

'The project has enhanced my understanding of sustainability, improved my teamwork skills, and provided opportunities to connect with like-minded individuals.'

'Networking with people coming from various different backgrounds, making it a diverse community as a whole.'

## DISCUSSION

Over the course of 14 weeks, data collected from both the control and treated groups (supplemented with spent grain) provided useful insights into plant growth and yield performance. At first glance, the control group appeared to perform better overall, with a slightly higher final bean yield and leaf count. However, a closer look at the graphs reveals a more complex and interesting picture of the plants' development across different stages.

The observed growth patterns align with established principles of plant nutrition and resource allocation. The treated group early height advantage likely reflects accelerated nitrogen mineralization from spent grain amendments, promoting vegetative growth through bioavailable macronutrients (N, P, K) and trace minerals (Fe, Mg, etc.). The control group's erratic early growth suggests nutrient limitation stress, with compensatory leaf production later facilitated by possible mycorrhizal adaptation or root biomass investment. The treated group's sustained height dominance correlates with organic matter's gradual nutrient release, supporting steady development—a documented benefit of organic fertilizers over synthetic counterparts. However, the control group's marginally higher yield aligns with the "dilution effect" hypothesis, where rapid vegetative growth in amended soils can reduce reproductive allocation (beans vs. stems). The narrow yield gap (5g) underscores environmental trade-offs: organic amendments enhance stress resilience and early biomass but may not maximize final yield under non-limiting conditions. These findings mirror studies on nutrient-use efficiency, where carbon partitioning priorities shift with soil nutrient dynamics.

In summary, while the control group achieved a marginally higher final yield and leaf count, the treated group consistently demonstrated stronger early growth, greater average plant height for most of the experiment, and reliable development. In many data points, the treated group matched or outpaced the control group. The spent grain medium used by the treated group likely provided steady nutrient support that contributed to this consistency. This could make it a favourable option for crops where uniform vegetative growth or earlier harvesting is important.

This project demonstrated the potential of using spent grain as a sustainable organic fertiliser. Although the final yields between both the tested groups were similar, the spent grain group showed more consistent early growth and stable development. While final yield differences were minimal, the reliability of growth in the treated group suggests that spent grain could be especially useful in environments with limited access to commercial fertilisers. The findings overall suggest that spent grain can offer a low-cost, eco-friendly alternative to synthetic fertilisers. It can promote a slower, sustained nutrient release which can contribute to the healthier development of crops. In a broader sense, it can reduce dependency on non-renewable resources and support the circular economy by repurposing industrial waste.

Further spent grain obtained from Neon Raptor Brewery, was offered as an alternative to manure at local allotments. There was positive engagement with the allotment community, with three members choosing to trial the spent grain on their plants. While no formal data was collected by the volunteers, they reported positive responses in how their plants reacted to the grain. The positive responses from the community engagement further indicates a growing interest in sustainable gardening practices. Future research should build on this work by expanding the study to include a wider range of crop types, soil conditions, and seasonal variations. Engaging more local growers, allotment holders, and small-scale farmers would not only strengthen the practical understanding of spent grain's effectiveness but also help shape it into a viable, community-driven solution for sustainable agriculture. Future efforts could expand community involvement in this project as more scientific data becomes available. This might include involving additional allotments and local farmers to trial spent grain and gathering objective data from participants for pilot testing. These steps could further connect the project with the local farming community and promote sustainable agriculture.

The BioGreen project, launched in the UK, has expanded globally. Of participants, 98% became aware of waste and zero waste concepts through the workshop, while 88% plan to pursue sustainability activities on their campuses. The integration of experiential pedagogy into academic frameworks demonstrated measurable enhancements in learner participation and competency acquisition (McPherson *et al.*, 2016). These opportunities foster practical application of knowledge in real-world settings, enhance critical thinking, promote peer connections, provide opportunities for growth and self-discovery, allowing students to build confidence and a sense of belonging (Lee and Perdana, 2023; Pretorius *et al.*, 2021). Such models enhance metacognition, empower students to embrace their accomplishments and mitigate the effects of imposter syndrome (Faming Wang and Ronnel King, 2025). Empirical evidence revealed that such pedagogical strategies effectively nurtured analytical reasoning, collaborative capacities, and communal cohesion, while concurrently advancing comprehension of the United Nations Sustainable Development Goals (Sulkowski *et al.*, 2020; Wu *et al.*, 2025; Stuckrath *et al.*, 2025).

Quantitative assessments indicated substantial outcomes, with 82% of learners endorsing beneficial engagement outcomes and 91% affirming strengthened institutional affiliation.

Notably, this educational paradigm cultivated student-led sustainability advocates who developed peer education initiatives, disseminated instructional materials and empowered social entrepreneurial skills (Issa *et al.*, 2025). The model's cross-cultural applicability was evidenced through successful global implementation, catalysing transformative learning practices among both students and faculty. These curricular innovations complemented conventional academic instruction by bridging theoretical knowledge with practical applications, thereby fostering workforce preparedness through multidimensional skill development and heightened consciousness of transnational challenges. Therefore, Higher education institutions should update curricula, teaching methods, and assessments to emphasize social responsibility and critical thinking, preparing students with the skills and values needed for equitable, evidence-based progress in today's world.

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**REFERENCES**

**Algurén B.** 2024. Toward behavioral learning outcomes: A case study of an experiential learning approach and students' self-reported facilitators and barriers for pro-environmental behavior. International Journal of Sustainability in Higher Education **26**(9), 265–280.

**Ali M, Mustapha I, Osman S, Hassan U.** 2021. University social responsibility: A review of conceptual evolution and its thematic analysis. Journal of Biological Education **286**, 124931.

**Arantes da Fonseca Y, Fernandes ARA C, Gurgel LVA, Baêta BEL.** 2024. Comparative life cycle assessment of early-stage technological layouts for brewers' spent grain upcycling: A sustainable approach for adding value to waste. Journal of Water Process Engineering **66**.

**Ásványi K, Gedeon E.** 2025. Enhancing sustainability consciousness in higher education: Short- and long-term impacts of a project-based learning approach. The International Journal of Management Education **23**(3).

**Backman M, Pitt H, Marsden T, Mehmood A, Mathijs E.** 2018. Experiential approaches to sustainability education: Towards learning landscapes. International Journal of Sustainability in Higher Education **20**(1), 139–156.

**Baiano A, Fiore A.** 2025. Development and characterization of brewers' spent grain-based materials. Circular Economy **4**(3).

**Blankesteijn ML, Houtkamp J, Bossink BAG.** 2024. Towards transformative experiential learning in science- and technology-based entrepreneurship education for sustainable technological innovation. Journal of Innovation & Knowledge **9**(3).

**Carneiro C, Vitorio Andreoli C, de Lourdes da Nobrega Cunha C.** 2014. Reservoir eutrophication: Preventive management. 1st ed. London: IWA Publishing.

**Chojnacka K, Kowalski Z, Kulczycka J, Dmytryk A, Górecki H, Ligas B, Gramza M.** 2019. Carbon footprint of fertilizer technologies. Journal of Environmental Management **231**, 962–967.

**Cordell D, White S.** 2014. Life's bottleneck: Sustaining the world's phosphorus for a food secure future. Annual Review of Environment and Resources **39**(1), 161–188.

**Gómez RL, Suárez AM.** 2023. Pedagogical practices and civic knowledge and engagement in Latin America: Multilevel analysis using ICCS data. Journal of Biological Education **9**(11), e21319.

**Issa HEA, Thai MTT, Saad S.** 2025. Empowering social entrepreneurial intentions through experiential learning and self-efficacy. The International Journal of Management Education **23**(2), 101154.

**Lee WE, Perdana A.** 2023. Effects of experiential service learning in improving community engagement perception, sustainability awareness, and data analytics competency. Journal of Accounting Education **62**, 100830.

**Mainardis M, Hickey M, Dereli RK.** 2024. Lifting craft breweries sustainability through spent grain valorisation and renewable energy integration: A critical review in the circular economy framework. Journal of Cleaner Production **447**.

**Mairitsch A, Sulis G, Mercer S, Bauer D.** 2023. Putting the social into learner agency: Understanding social relationships and affordances. International Journal of Educational Research **120**, 102214.

**McPherson S, Anid NM, Ashton WS, Hurtado-Martín M, Khalili N, Panero M.** 2016. Pathways to cleaner production in the Americas II: Application of a competency model to experiential learning for sustainability education. Journal of Cleaner Production **135**, 907–918.

**Nassary EK, Nasolwa ER.** 2019. Unravelling disposal benefits derived from underutilized brewing spent products in Tanzania. Journal of Environmental Management **242**, 430–439.

**Pretorius RW, Carow S, Wilson G, Schmitz P.** 2021. Using real-world engagements for sustainability learning in ODeL in the Global South: Challenges and opportunities. International Journal of Sustainability in Higher Education **22**(6), 1316–1335.

**Richards J, Spanjaard D.** 2025. It's more than just internships, placements, and guest lecturers: Partnership pedagogy in practice. Journal of Biological Education **36**, 100545.

**Savini F.** 2023. Futures of the social metabolism: Degrowth, circular economy and the value of waste. Futures **150**, 103180.

**Stuckrath C, Rosales-Carreón J, Worrell E.** 2025. Conceptualisation of campus living labs for the sustainability transition: An integrative literature review. Environmental Development **54**.

**Sulkowski AJ, Kowalczyk W, Ahrendsen BL, Kowalski R, Majewski E.** 2020. Enhancing sustainability education through experiential learning of sustainability reporting. International Journal of Sustainability in Higher Education **21**(6), 1233–1247.

**Uddin MK, Saha BK, Wong VNL, Patti AF.** 2025. Organo-mineral fertilizer to sustain soil health and crop yield for reducing environmental impact: A comprehensive review. European Journal of Agronomy **162**.

**Wang F, King RB.** 2025. Socio-emotional skills matter for academic resilience: A global perspective. Learning and Individual Differences **123**, 102758.

**Wu T-T, Sari NARM, Putri APRZ, Chen H-R, Huang Y-M.** 2025. Fostering undergraduate accounting students' educational attainment through CT-enhanced collaborative project-based learning. The International Journal of Management Education **23**(3).