A compensatory pedagogical intervention through the lens of sustainability for equity-driven education

A Compensatory Pedagogical Intervention through the Lens of Sustainability for Equity-Driven Education

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Abstract

This study presents course-based undergraduate research framed within sustainability as an effective tool for active learning and a compensatory pedagogical intervention aimed at promoting equity in engineering education. This collaborative experience positions students at the heart of the learning process, fostering equitable education through its compensatory impact. The objectives include bridging the achievement gap, increasing graduation rates, and cultivating students' enthusiasm and readiness for future academic and professional pursuits. The study first presents an initiative called the "course-based undergraduate sustainability research experience (CUSRE)" as a central methodology in teaching two undergraduate courses at the University of Ottawa, Canada. Students worked collaboratively in small groups to acquire key skills and sustainable development (SD) knowledge through student-directed personalized research cases and projects. This learning experience yielded substantial knowledge gains and a high success rate. The intervention was expanded and tailored to the Global Banking School in the UK, making it more suitable for a wider audience. The results support a collaborative teaching environment and promote fairer assessments.

1 Introduction

There is growing awareness that despite efforts to promote equality, schools often perpetuate various inequalities resulting from disparities along different lines. Educational equity usually highlights the inseparable nature of these disparities (OECD, 2023). Accordingly, equity-driven learning (EDL) can counteract broader inequalities, promote fairness and inclusion, and allow all students to benefit from education regardless of their disadvantages.

EDL is about meeting the needs of every student, without challenging the structure and mechanism of the learning process, by involving equal access and outcomes (Cabral-Gouveia, 2023). It aims to provide an equal opportunity for all students, including those with different disadvantages, especially those attributed to socioeconomic status, race, ethnicity, gender (Kinzie et al., 2008), or those with varying learning styles. The focus of EDL should be to promote equity-mindedness. This involves the viewpoints of educators who acknowledge and tackle disparities in student outcomes, explore the contributing factors, and take actions, often with personal and institutional accountability, to amend them (Murrihy, 2017).

Educational innovation towards equity measures learning potential (fairness) and ensures that all students obtain at least a basic level of knowledge and skills (inclusion). To successfully achieve that, educators must have equity-mindedness to understand the strategic importance of combining values and knowledge pathways. Establishing and implementing such a culture is the key to supporting students in directing their

learning. Some important factors to adapt and implement include mindset, engagement and assessment structures. This is crucial in decreasing grade repetition, increasing study completion, and narrowing the achievement gap, all of which refer to observed patterns of inequity in student outcomes.

An effective way to supplement effective learning is by introducing small group-based tasks as an intervention strategy. These participatory tasks serve as performance-based compensatory mechanisms that encourage students to collaborate and succeed. According to Sleeter (2007), compensatory pedagogy is a strategy to manage social and cultural diversity by providing extra resources or special treatment for deprived groups. An increase in group performance occurs when one or more members work harder to compensate for their fellow members' real or imagined shortcomings. The above intervention strategy can be realized through a collaborative research-based curriculum (RBC). This implies the application of learning and teaching interactive and active approaches that link research with teaching (Noguez, and Neri, 2019). In this sense, research is meant to challenge and explore new ideas. Various methodologies have been proposed to operate under RBC, including case studies (Habash, 2024a) where students interact actively with their teachers, develop research questions, and investigate tools to generate solutions.

Many academic institutions support the integration of research-based curriculum (RBC) into various study programs due to its compensatory effects or other reasons. However, most institutions lack the resources to involve all or most undergraduates in research (Adebisi, 2022). In addition, the traditional approach to RBC is for a few students only, typically juniors or seniors, to work closely with a professor on a research project outside of class in the academic year or over the summer (Hansel, 2018). Collaborating with faculty on research offers students a transformative experience, enabling them to think and question like scientists while building skills to explore the world and discover their place within it (Kardash, 2000).

Ensuring every student can participate in research addresses implicit bias and educational inequity. Several university faculty members tackled this issue by developing alternative methods to involve all students in research and extend these educational benefits to a larger number of individuals (Wei and Woodin, 2011). This inequity of the traditional RBC may be addressed by what is called a course-based undergraduate research experience (CURE). Early research has demonstrated that CURE can provide several benefits to faculty members. These benefits include a closer integration of teaching and research, which can positively impact promotion and tenure. Participation in CURE can also lead to research publication in conference proceedings and journals, and a greater impact on research programs. Additionally, faculty members can benefit from identifying, recruiting, and training students to join their research labs, which can help foster a productive and successful research environment (Fukami, 2013). Importantly, there is currently no specific CURE in the literature addressing engineering education.

This study may be among the first to propose an enhanced model of CURE in engineering through the lens of sustainability. The proposed “course-based undergraduate sustainability research experience (CUSRE)” was implemented at the University of Ottawa, Canada in late 2023 and 2024. The CUSRE promotes sustainability as a value and practice in a second-year “Professional Practice” course and a fourth-year “Power Engineering” course. The study offers insights into the CUSRE methodology and the compensatory pedagogical intervention for educational equity. This intervention was scaled and adapted to a British educational context, making it more relevant to a broader audience.

2 Sustainability Dimension

Sustainability is a wide-ranging concept that is transversal across disciplines, education, and professions and may be anchored in the analysis of social, economic, and environmental (Duarte et al., 2020) and ethical dimensions. It has become a critical goal for contemporary humanity, and engineering is widely viewed as the primary means for achieving sustainability. As noted by Carew and Mitchell (2008), sustainability encompasses both factual and value-based components. It is more than the sum of these components; it is a way of creating knowledge and learning that goes beyond. Sustainability in education should be a key philosophical endeavour, grounded in the concept of "eudaimonia" from Aristotelian virtue ethics, which encompasses well-being, happiness, and flourishing (Cirkony et al., 2023).

An effective way to incorporate sustainability into education and research is by adopting the 17 interweaving SD goals (SDG) that make up the United Nations 2030 Agenda. These SDGs are aspiring to achieve a more equitable, inclusive and healthy world (Habash, 2024b). To directly participate in furthering the fourth SDG (Quality Education), the three functions of the higher education sector, knowledge acquisition, knowledge creation, and knowledge dissemination, can be harnessed to support all the SDGs (Parr, 2022). Among those who can impact this is the upcoming cohorts of engineering graduates who can play a crucial role in shaping sustainability for socio-technical development. This requires the education system to consistently impart the necessary pedagogies for envisioning sustainability as an ethical value to guide action in knowledge production. Among the principal spaces for knowledge production are universities. In this regard, the CDIO framework, which follows a “conceive, design, implement, operate” approach, has been updated to include new educational practices such as RBC and SD (Malmqvist et al., 2000).

To achieve such inclusivity, it is important to recognize that there is a range of past experiences to build upon for viable sustainability research and education, but with no clear reference to the ethical dimension. Arizona State University (ASU, 2024) has established a Sustainability Undergraduate Research Experience (SURE) program that provides students with research opportunities to help build career skills and enhance their competitiveness for jobs and graduate school. Stanford University developed the Sustainability Undergraduate Research in Geoscience and Engineering (SURGE) program for students from any U.S. institution interested in Earth and environmental sciences, energy, ocean sciences, or civil engineering. The University of California at Los Angeles (2024) founded the Undergraduate Research Scholars Program (URSP) as a signature undergraduate course of the sustainable grand challenge. The URSP unites undergraduate students across all disciplines in their research experiences in urban sustainability.

3 Collaborative Learn-by-Research

The curriculum is thoughtfully designed to create a robust integration of sustainability and engineering through a research-oriented approach. This is accomplished through dedicated support modules, the nature of the challenges presented, and the expectations set by the instructor. To guarantee that students receive a well-rounded learning experience, a variety of teaching strategies and assessment methods were implemented during the 12 guided teaching sessions. These methods included daily attendance, online and offline interactions, two multiple-choice question (MCQ) tests, four research case studies, and a project consisting of three components: a proposal, a video presentation, and a research paper (Figure 1).

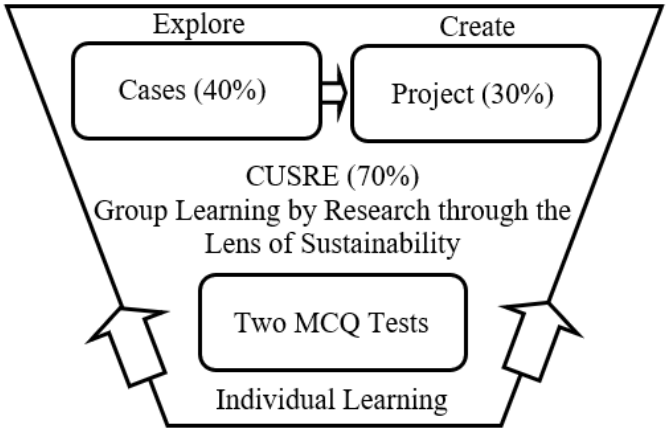

Figure 1: Course learning tasks with CUSRE as a central methodology.

This study considers two undergraduate electrical engineering courses taught by the first author: a second-year "Professional Practice" course (72 students) and a fourth-year "Power Engineering" course (60 students). In 2024, a CUSRE was assigned for each course. In CUSRE 1, students learn about education for SD by investigating its factual and ethical knowledge. In the advanced CUSRE 2, students explore how intelligent technologies support the development of sustainable power systems through research replication focusing on design and simulation. Sustainability differentiates CUSRE from CURE and SURE and strengthens the case for choosing CUSRE as the preferred method for the course's pedagogical design.

A central aspect of each CUSRE is active learning through which students engage in research activities and reflect on their experiences about the intended learning process and personal development. According to Tormey et al. (2015), active learning can deepen the acquisition of knowledge, support the development of competencies, and foster the realignment of values as learners put theory into practice. This learning, in the concept of 'teach less, learn more', is a teaching method that involves engaging students in the learning process through activities (Jaroenkhasemmeesuk et al., 2023) including case studies, flipped classroom, simulations and gamification, peer teaching, debates and discussions, brainstorming sessions, field trips and site visits, and other collaborative activities that encourage students to take an active role in their learning.

Finally, an important aspect of active learning design is the distinction between the planned curriculum (what is intended to be taught) and the actual curriculum (what students end up learning). Some of this difference is attributed to a "hidden curriculum" (Tormey et al. 2015) which refers to the implicit learning that occurs during implementation. Many research experiences involve the implicit development of skills that naturally emerge from participating in the learning process.

4 Compensatory Pedagogical Intervention

Two major research questions of this study are (1) How does course-based collaborative research impact educational equity and students' awareness of SD? (2) How can this pedagogical intervention help reduce the achievement gap and boost success rates? These are addressed in the following sections.

4.1 CUSRE 1: Knowledge-based Research

An anonymous survey of students of the second-year course on "Professional Practice" was conducted to evaluate the effectiveness of RBC in an authentic learning environment. Data from the multiple-answer survey showed that 67% enjoyed the research cases compared to projects (40%) and tests (30%). The students preferred the CUSRE directly related to SD, with 52% approval. About 78% of students appreciated the opportunity to choose their topic of research within the CUSRE. Approximately 96% of students recognized the significance of professional social responsibilities in enhancing society, engaging with the community, fostering racial understanding, and assisting those in need. Among students who have historically been excluded from research opportunities (before 2024), there was an 11% equity gap between low-achieving and high-achieving students; however, this gap has been narrowed to around 7%.

4.2 CUSRE 2: Design-based Research

An anonymous survey of students for the fourth-year course on "Power Engineering" was conducted to evaluate the effectiveness of design-based research as an approach for realizing real-life solutions that "by design" crisscross the sustainability practice space. 91% of the students were excited about the applied knowledge gained through sustainability. Most of students regarded the CUSRE as useful and successful in realizing the importance of engineering design for sustainability. About 92% of the students "strongly agreed, just agreed, or slightly agreed" with the impact of the educational video creation and article writing exercise. While the process can bring satisfaction, it may also lead to some students' unease due to the responsibility placed on them for their learning tasks. Historically, students who were excluded from research experiences (before 2024) faced an 11% equity gap between low-achieving and high-achieving students; however, this gap has since narrowed to approximately 4%.

5 Scaling and Adapting the Intervention

The authors have considered expanding on how the intervention can be scaled or adapted to different educational contexts beyond the University of Ottawa and making it more applicable to a broader audience. For this task, the second author examined how some non-traditional students (adults), such as those studying construction management at the Global Banking School (GBS) in London, UK, find the learning and research environment inspirational and supportive, primarily due to its collaborative nature and subsequent assessment. Accordingly, three groups of students studying three modules required by the program, which is delivered in partnership with Bath Spa University, were selected to research the impact of collaborative learning on the assessment outcome. The three selected modules, "Preparing for a Professional Career, Environment and Sustainable Issues, and Professional Practice," have been offered at three different levels of study from Level 3 to Level 5. For this intervention, each of the three

selected modules has been assessed using two different strategies: group assessment (GA) and individual assessment (IA).

A questionnaire was shared with 110 undergraduate learners enrolled in each of the modules. It offers five possible options for scaling 20 statements. The questionnaire addresses issues related to assessments offered during traditional lectures and using online resources with a sequence of carefully designed online tasks, aimed at lessening the impact of the assessment style.

Feedback from learners on the questionnaire highlights that GA offers students the opportunity to share their learning experiences while fostering essential employability skills such as teamwork, communication, and leadership. The responses reflect how GA promotes a collaborative learning environment, which not only enhances student engagement but also facilitates deeper learning and the development of analytical and cognitive skills through the review of peers' work. It also helps reduce social isolation, especially for first-year students, as the digital era can intensify feelings of loneliness and disconnection from real-world relationships. Unlike GA, the feedback from IA offers insights into how the assessment delivers personalized feedback, enabling learners to demonstrate their knowledge in various ways and fostering self-reflection, which ultimately improves personal learning outcomes.

The intervention was assessed using two types of data: server statistics of successfully submitted coursework requests for marking (summative assessment) after four weeks of teaching on Moodle. Server statistics were examined with the frequency distribution tool to enable practical comparisons between individual and group data. This tool helped to analyze how learners in the three groups performed during GA compared to IA and to identify clusters and gaps in the marks.

The outcomes indicate that 51.2% of the GA marks are tightly grouped within the range 50-59, higher than the 43.6% of IA marks for the same range. But the range 40-49 shows that the frequency of GA marks is 21.1% which is lower than the 30.8% of IA marks, an indication of a wider performance gap within IA marks. A considerable difference between marks within the range 60-69 with a higher proportion of marks achieved using GA. The pass rate has been improved using GA with only 1.9 % required to retake the assessment (to achieve the pass mark) as compared to 3.7% in the IA. Similarly, a notable difference with marks at the top of the range (70-79) was noticed, with more learners achieving higher grades using GA compared to IA.

6 Conclusion

In this study, the classroom is envisioned as a community dedicated to knowledge creation, continually reinventing itself through the integration of sustainability within the framework of active learning pedagogy. This approach is essential for developing research competencies that empower individuals to address SD as a shared identity and responsibility within engineering education. The study primarily focused on embedding research into the learning process, while promoting educational equity and inclusivity in the classroom. This is achieved by narrowing the achievement gap, encouraging open-mindedness rather than rote learning, and actively engaging all students, irrespective of their social backgrounds or learning styles. As an outcome, it is recommended that the curriculum structure should focus on research as a catalyst for sustainable learning transformation to effectively improve the quality of students' work. In so doing, several core purposes are established including building research skills, raising awareness and consciousness

around the SD, and fostering equity and inclusion in engineering education. Finally, the study showed that collaborative research as a subset of active learning is an effective intervention strategy to enhance academic achievement and narrow the gap between high and low scores by using different types of assessment strategies that reinforce assessment for learning rather than the assessment of learning. The scaling and adaptation intervention findings offer insights into the impact of assessment strategies on reducing the gaps between marks achieved.

Acknowledgement

The authors thank the numerous students who have taken the courses and participated in the surveys.

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