A Technology-Enhanced Blended Learning Model for Sustainable Education

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Abstract. This study presents a technology-enhanced blended learning model designed to advance sustainable education in higher education institutions. The research focuses on the "Era of Carbon Neutrality" curriculum at Sanming University, integrating the Chinese Students' Core Competency Framework with UNESCO's Education for Sustainable Development Goals. The curriculum employs a multi-dimensional evaluation method combining online and offline assessments, enabling comprehensive evaluation of students' learning processes and outcomes. Over two semesters, the course demonstrated high student engagement and effective transdisciplinary learning, with most participants completing significant portions of online tasks. This model not only addresses educational gaps but also promotes social responsibility and practical innovation among students. As the global community strives for carbon neutrality, the study underscores the need for higher education to adapt and innovate in training individuals equipped to contribute to a sustainable future. The proposed method offers a viable pathway for educational institutions to align their strategies with sustainability goals, fostering the next generation of leaders capable of navigating complex environmental challenges.

Keywords: Technology-Enhanced Learning, Sustainable Education, Transdisciplinary Curriculum Design, Evaluation Framework.

1 Introduction

Higher education plays a crucial role in shaping leaders who influence the environment, economy, society, and culture. The United Nations Educational, Scientific and Cultural Organization (UNESCO) enhances higher education's contribution to sustainable development through its Global Engagement Program, focusing on embedding sustainability within education [1]. However, the implementation of Sustainable Development Goals (SDGs) faces challenges, particularly in less developed regions exacerbated by the COVID-19 pandemic [2]. In the post-pandemic era, higher education's proactive role in addressing SDGs has gained recognition [3], prompting institutions to integrate sustainability into curricula [4]. Although UNESCO's 2017 publication provides recommendations for Education for Sustainable Development (ESD) implementation [5],

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a lack of effective ESD content due to rapid socio-economic development and emergence of climate crises [6]. Developing an effective framework for sustainable education challenging. Despite some existing assessment processes, effectively activating this learning remains elusive [7], with cultural and political contexts influencing ESD integration [8]. Integrating ESD into existing educational systems presents further challenges [9].

China's education system is shifting towards competency-based education, focusing on developing students' core competencies. As climate change becomes increasingly urgent, achieving carbon neutrality is a global priority. However, UNESCO findings reveal that climate change education is lacking in many national curricula [10]. Addressing global warming as a "wicked problem" requires interdisciplinary and collaborative efforts between academia and society [11]. ESD should encourage students to engage in boundary-crossing learning processes essential for navigating an unpredictable future [12]. Transdisciplinary curricula in higher education are increasingly recognized as critical for generating innovative solutions [13].

China's dual carbon goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 pose new challenges in education. The Ministry of Education's 2022 "Work Plan" emphasizes green and low-carbon education, requiring higher education institutions to optimize curricula and teaching methods to develop leaders capable of driving low-carbon development. This study addresses two questions: How can ESD be implemented through transdisciplinary curriculum design? How can students' ESD learning outcomes be evaluated? As higher education increasingly incorporates Information and Communication Technology (ICT), Technology Enhanced Learning (TEL) offers various applications for advancing education [14]. This study examines "The Era of Carbon Neutrality" curriculum at Sanming University, proposing a technology-enhanced blended learning model for ESD through transdisciplinary curriculum design, teaching practice, learning feedback, and multi-dimensional evaluation.

2 Case Study of ESD

2.1 Curriculum Design of "The Era of Carbon Neutrality"

The curriculum design includes four components: core competency, transdisciplinary competency, lesson design, and learning evaluation. Offered to all undergraduates, "The Era of Carbon Neutrality" curriculum integrates the "Chinese Students' Core Competency Framework" with UNESCO's "Education for Sustainable Development Goals: Learning Objectives," highlighting shared educational philosophies. Both frameworks emphasize the role of education in fostering individuals who contribute positively to society, with a focus on holistic student development. They prioritize competencies like systems thinking and collaboration, and advocate lifelong learning. These commonalities underscore the universality of educational aspirations, offering opportunities for mutual learning across cultures. Despite diverse contexts, both frameworks are dedicated to developing well-rounded individuals capable of meeting 21st century challenges with a global perspective.

The curriculum integrates core and transdisciplinary competencies to address carbon neutrality challenges (Table 1). Students engage in discussions exploring the intersection of carbon neutrality strategies with urbanization, scientific knowledge about net-zero emissions, and mechanisms of carbon inclusivity. The curriculum encourages reflection on personal choices with a carbon neutrality framework and fosters social responsibility through discussions on greenhouse gas emissions. Practical innovation connects students with carbon neutrality practices relevant to their majors, supported by quizzes and discussion on innovative models across sectors. This holistic approach equips students with the competencies necessary to contribute to a sustainable future.

Table 1. Curriculum design components.

Core competency	Transdisciplinary competency	Lesson design	Learning evaluation
Humanistic foundation	Cultural understanding of global climate impact	Carbon neutrality strategies of different countries	Quiz and discussion on synergy between neutrality and urbanization
Scientific spirit	Basic scientific knowledge of carbon neutrality	Corporate pathways to net-zero emissions	Quiz and discussion on net-zero strategies
Learning to learn	Autonomous, cooperative, and inquiry-based learning	Carbon market dynamics	Quiz and discussion on carbon inclusive mechanisms
Healthy living	Green living concepts, low-carbon lifestyles	Personal lifestyle choices in carbon neutrality context	Quiz and discussion on lifestyle reflections
Responsibility	Individual roles in carbon neutrality and social responsibility	Greenhouse gas emissions and climate change	Quiz and discussion on the tragedy of the commons
Practical Innovation	Carbon neutrality practices relevant to students' majors	Carbon management in various sectors	Quiz and discussion on innovative carbon neutrality models

2.2 Multi-Dimensional Evaluation Method

The curriculum uses a blended online-to-offline (O2O) evaluation method, where learning processes and final report contribute 40% and 60% of the total grade, respectively. The evaluation includes attendance (25%), classroom performance (50%), and

homework (25%). Technologies like the internet and online teaching platform facilitate assessment in large classes.

Final assessments require students to submit practical reports, either individually or in teams. The curriculum emphasizes university social responsibility (USR) and global sustainable development, encouraging students to explore interdisciplinary knowledge with each other. After receiving teacher feedback on their homework, students select report topics, incorporating a self-assessment element. Assessment options include essays, volunteer activities, green projects, videos, or competitions. The "Impact" score is peer-reviewed, assessing how many people were influenced by the students' effort, such as through participation or viewership, thereby providing a broad and comprehensive evaluation. The evaluation framework emphasizes students' transdisciplinary integration and their contributions to environmental sustain-ability as shown in Figure 1.

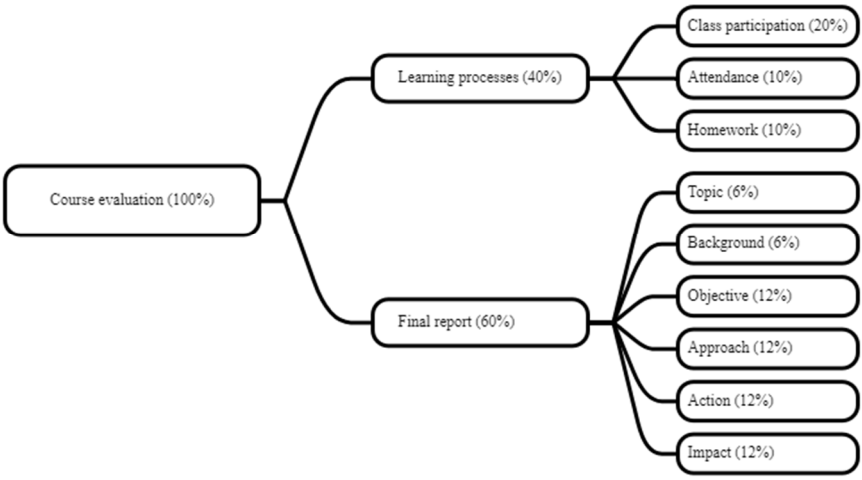

Fig. 1. Multi-dimensional evaluation framework.

3 Technology-Enhanced Blended Learning for ESD

3.1 Implementing ESD with a Technology-Enhanced Blended Learning Approach

The curriculum is accessible to all undergraduates, with a maximum of 150 students per class. It uses a blended teaching model supported by the Chaoxing Learning Platform. The instructional schedule includes carbon neutrality news, lesson content, and discussions. Lessons combine offline teaching with multimedia formats like online news and videos, followed by interactive quizzes and discussions. After each lesson, offline interactions are paired with online quizzes or questionnaire voting for immediate feedback. Discussions, stemming from current news, cases, or student practices, are conducted in an O2O manner, enabling simultaneous participation. Students participate using smartphones or tablets, with real-time word clouds generated from the online

platform, or expanding discussions based on students' contributions. Additionally, statistical data from the platform allows for timely learning warnings to students with low participation, aiding instructors in monitoring progress. All activities, from team formation to practical theme selection and discussions, are managed through online shared documents, enabling real-time collaboration among class members.

3.2 Results of Technology-Enhanced Blended Learning on ESD

The curriculum was implemented over two semesters -- fall 2023 and spring 2024 -- with 297 students enrolled across 35 different majors, such as civil engineering, environmental engineering, and financial management. The online platform recorded 188,879 page views and 1,369 interactions by August 2024. In fall 2023, 26 tasks were assigned, with 65% of students completed over 77% of them, as shown in Figure 2 (a). In spring 2024, 23 tasks were assigned, and about 72% of students completed over 78% of them, as shown in Figure 2 (b).

"The Era of Carbon Neutrality" curriculum significant impacted students, as evidenced by their reflections and feedback. Students reported heightened awareness and a comprehensive understanding of carbon neutrality, recognizing it as critical in addressing climate change. They expressed a strong sense of personal responsibility and commitment to sustainable development in their lives and careers. The curriculum broadened their perspectives to include an appreciation for the global dimensions of carbon neutrality, including international policies and the balance between environmental protection and economic development. Additionally, students gained insights into the technical aspects of carbon-neutral technologies and the urgent need for action, motivated by proactive measures taken by various countries. This learning experience inspired students to make meaningful contributions to carbon neutrality, instilling a profound sense of mission for the future of our planet. Some students also participated in the International Environmental Protection Public Welfare Competition, winning 2 silver and 1 bronze award in the China Division.

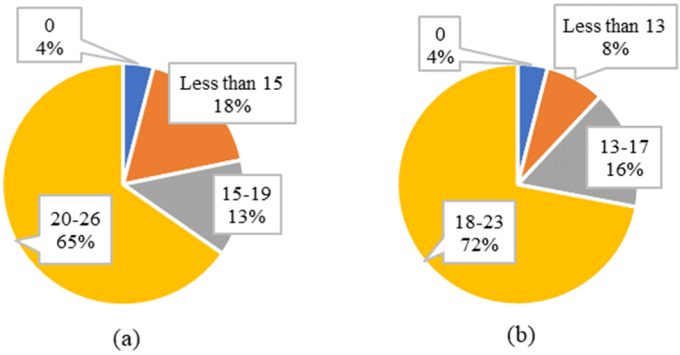

Fig. 2. Lesson tasks completion rate.

4 Conclusion

The study demonstrates the effectiveness of a technology-enhanced blended learning model in promoting sustainable education through the "The Era of Carbon Neutrality" curriculum. The integration of ICT enriched the learning environment, deepening students' understanding of SDGs. A multi-dimensional evaluation method ensured comprehensive assessment, reflecting academic rigor and practical relevance. The model successfully increased student engagement and facilitated transdisciplinary learning, crucial as China targets carbon neutrality. This approach provides a viable pathway for higher education institutions to innovate educational strategies, fostering leaders equipped to address sustainability challenges.

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