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# Integrating Climate Action in English for Computer Science: A CLIL-Oriented Education for Sustainable Development Initiative

Dewi Sari Wahyuni[1]*, T. Sy. Eiva Fatdha[2]

## Abstract

This study examines the integration of climate action concepts, specifically green computing and computing for green, into English language learning for computer science students using the Content and Language Integrated Learning (CLIL) approach. English Language Learners (ELLs), most of whom are non-native English speakers (NNES) in the field of Computer Science, require a language learning model that not only improves linguistic skills but also fosters awareness and active participation in global climate change issues. Through qualitative methods, including a literature review, CLIL classroom observations, and interviews with instructors, this study identifies best practices in designing content-integrated English language curricula that combine language proficiency and ecological literacy. Green computing principles are applied not only in learning materials but also in research methods to reduce carbon footprints. Findings indicate that integrating sustainability topics into English language learning within the context of Computer Science effectively enhances students' language skills and environmental awareness. Students become more motivated to act as agents of change in preserving the environment. The practical implication is that interdisciplinary collaboration and innovative CLIL curriculum design can play a crucial role in preparing Computer Science graduates to be not only technically competent but also linguistically competent, as well as having sustainability awareness.

**Keywords:** climate action; CLIL; green computing; ecological literacy; ESD

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[12]*Universitas Sains dan Teknologi Indonesia*
**Author Correspondent: dewisariwahyuni@usti.ac.id*

## Introduction

Addressing global climate change requires coordinated action across multiple sectors, including higher education. With the environmental impact of Information and Communication Technology (ICT) responsible for an estimated percentage of global carbon emissions, a figure projected to double by 2030, the need for integration of climate action measures, such as mitigation and adaptation, into university curricula becomes increasingly urgent. Education serves as a catalyst for climate action by fostering students' knowledge, awareness, and critical thinking skills, thereby enabling them to engage meaningfully with climate solutions (Goulah, 2017; Martín-Ramos et al., 2025; Saiful & Yunianti, n.d.) .

English language learning in higher education, particularly for Computer Science students, presents distinct challenges. In Indonesia, Computer Science students typically enrol in English for Computer Science (ECS) or English for Specific Purposes (ESP) courses designed to develop professional communication skills. However, traditional curricula for these courses often prioritize technical language mastery and career preparation, while neglecting the integration of technological sustainability. By linking ecological literacy to the evolving identity of students as responsible future environmental professionals, these courses can enhance their engagement and motivation to become environmentally conscious. Integrating sustainability into English language instruction not only enriches their language skills but also aligns with their aspirations to create technology that serves sustainable goals. For instance, students can work on a project theme such as 'Designing a Green Data Centre,' where they research energy-efficient technologies and present their findings in English. Discussion prompts such as 'What are the environmental impacts of e-waste?' can also be incorporated to encourage students to articulate complex concepts in a foreign language while fostering environmental awareness (Al Amin & Greenwood, 2018; Huot & Em, 2024).

(Wahyuni et al., 2022, 2023, 2024)found that English courses in computer science focus on hardware or software terms, as well as job prospects, but rarely address technology sustainability. Sustainability is highly relevant in this context because digital technology significantly contributes to carbon emissions and electronic waste. Approximately 50 million tons of electronic waste are generated globally each year. In Indonesia, it is reported that the country produces around 1.6 million tons of e-waste annually, which exacerbates local environmental issues, including landfill overflow and the leakage of toxic materials into water sources (Baldé et al., 2024; Singh, 2025). E-waste contributes to pollution and poses health hazards. Despite its importance, educational programs often overlook this dimension, resulting in graduates who lack an understanding of the environmental impact of technology and their potential role in climate action within the digital age.

Non-native English speakers (NNES) in Computer Science programs also face language barriers that can impede their comprehension of technical material and limit academic participation. Guzman et al. (2021) note that international computer science students who are not native speakers often have difficulty following English-language lectures and feel academically alienated. This highlights the importance of instructional strategies that foster both language proficiency and subject matter comprehension. Content and Language Integrated Learning (CLIL) provides a promising approach by integrating language and subject learning. Through CLIL, students simultaneously acquire content knowledge, such as Computer Science, and a foreign language, thereby enhancing language proficiency and deepening technical expertise. Studies conducted across three Asian universities demonstrate that CLIL is effective in enhancing language skills and content comprehension, showing marked improvements in student outcomes compared to traditional learning methods. (Belda-Medina, 2025; De Meo et al., 2016; Massler et al., 2014; Piotrowska & Alekseeva, 2020; Tavella & Loutayf, 2023; Wallace et al., 2020).

(Yu et al., 2024) found that CLIL effectively integrates sustainability education in language learning. Through CLIL, students engage with complex issues, such as climate change, using authentic sources. This approach yields improved language skills and enhanced retention of subject content. (Kaur, 2022) showed that students taught environmental topics through CLIL gained more environmental knowledge than those in traditional classes. These findings are consistent with (Bradford, 2019) argument that English-medium instruction (EMI) programs in higher education should address both language development and the improvement of pedagogical quality and content relevance. An excessive focus on language acquisition can impede mastery of subject content. Integrated approaches, such as CLIL, are therefore highly relevant in the context of English for Specific Purposes (ESP) for Computer Science, as they enable students to balance linguistic competence with subject-specific expertise. As awareness of the climate crisis grows, integrating sustainability issues into higher education is vital. Through its ESD program, UNESCO urges all subjects to incorporate sustainability concepts, preparing a generation to face global challenges (Chusniyah et al., 2025).

In Computer Science, the discipline supports climate action primarily through two avenues. The first is green computing, which involves adopting environmentally responsible computing practices to mitigate the negative environmental impacts of ICT. The second is computing for green, which refers to leveraging computing for sustainability solutions in sectors such as energy and the environment. Integrating these concepts into English language instruction adds value by enhancing students' professional English skills, climate literacy, and sense of social responsibility. Consequently, Computer Science students are prepared to become environmentalists (Abernethy & Treu, 2014; Beaubouef, 2003; Gordon, 2010; Ivanova & Zarovniaeva, 2020; Sun & Kuang, 2020; Wahyuni et al., 2024).

The research questions addressed in this study are: (1) What are the effects of integrating climate action topics, specifically green computing and computing for sustainability, on student outcomes in CLIL-based English instruction? (2) How do students respond to and engage with climate action topics? (3) What are the challenges and best practices from lecturers' perspectives in teaching sustainability-themed CLIL?

The objectives of the study are to enhance language proficiency, awareness, and engagement among Computer Science students, thereby preparing them to act as agents of change in the context of sustainable digitalization. The findings aim to inform recommendations for ESP/English in Computer Science curricula in higher education, thereby increasing their relevance to global issues and sustainable educational standards.

## Content and Language Integrated Learning (CLIL)

Content and Language Integrated Learning (CLIL) integrates language and subject teaching into a single, cohesive process. In CLIL, subjects such as Computer Science are taught in a foreign language, enabling students to learn content while simultaneously improving their language skills. The CLIL concept was first proposed by David Marsh (1994) and has been widely implemented in Europe and various countries as a way to increase the mobility and competitiveness of graduates. CLIL is referred to as an innovative 'dual-focus' method for achieving two goals simultaneously.

(Massler et al., 2014) divide the implementation of CLIL into three types based on the emphasis on learning objectives. Type A: focus on content, assessment on content mastery; Type B: focus on language, with content themes, assessment on language skills; Type C: balanced, full integration of language and content.

In Computer Science programs, CLIL implementation tends to lean toward type A or a combination, as English courses typically integrate technical computer material as context. A local study by (Wahyuni, 2024; Wahyuni et al., 2023) demonstrates that content-based English language teaching (CLIL-based ESP) in computer science can be enhanced through interactive modules centered on sustainable development, thereby increasing student engagement in the learning process. (Rifah et al., 2022) also reported that the development of an ESP-based CLIL model in higher education significantly increased student activity and engagement. (Çelik & Yangın Ersanlı, 2022). These findings confirm the potential of CLIL to make language learning more contextual, engaging, and meaningful for students.

CLIL learning that addresses climate issues has the potential to foster these values. For example, debates on environmental issues, case studies, and community service projects enable students to understand technical content in English and encourage them to participate in climate action. During one classroom session, a student initially struggled with the concept of electronic waste management. However, after participating in a group debate about the comparative impacts of e-waste versus traditional waste, the student had a breakthrough moment, expressing a newfound understanding of the urgency and complexity of e-waste issues. This shift was evident in their subsequent essay, where they articulated innovative solutions for reducing e-waste in urban areas, demonstrating higher-order thinking and a deep engagement with the topic. CLIL learning that addresses climate issues has the potential to foster these values. For example, debates on environmental issues, case studies, and community service projects enable students to understand technical content in English and encourage them to participate in climate action (De Meo et al., 2016; Jitpaiboon & Sripicharn, 2022; Olsson & Sylvén, 2023; Rifah et al., 2022; Tavella & Loutayf, 2023; Wallace et al., 2020).

The implementation of CLIL in higher education requires cross-disciplinary collaboration. Wallace et al. (2020) emphasize the importance of partnerships between language teachers and subject teachers in designing and implementing CLIL in higher education. Their study in Canada shows a model in which language teachers are placed in subject departments to help integrate language support into discipline courses. In Indonesia, challenges in implementing CLIL include limited resources and training for lecturers. Many language lecturers are unfamiliar with technical content, while subject lecturers may struggle to simplify language for non-native English speakers (NNES). Therefore, specialized professional training and the provision of authentic learning resources on environmental technology themes are needed. To help address these resource constraints, lecturers could leverage open-source code repositories and digital libraries to access a wealth of free materials and examples that can be adapted for classroom use.

Many language lecturers are unfamiliar with technical content, while subject lecturers may struggle to simplify language for non-native English speakers (NNES). Therefore, specialized professional training and the provision of authentic learning resources on environmental-technology themes are needed. If these challenges are addressed, CLIL can serve as a dynamic platform for connecting language learning with global issues such as climate change. Overall, CLIL represents a highly relevant approach for computer science programs in the global era. This method aligns with pedagogical innovation recommendations that emphasize the need for graduates to possess 21st-century skills and sustainable literacy. Through CLIL, computer science students can master academic and professional English while deepening their knowledge of critical topics such as climate action, thereby shaping them into competent and socially responsible professionals.

**Climate Action in Green Computing**

The concept of green computing refers to practices and strategies in the field of Information and Communication Technology (ICT) that aim to minimize the negative environmental impacts associated with ICT. This includes efforts to improve energy efficiency, design energy-efficient hardware and data centres, reduce the use of hazardous materials, and manage electronic waste (e-waste) wisely.

In today's digital age, the carbon footprint of the computing and digital industries is enormous. ICT devices contribute to carbon emissions through their high electricity consumption and the emissions generated by their supply chains, from production to distribution. Additionally, electronic waste is one of the fastest-growing waste streams globally. This waste contains hazardous materials that can pollute the environment if disposed of improperly, and at the same time, discards valuable resources that could be recycled. These issues render green computing a necessity for the computer science community to support global sustainability. In the context of climate action, green computing plays a direct role in climate change mitigation by reducing greenhouse gas emissions from the ICT sector. (Ojo et al., 2019) emphasize that the implementation of Green IT in organizations contributes to corporate environmental performance through sustainable practices in the production, use, and disposal of ICT devices. Their research in Malaysia shows that adequate knowledge of Green IT and an environmentally friendly management culture have a positive impact on the attitudes of IT professionals in implementing green computing practices. This suggests that efforts to enhance green computing literacy and awareness at the university level represent a strategic step in fostering pro-environmental behaviour among future IT professionals.

Integrating green computing materials into English for Specific Purposes (ESP) Computer Science can be done in various ways. Case studies and thematic discussions are practical approaches for exploring complex issues. For example, lecturers can invite students to analyse the case of company X's data centre design, which successfully reduced its energy consumption by 30% through the implementation of new cooling technology, thereby significantly diminishing its carbon footprint. Students read articles or technical reports in English about the case and then discuss them in groups, focusing on the energy efficiency measures taken, their impact on carbon emissions, and the obstacles encountered. This activity trains students' reading comprehension and technical vocabulary skills, while expanding their knowledge of current green computing practices.

To facilitate educators in adapting this approach to their own classrooms, an adaptable activity template can be used: (1) Select a relevant case study that highlights a successful green computing initiative. (2) Gather authentic English-language materials related to the case, such as articles and reports. (3) Prepare guiding questions that steer students' analysis toward energy efficiency measures and environmental impacts. (4) Organize students into small groups to encourage collaborative discussion. (5) Conclude with a group presentation or written reflection on the lessons learned from the case study, emphasizing the integration of technical language and concepts.

A similar approach was used in the research by (Squillace et al., 2023), which explored user behaviour in reducing electronic waste. They found that educating users about recycling and raising environmental awareness encourages behavioural changes, such as using devices longer and selling or recycling old gadgets, which leads to a reduction in electronic waste accumulation. These findings can be implemented in classroom activities. For example, students can be asked to conduct a small survey on electronic device usage behaviour on campus and present the results in English, then discuss solutions to reduce electronic waste at the individual level together.

In addition to improving language skills, green computing principles can also be applied to problem-based projects. For example, students can be assigned a project to create a technical proposal in English for a "Digital Green Campus" that aims to reduce its carbon footprint. In this project, students work in teams to audit energy use in computer labs, calculate estimated emissions, and then propose innovations such as power management systems, server virtualization, or computer recycling programs. During the project, instructors act as language facilitators, helping students express their technical ideas in clear and structured English, teaching persuasive phrases for proposals, and performing other related tasks. A noteworthy example can include a pre- and post-lesson vocabulary exercise where students initially use general terms like 'reduce energy' and later employ more specific technical vocabulary such as 'optimize energy efficiency,' 'implement dynamic voltage scaling,' and 'establish green IT protocols.' This concrete demonstration of vocabulary gains is aligned with (Göksu et al., 2017) recommendation that project-based learning can effectively connect content and language learning while enhancing students' environmental awareness. (Ronen & Kerret, 2020).

The benefits of integrating sustainability content, such as green computing, into English classes have been proven to be positive. Students not only enrich their language skills but also develop a critical mindset towards the social impact of technology.(Bouman et al., 2020) state that when individuals have a high level of knowledge and concern, they are more likely to take concrete action on climate change. Therefore, instruction that emphasizes green computing can foster this concern among computer science students.

For example, after exploring the issue of electronic waste, students were motivated to create an electronic waste awareness campaign on campus. This approach transforms language learning into a process that not only fulfils curricular requirements but also motivates students to contribute as agents of change at the community level.

From a lecturer's perspective, teaching green computing topics in English requires interdisciplinary preparation. Lecturers need to combine references from the field of computer science with language teaching methods. The success of this practice has been proven in CLIL collaborative studies in higher education. With careful planning, integrating climate action initiatives such as green computing into English classes can produce learning experiences that are relevant to the academic needs of contemporary computer science students while also increasing their environmental awareness.

**Climate Action in Computing for Green**

In addition to making computer technology more environmentally friendly, the field of Computer Science also contributes indirectly to climate action through digital innovations for sustainability. This concept is about computing for the environment. Computing for the environment can be defined as the use of advanced computing technologies, such as artificial intelligence, machine learning, the Internet of Things (IoT), big data, and cloud computing, to support sustainable practices and solutions in addressing environmental issues across various sectors.

The concept of computing for the green environment positions technology as a driver of large-scale green transformation. Research and industry trends show an increased focus on environmentally friendly computing. Othman et al. (2022) developed an energy-efficient and privacy-preserving data aggregation scheme for health IoT, combining cloud computing and algorithmic optimization to reduce computational load and power consumption. The application of green computing principles in the field of healthcare IoT proves that computing innovation can be directed towards achieving resource efficiency without sacrificing performance. Similarly, the application of AI and data analytics can reduce the carbon footprint of IT infrastructure by optimizing workloads and predicting real-time resource demand. Many large technology companies have committed to “AI for Earth” or “AI for Climate” initiatives that leverage machine learning for environmental conservation. For example, these initiatives utilize computer vision to monitor forests and prevent illegal logging, as well as AI models to improve solar panel efficiency. All of these examples emphasize that computer science expertise is key to cross-disciplinary solutions for climate change.

Integrating green computing topics into English language learning through CLIL can be done by highlighting the relationship between technology and sustainability. One way is to present authentic material, such as articles or videos, about green technology projects. For example, an article about using machine learning to optimize garbage truck routes, thereby reducing fuel emissions. Students can be asked to summarize the article, practicing their reading comprehension skills, and then discuss in English how the algorithm works, how much emissions are reduced, and so on. This activity enriches students' vocabulary in interdisciplinary fields and broadens their understanding of how the programming and algorithms they learn can be applied to solve real-world problems.

Inspired by this, English lecturers can collaborate with environmental science lecturers to hold simulation sessions: students, in groups, take on the role of policymakers who must “negotiate” to determine a combination of solutions so that global temperatures do not rise further. All negotiations are conducted in English. This activity hones speaking and argumentation skills while instilling an understanding of the complexity of climate action. Computer Science students in this role can provide a technological perspective, for example, stating “we will implement smart grids, which will have X impact on emissions”, so that they learn to communicate technical ideas to non-technical audiences. The topic of computing for a green environment also encourages students to think creatively and innovate. Brainstorming green technology projects can serve as a final assignment, such as designing ideas for smart applications or systems to address local environmental problems. Students write short proposals in English about their ideas, such as an IoT-based flood monitoring application for their city, present them in class, and receive feedback. This exercise integrates English writing and presentation skills with scientific competencies. Additionally, it fosters a proactive attitude, reinforcing the expectation that future computer scientists can and should contribute to climate change solutions.

(Bouman et al., 2020) remind us that concerns about climate change must be balanced with a sense of personal responsibility to encourage action. In the context of students, fostering a sense of ownership is essential. By working on real projects, even small-scale ones, related to the environment, students perceive themselves as part of the solution rather than passive learners. This initiative aligns with the goal of sustainable education to develop agents of change. The main themes in climate education today emphasize the role of youth as agents of change and the importance of transformative educational practices that connect knowledge with action. Therefore, English language learning that integrates computing for green purposes aims to realize transformative education in the field of ESP: students learn language through action (learning by doing) and critical reflection on global issues.

From the perspective of lecturers, the challenges in teaching green computing are similar to those in green computing: finding appropriate teaching materials and balancing the level of language difficulty with technical complexity. The solution is for lecturers to utilize open sources, such as UN reports, popular scientific articles, or TED Talks videos on technology and climate, which are in English and easy to understand. According to Yu et al. (2024), authentic materials are effective in improving language skills and sustainability awareness when used in conjunction with interdisciplinary pedagogy.

It is also important to establish dialogue between language instructors and instructors from other fields to ensure content accuracy. For example, before a discussion class on AI for the environment, instructors can consult with colleagues in the Computer Science department to ensure that the technical points conveyed to students are accurate yet simple. In summary, programming for sustainability as a CLIL topic offers significant opportunities for computer science students to broaden their understanding of the role of technology in addressing sustainability issues. This integration enriches English language learning with substantive content, encourages interdisciplinary thinking, and fosters innovation to address environmental challenges.

## Method

This study uses a descriptive qualitative approach to explore the practice of integrating climate action into English language learning in depth. The research subject is a Computer Science study program at a university in Indonesia that has implemented sustainability elements in its English for Computer Science course. Data collection was conducted using three main techniques: (1) Literature review: analysing curriculum documents, syllabi, and teaching materials related to the integration of environmental topics in English language learning, as well as previous research on CLIL and sustainability education; (2) Classroom observation: the researcher directly observed English for Specific Purposes (ESP) lectures in Computer Science classes that discussed the themes of green computing and sustainability, during 4 consecutive meetings.

The observation focused on teacher-student interactions, learning activities, language and content use, and student responses to climate action material. During the observations, the researcher used an observation guide and recorded key phenomena; (3) Semi-structured interviews with lecturers: conducted with three lecturers who taught English for Computer Science and one curriculum coordinator. The interviews explored the lecturers' perspectives on their motivation for incorporating climate issues into the syllabus, the strategies employed, the challenges they faced, and their perceptions of the effectiveness of the learning process. The interview was recorded, transcribed, and thematically analysed.

Data validity is maintained through triangulation of sources and methods. Findings from classroom observations are confirmed through interviews with lecturers and reinforced by information from curriculum documents. For example, if observations indicate that students are enthusiastic about discussing green computing, researchers verify whether lecturers share similar views in interviews and whether the curriculum effectively targets increased student awareness. This triangulation ensures consistency of information and increases confidence in the research results. Green research principles were also applied in alignment with the study theme. All documents and literature were managed digitally to reduce paper use. Interviews and discussions of the results were conducted through online meetings to minimize travel and reduce the carbon footprint. Thus, the research method not only examined green computing as an object of study but also adopted sustainability values in its implementation.

Data analysis was conducted using thematic analysis techniques. Interview transcripts and observation notes were reviewed multiple times, and relevant text units were coded accordingly. These initial codes were grouped into broader categories, such as "learning strategies," "language versus content constraints," "student reactions," "impact on language skills," and "impact on environmental awareness." From these categories, key themes were identified that addressed the research questions, including increased engagement and motivation, enhanced environmental literacy, the importance of lecturer collaboration, and the identification of limitations and support needs. These themes are described in detail in the Results and Discussion section, accompanied by data excerpts and connections to previous research findings.

## Results and Discussion

Analysis of the data indicates that integrating climate action into English language learning in computer science programs has a positive impact on student learning experiences. The main findings of this study are discussed below:

1. I Increased Student Engagement and Motivation

Class observations revealed high student enthusiasm when sustainability topics were discussed in English. For example, during a discussion session on electronic waste, most students actively shared their opinions and personal experiences regarding the management of old gadgets. Interviews with lecturers confirmed these observations: "ESP classes are usually quite quiet when discussing grammar or technical readings. However, when I invited them to discuss the environmental impact of cell phones and laptops, the discussion immediately came alive," stated one lecturer (Lecturer A, interview, 2025). This increase in engagement aligns with the findings of (Rifah et al., 2022), who reported that the ESP-CLIL approach increases student engagement in language classes.

Contextual and relevant climate action topics made language learning more meaningful for students, as opposed to abstract linguistic exercises. Motivation increased because students could relate the material to their real-life experiences and field of study.

These findings are consistent with the views of those who recommend incorporating environmental issues into language curricula to increase relevance and student engagement. Thus, the integration of climate action serves as a contextual mechanism that attracts the interest of non-native English-speaking students in technical fields (Acosta Castellanos & Queiruga-Dios, 2022; Kazazoglu, 2025; Pratolo et al., 2024; Saiful, 2025).

2. Simultaneous Improvement in Language and Content Skills

Observation and analysis of course materials indicate improvement in two dimensions of student competency: academic English skills and understanding of sustainability concepts. For example, at the end of the semester, students were assigned a 500-word argumentative essay in English on "The Role of Computer Science in Addressing Climate Change." Most students produced essays with clear structure and used technical and environmental vocabulary appropriately, such as "carbon footprint," "renewable energy," "data centre efficiency," and "recycling programs." Lecturers observed that the quality of writing improved compared to earlier assignments. Additionally, the content of students' arguments demonstrated a deeper understanding of the topic, as they explained concepts such as smart cities for energy conservation and the energy challenges associated with cryptocurrency. These results indicate that the dual objectives of CLIL have been achieved: students learn language through content and content through language.

3. Improving Student Literacy and Environmental Awareness

A primary goal of integrating climate action is to equip students with ecological literacy and foster environmental awareness. Evidence of achieving this objective is observed through changes in student behaviour and perspectives during and after classes. Informal interviews revealed that many students began to evaluate their personal technology-related habits. For example, one student stated, "I started thinking about PC electricity usage at home, now I turn off the PC more often when not in use." Another student reported encouraging friends to collect small electronic waste, such as batteries and broken chargers, for donation to an electronic waste bank. Although anecdotal, these examples demonstrate the internalization of sustainability messages among students. Cognitively, students now understand terms such as sustainability, climate change, and renewable energy in a professional context.

Emotionally, students' awareness and sense of responsibility increased. This transformation is expected to serve as a long-term asset in their future IT careers. Evidence of increased climate literacy was also observed in quiz and test results. In the initial semester exam, only 30% of students knew the term "carbon footprint." Following the lecture, more than 85% of students were able to correctly define the term and provide examples of actions they could take to reduce their carbon footprint. These findings reinforce the conclusion that ESD-themed CLIL is efficacious in improving students' environmental knowledge.

(Kaur, 2022) at the University of Leeds reported similar findings: integrating sustainability topics into language curricula improves academic literacy and sustainability literacy among learners. Therefore, integrating climate action into Computer Science English classes produces not only more competent students but also more environmentally conscious graduates.

4. Best Practices in Design and Implementation

Based on observations and interviews with lecturers, this study summarizes several best practices for integrating climate action into language learning (ESP) in the field of Computer Science:

*Collaborative and Interdisciplinary Planning:* Engage lecturers from related disciplines, such as Computer Science and Engineering, in curriculum planning or as guest speakers. This collaboration ensures content accuracy and helps language lecturers prepare relevant and up-to-date materials. For instance, language lecturers collaborated with computer network lecturers to create a 'Green Data Centre' module, which resulted in more substantial materials and increased confidence among language lecturers in teaching technical content.

*Flexible and Project-Based Curriculum:* Design the curriculum to allow space for thematic projects or final assignments related to sustainability. As suggested by (Wahyuni et al., 2022) in the PROSPER Model, sustainable project-based learning can enhance collaboration and creativity while instilling environmental awareness. In the studied classes, the 'Digital Green Campus' project provided an integrative and meaningful learning experience.

*Authentic and Contextual Materials:* Utilize genuine learning materials that are tailored to students' levels. Such materials connect classroom learning to the real world, thereby motivating students to engage. For example, using a PLOS One article on climate education or a UN report on electronic waste can provide language assignments. Local material can further engage students by making the content relatable.

*Language Support and Evaluation:* Ensure that language support is robust, even when covering complex materials. This includes offering glossaries for difficult vocabulary, providing example sentences, essay templates, and language structure exercises, before tackling more complex content discussions. Additionally, employ dual evaluation tools that assess both language skills and content comprehension, as evidenced by project presentation assessments having separate rubrics for language and content aspects.

*Environmentally Friendly Practices:* Model and cultivate a classroom culture that values the environment. For instance, collect assignments via LMS to save paper, use dark backgrounds for lecture slides to conserve projector energy, and regulate classroom air conditioning settings responsibly. These actions reinforce the environmentally friendly computing message and are reflected in students' behaviours, such as bringing reusable water bottles to class.

These practices, grounded in the experiences of participating lecturers and supported by relevant literature, should be adapted to the context of other institutions. However, the core elements, collaborative planning, appropriate materials, language support, and holistic evaluation, can be universally applied.

5. Challenges and Areas for Development

This innovative integration also faces several challenges. Lecturer B noted, "The biggest obstacle is time. The curriculum is already packed, so it can be challenging to incorporate additional topics unless we are creative in presenting them. In addition, not all students have a background in environmental knowledge, so they need to be given context first." Limited time allocation is a common challenge, but it can be addressed by integrating climate topics with compulsory content. For example, when teaching conditional sentences, lecturers can use examples related to climate change ("If the temperature rises by 2 degrees,..."). To address students' limited background knowledge, warm-up activities such as brainstorming or simple quizzes can be used to establish foundational understanding.

Another challenge is the availability of English teaching materials appropriate for students' proficiency levels. Lecturers often need to simplify scientific texts or select popular articles to avoid overwhelming non-native English speakers (NNES). In the future, open educational resources (OER) specifically designed for CLIL with a focus on sustainability will be needed to support lecturers. Current options include platforms such as

OER Commons, which offers a variety of resources across disciplines, and the Open Learning Initiative, which provides free course materials that can be adapted for CLIL instruction. For professional development, programs such as Coursera's Sustainable Development Goals course series and the CLIL Methodology Course by FutureLearn can offer educators practical insights and techniques. This need is supported by the findings of (Yu et al., 2024), who call for the development of OER and teacher training to support the integration of sustainability in English language teaching (ELT).

A long-term evaluation of the impact of this integration on graduate profiles is beyond the scope of this study and remains an area for further research. Future studies could investigate whether graduates who have participated in CLIL-sustainability learning are more proactive in green initiatives in the workplace and whether their professional language skills surpass those of students who study these topics separately. Longitudinal and comparative studies are recommended to address these questions. We encourage educators, researchers, and institutions to collaborate on such studies, contributing to a collective scholarly effort that can further validate and expand upon our findings. Creating a network for sharing research outcomes and best practices can drive continuous improvement and innovation in integrating CLIL with sustainability topics in Computer Science education. Nevertheless, lecturers and students involved in this study expressed satisfaction and optimism regarding this learning model, noting its added value in alignment with the goals of the Sustainability journal and the SDGs agenda in higher education.

## Conclusion

The integration of climate action, including green computing and computing for sustainability, into English language learning for computer science students is both feasible and beneficial. The CLIL approach enables language teaching and sustainability content to be delivered concurrently, resulting in several positive outcomes: (1) improvement in students' academic English proficiency and understanding of sustainability issues in ICT; (2) increased learning motivation and engagement, as students perceive the material as relevant to their expertise and global realities; and (3) the development of environmental awareness and attitudes, with students adopting a green perspective on technology and motivation to become agents of change in their communities. This model prepares Computer Science students to become graduates who are not only technically competent and proficient in English, but also possess ecological literacy and social responsibility as part of the solution to climate change challenges.

From a pedagogical perspective, the key to successful implementation lies in designing collaborative and holistic curricula. Cross-disciplinary cooperation between language teachers and subject teachers ensures effective integration, while support for language aspects, such as scaffolding and integrated assessment, should not be overlooked. Creating a conducive learning environment in which sustainability values are internalized in everyday classroom culture is also essential. Although challenges such as time and material constraints exist, these can be addressed through teacher creativity and institutional support, including the provision of OER and teacher training.

It is recommended that higher education institutions begin formulating curriculum policies that support education for sustainable development (ESD) across all study programs, including English language courses. This step aligns with global commitments and will significantly enhance the quality of graduates. Future research could examine the long-term impact of this learning model on student achievement or its application in other disciplines, such as English for business with corporate social responsibility (CSR) topics.

Efforts to integrate climate action into the learning process represent an investment in education for a sustainable future. As stated by (Nwankwo et al., 2020), an integrated education paradigm that utilizes Information and Communication Technology (ICT) in all aspects of the academic process is necessary to contribute to achieving the Sustainable Development Goals (SDGs). This research demonstrates one manifestation of this paradigm. Continued innovation and collaboration in education can position the sector as a pioneer of change, producing high-quality human resources prepared to address the challenges of climate change with knowledge, language proficiency, and concrete actions.

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