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ARTICLE

Carbon Literacy Interventions in Business Education: Assessing Students' Attitudes and Performance before and after Training

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ABSTRACT

As the urgency for addressing climate change intensifies, the integration of carbon literacy into business education emerges as a pivotal strategy for cultivating environmentally conscious business students. This study examines the impact of carbon literacy programs on business students, focusing on how such programs influence their attitudes and behaviors toward sustainability. Employing a mixed-methods approach, the research analyzes pre and post surveys, alongside qualitative focuses groups interviews, to gauge shifts in understanding and personal commitment to carbon reduction practices. The survey applied the scale adapted form included seventeen items, the sample was 180 students in honor degree (Last year in business school). The findings revealed that exposure to carbon literacy not only enhanced knowledge about environmental issues but also fostered a significant transformation in students' attitudes towards sustainability, leading to initiative-taking behavioral changes. Furthermore, this study highlights the potential of carbon literacy education to instill a sense of responsibility and empowerment among future business leaders, equipping them with the skills needed to make informed decisions that prioritize environmental stewardship in their professional endeavors. This study underscores the necessity of integrating carbon literacy into business curricula to better prepare students to tackle the challenges of climate change in their future careers. A key limitation of this study is the persistent challenge of translating positive attitudes into actual behavioral change among young individuals, particularly university students.

Keywords: Carbon Literacy; Attitudes; Sustainability Education; Experiential Learning; Higher Education; Leadership

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Development

1. Introduction

Business schools worldwide have worked to incorporate sustainability principles into their curricula for over two decades. However, as the world faces a climate emergency, the question of whether such initiatives have had any significant impact on the future business leaders of the world remains an open question. This is true to such an extent that there is a call for improvement thinking of business education to address the current model of business education, which we do not believe will prepare students with the knowledge they need for a new era of combating climate change and for ensuring that the international community meets the Sustainable Development Goals.

While research to date on the impact of carbon reduction in higher education has identified a relationship between Planned Behavior, positive measures, and awareness of learning about the environment in the context of business education, empirical evidence that any of these business school initiatives are successful has thus far proved inconclusive. Moreover, there is also an ongoing debate as to whether the focus on such initiatives has had the unintended consequence of impinging on the core subjects that require coverage in a business education degree, much less in the programs of other degrees.

1.1. Rational

Business students, including those in Business management, Human Resources, Marketing, International business, accounting, and finance, are significant stakeholders in carbon reduction, and engagement in such learning is relevant across the business and wider community. Carbon counting is, however, invisible in most businesses, despite carbon management challenges providing opportunities for innovation and long-term growth. Engagement in innovative transdisciplinary units of study can offer relevant student learning experiences and, as such, can play a key role in addressing important social, economic, and environmental challenges of managing carbon. This research draws on principles of experiential learning and double loop learning to explore student reflections and perceptions of self-awareness of carbon emissions and knowledge. Their reflections may have significant implications for individual carbon practices as well as wider business carbon management.

1.2. Research Objectives

This study aims to examine the impact of the carbon management experiential learning program on knowledge enhancement and practice changes related to carbon emission reduction among business students. Specifically, the objectives are to: (1) report the carbon reduction knowledge and practices among the students before the activities, and examine any difference in attitudes related to carbon reduction efforts among students from different genders, educational backgrounds, and levels; (2) evaluate the program from the students' perspectives and ascertain learning effectiveness; (3) determine how the program influences the students' carbon reduction knowledge and practices; and (4) identify the changes in students' behavior in order to explore the practical values of carbon management skill development and climate change behavior education. For conducting the first two objectives, statistical techniques and remarks from user reports will be adopted. For the third and fourth objectives, before and after activities, designers implemented the program in association with survey studies and interviews. Following the objective, practical implications, and further research suggestions.

To evaluate the attitudes towards carbon footprint and the understanding of carbon footprint presentations among students before and after an educational intervention.

1.3. Significance of This Study

As businesses adopt practices that help them reduce their carbon footprint, it becomes increasingly important for individuals who work in these businesses to understand carbon reduction practices. Many of these future workers are currently students studying topics in business and related fields. As business students in business, these students have many opportunities to effect change and promote environmentally friendly policies and practices. These leaders might not only motivate business organizations to engage in car-

bon reduction practices but might also work to implement and support such practices with their own human resources. This study examines how participating in an experiential carbon reduction workshop influences students' carbon reduction knowledge, skills, and behaviors. The workshop builds on applied research in the areas of carbon reduction, social learning, and experiential learning. Importantly, it facilitates a connection between student theory and real-life carbon reduction practice. Experiential learning is a long-standing and well-documented method for promoting deep learning and other positive educational outcomes. Experiential learning occurs cyclically, moving through the stages of experience, sharing, conceptualization and planning. Because experiential learning is a cyclical process, individuals can begin at any phase of the cycle. The experiential learning process built into the workshop suggests that students not only gain exposure to the intervention but also experience opportunities to encounter vicarious learning, institutional learning, and social interaction. The combination of these learning opportunities is referred to as social learning. In addition to knowledge development, social learning allows participants to feel empowered and have the potential for business students. By being exposed to the experiences of others, learners can become empowered through the mirror of success.

1.4. Why Carbon Reduction Is Important

Integrating carbon literacy into business curricula is essential for preparing future managers and entrepreneurs to navigate and lead in a low-carbon economy. It equips students with the knowledge and competencies required to make informed, sustainable decisions that align with contemporary environmental challenges. Research highlights the influential role business graduates play in shaping corporate strategies, supply chains, and investment decisions that directly impact carbon emissions [1]. Embedding carbon literacy fosters systems thinking, ethical awareness, and strategic sustainability skills, enabling learners to connect financial performance with environmental responsibility [2]. Furthermore, studies show that carbon literacy enhances graduate employability, supports alignment with ESG and net-zero policies, and stimulates innovation toward sustainable business models [3, 4]. Ultimately, carbon literacy transforms business education from a traditional profit-centric approach to one that cultivates climate-conscious leadership, vital for the 21st-century economy, and is one of the Education for Sustainable Development (ESD) concepts and approaches.

1.5. Study Questions

RQ1: What is the impact of carbon literacy education on business students' sustainability-related knowledge, attitudes, and behaviors?

RQ2: How do students perceive the effectiveness of carbon literacy programs in preparing them for environmentally responsible leadership roles?

RQ3: What barriers prevent the translation of improved sustainability attitudes into consistent behavioral change among students?

1.6. Past Studies on Sustainability Education and Carbon Literacy

The literature reflects an expanding interest in carbon literacy education as a targeted and actionable component within broader sustainability education in academic institutions. Evidence indicates that well-made programs of carbon literacy can enhance participants' knowledge, motivation, and certain self-reported behaviors, particularly when implemented within supportive educational institutional environments. Nonetheless, interpreting these improvements into sustained and measurable reductions in carbon emissions remains inconsistent, regularly prompted, and influenced by essential and relative factors and issues. To advance from talented pilot initiatives to obvious climate impact, the field requires more robust theoretical foundations and studies, longitudinal studies, standardized assessment tools, and stronger integration between individual learning outcomes and systemic change within the educational institutes [5].

Different students highlighted carbon literacy at different levels. On the first level, the level of Measurement, assessment and Impact evidence, a study highlighting the outcomes assessed in carbon literacy research varies widely, ranging from self-reported knowledge and attitudes to behavioral intentions and, less frequently, observed actions and quantified carbon footprints. Many studies rely on pre- and post-intervention surveys with short-term follow-ups, which may be susceptible to social desirability bias and offer limited external validity [6]. More rigorous studies attempt to estab-

lish links between carbon literacy and actual emissions or their proxies. For example, recent empirical research has explored correlations between individual carbon literacy scores and measurable carbon-related behaviors or footprints. These studies reveal complex relationships: while higher levels of carbon literacy are often necessary for reducing emissions, they are not always sufficient. Structural and socioeconomic constraints frequently moderate the extent to which increased literacy translates into tangible environmental outcomes [7].

On the level Mechanisms and mediators: when literacy leads to action, Learners who acquire practical skills and perceive themselves as capable of taking meaningful action, referred to as self-efficacy, are more likely to engage in behavior change [6]. In addition, Contextual constraints such as infrastructure, institutional policies, and socioeconomic conditions play a significant role in determining whether increased knowledge leads to actual reductions in carbon emissions. Studies caution against whether individual education alone can drive systemic decarbonization, emphasizing the need to address broader structural factors [8].

2. Literature Review and Theoretical Framework

2.1. Sustainability Education Development (ESD)

Education for Sustainable Development (ESD) is a broad, interdisciplinary field that emphasizes the development of knowledge, skills, values, and agency necessary to support sustainable societies. However, the literature reveals ongoing debates regarding its core aims, ranging from traditional knowledge transmission to more critical and transformative pedagogical approaches, and highlights inconsistencies in its implementation across different educational contexts. Recent reviews underscore that many ESD programs remain conceptually diverse and under-theorized, calling for more clearly defined pedagogical objectives and greater critical reflexivity concerning issues of power, justice, and future-oriented thinking [9]. Carbon literacy is a more focused concept, typically defined as an awareness of the carbon implications of everyday actions, combined with the motivation and practical ability to reduce emissions. It functions both as a conceptual framework outlining what learners should understand and be capable of doing and as a structured training initiative, exemplified by programs such as the Carbon Literacy Project. Within academic evaluations, carbon literacy is often considered a subset of climate or climate-change literacy, with a distinct emphasis on emissions-related knowledge and behavior change [10].

While previous research has highlighted the importance of sustainability education in enhancing environmental awareness [1, 2], there remains a lack of empirical studies assessing the tangible effects of carbon literacy initiatives on business students' behavioral intentions and actual carbon-reduction practices. Much of the existing literature is predominantly descriptive or conceptual (Stein [3]), with limited use of mixed-methods approaches that capture both attitudinal changes and behavioral outcomes. This study addresses that gap by offering empirical evidence from a developing country context, illustrating how structured carbon literacy programs can promote transformative learning, foster individual agency, and encourage sustainability-oriented behaviors among future business leaders. By integrating both quantitative and qualitative data, the research deepens our understanding of how educational interventions can effectively convert environmental awareness into meaningful action, thus advancing theoretical and practical discussions on carbon literacy in higher education.

2.2. Carbon Reduction

The rise in global warming and shifts in biodiversity have put the sustainability of the planet at immediate risk. Individuals from various fields, including researchers, academics, practitioners, and scientists, have come together to propose solutions for preserving environmental sustainability.

King and Lenox [11] assert that unplanned and irresponsible actions by industries pose significant threats to sustainability. In response, companies are increasingly working to reduce their environmental impact by incorporating environmental considerations into supply chain operations.

Tapia Granados and Spash [12] indicated a strong correlation between annual emissions costs and economic growth. Meanwhile, Tseng and Hung [13] created a strategic decision-making model that considers the social costs and operational expenses associated with carbon dioxide emissions within the supply chain system [14]. Their evaluation was conducted through various scenarios, supported by case studies on in-

dustrial apparel[15]. Retailers can collaborate with manufacturers to effectively reduce carbon emissions. In their study, numerical experiments and analyses were successfully conducted to determine the optimal cost-sharing and ideal premium rates for the wholesale price[16].

In recent years, both the business and scientific communities have shown significant interest in discussing the growing threat of gas emissions[17]. According to Chen et al.[17], achieving effective emission reductions is unlikely if companies take independent actions without coordinating with their business partners. Such uncoordinated efforts can lead to increased emissions from other partners, ultimately undermining overall emission reductions in companies.

2.3. Theory of Planned Behavior

The Theory of Planned Behavior (TPB) expands upon the Theory of Reasoned Action (TRA)[18], particularly when it comes to boycotting, TPB provides a comprehensive framework for understanding consumer behavior[19]. A person's desire to engage in a behavior is what ultimately determines their conduct, and this intention is influenced by their attitude toward the behavior, subjective norms, and perceived behavioral control[20, 21].

It is believed that the integration of these three elements plays a role in shaping the behavioral intention to boycott[19]. First, consumers are more likely to join a boycott if they see it as a positive experience, whereas they are less likely to do so if they see it negatively[22]. Subjective norms, the second component, show that while the absence of social pressure often reduces the possibility of a boycott, perceived social pressure typically raises consumer intentions to boycott[19, 23]. Finally, perceived behavioral control discusses how a person's assessment of the ease or complexity of a behavior affects their engagement[19].

Studies have indicated that boycotting is usually a deliberate action rather than spontaneous. Farah and Newman[22] discovered that 90% of the variation in consumers' intentions to boycott was explained by the Theory of Planned Behavior (TPB), highlighting the framework's dependability in interpreting consumer behavior. According to Delistavrou and Tilikidou[19] and Xie et al.[24], the TPB offers a theoretical framework that is appropriate for analyzing and forecasting consumer intentions to participate in boycotting activities

2.4. Experiential Learning

Kolb's Experiential Learning Theory (ELT) remains a foundational framework, describing learning as a dynamic cycle encompassing concrete experience, reflective observation, abstract conceptualization, and active experimentation, interweaving cognitive and behavioral processes. Despite its enduring influence, critics have highlighted its oversimplified structure and limited engagement with observational and contextual nuances. Building on this, Robinson and Leigh's[25] comprehensive review (Management Learning journals, 2010–2024). Introduces a multi-layered approach to experiential learning. They identified three distinct levels: EL-centric research, component-level studies, and context-level analysis. Using abductive reasoning grounded in Kolb's dimensions, this review maps scholarly contributions across these layers. A consistent theme throughout experiential learning models is reflective practice's centrality. Whether through micro-level reflection or broader macro-reflection, learners are empowered to critically evaluate and reshape their thought processes and behaviors, a principle emphasized by Robinson and Leigh[25], and echoed by contemporary educational writing scholars

Mertayasa et al.[26] examine experiential learning in Indonesian secondary schools, demonstrating consistent enhancements in critical thinking skills such as argument evaluation, drawing rational conclusions, and analytical reasoning across the progression from concrete experience to active experimentation. In higher education, a quasi-experimental study redesigned an intercultural communicative competence module for Indonesian university students[26]. Incorporating role-play, simulations, structured reflection, and debriefing within an experiential learning cycle, the intervention led to measurable gains in intercultural competence, evaluated using Byram's[27] framework, before and after implementation, in addition Araujo et al.[28]. explored hackathons as a platform for experiential learning in software engineering. Guided by Self-Determination Theory, their seven-day hybrid hackathon with forty students resulted in notable improvements in creative thinking, collaboration, and applied knowledge, positioning hackathons as an effective vehicle for soft skill development. Meanwhile, Wang et al.[29], in 2025, present an innovative business education initiative that blends generative AI with authentic learning experiences. The experimental course fosters creative problem-solving

and dynamic interactions between AI-driven insights and practical applications. However, the study also underscores critical challenges, including varying levels of instructor AI fluency and the rapid evolution of AI tools in education.

The main challenges and gaps are as follows: Conceptual inconsistency: Terminology and typological frameworks differ significantly across studies, particularly within simulation-based and immersive learning contexts, leading to fragmented discourse and limited generalizability. Equity and access: Although experiential approaches are increasingly adopted on a large scale, disparities in inclusion remain. Some education systems face implementation gaps documented outside traditional academic literature and linked to regional data sources such as PARAKH. Educator perspective and implementation burden: There is a noticeable lack of research into the logistical demands, emotional labor, and institutional complexities that educators navigate when designing and delivering experiential programs (for example, field trips, internships Longitudinal impact and sustainability: More evidence is needed to assess long-term outcomes such as sustained behavioral changes, career trajectory shifts, and the continued effectiveness of experiential interventions over time.

2.5. Double Loop Learning

Chris Argyris and Donald Schön's influential work introduced the concept of double-loop learning, a process that goes beyond simply correcting errors (as in single-loop learning) to interrogate and reshape the deeper values, norms, and assumptions that produce them. This involves critically re-evaluating the "governing variables," such as the underlying mental models and decision-making rules. In contrast, single-loop learning retains these foundational structures, focusing on behavioral adjustments within existing frameworks [30].

Double-loop learning enhances organizational resilience, adaptability, and innovation by promoting critical reflection on entrenched practice. This reflective process enables organizations to respond effectively to the complexity and volatility of their environments. Argyris's methodology has been translated into practice through case-based teaching tools designed to build leadership and facilitation skills in double-loop learning contexts. Moreover, a systematic review examining rural–urban synergies revealed an equal distribution of studies employing double- and triple-loop learning frameworks. This finding underscores the notion that meaningful organizational transformation often originates from double-loop processes that serve as the foundation for deeper systemic change [30].

The effective implementation of double-loop learning within organizations hinges on several key conditions: psychological safety, structured reflective practices (such as after-action reviews and learning journals), decentralized decision-making, and a culture that welcomes dissenting perspectives. Avby [31] merges the PDCA cycle with ambidextrous learning, highlighting the importance of deep reflection during the planning phase. As Lukic [32] mentioned, this involves posing fundamental questions like "Why do we work the way we do?" and "How could we work differently?", probing beyond routine fixes and steering toward profound double-loop inquiries.

Double-loop learning remains a pivotal framework for driving deep organizational transformation. Its value in fostering strategic adaptability, critical thinking, and innovation is well documented in the peer-reviewed literature. However, translating theory into practice requires careful attention to cultural norms, leadership dynamics, and organizational structure. Looking ahead, future research should explore the following priorities: Developing systematic approaches to distinguish and measure different learning loops across sectors; Empowering frontline and lower-tier employees to question established norms and influence policy; and conducting longitudinal studies to assess the sustained impact of double-loop learning initiatives on organizational evolution.

3. Research Design

This study will utilize a quasi-experimental design with pre- and post-test surveys to measure changes in attitudes and knowledge regarding carbon footprints among two groups of students. This study applies two approaches, quantitative and qualitative, as follows:

This methodology provides a clear framework for conducting research on students' attitudes and actual personal carbon footprints. By implementing pre- and post-surveys, we measured the impact of training students on carbon reduction and how this can affect their behavior change.

3.1. Quantitative Approach

Participants and Sample Size: 180 students completed the carbon footprint attitude survey and measured their carbon emissions. As shown in **Table 1**:

Table 1. Pre-Surveys.

Pre-Survey		
	Pre-Survey (1)	**Pre-Survey (2)**
Objective	Measure students' attitudes towards carbon footprints	Measure students' actual personal carbon footprint before the training
Sample	180 students	180 students.
Instrument	A structured questionnaire with Likert-scale items assessing knowledge, beliefs, and attitudes regarding carbon footprints.	A structured questionnaire assessing knowledge on carbon footprints, possibly including multiple-choice questions or true/false statements

Selection Criteria: Participants will be selected from the business school at Business Administration and Political Science (BAEPS), level Honer, in the employee relations class, ensuring a diverse representation of students from different specializations, HR. Marketing, International Business, Finance, and Accounting.

Instrument: Tools for measurement: The questionnaire consisted of two parts that assessed the various study variables, as shown in **Appendix A**. The first part collected demographic data, such as gender and school. The second part, measuring Carbon reduction attitude for the business students, comprises 17 items developed by Tolppanen and Kang [33]. All responses ranged from (1) not at all; (2) occasionally; (3) sometimes; (4) frequently; and (5) frequently, if not always, on a 5-point Likert Scale in English.

Data Collection Methods

Educational Intervention before survey two (Post survey)

- After the pre-surveys, an educational intervention (e.g., a workshop, seminar, or class) was conducted to enhance students' understanding of carbon footprints, as shown in **Table 2**.

Table 2. Post-surveys.

Post-Survey		
	Post-Survey (1)	**Post-Survey (2)**
Objective	Measure students' attitudes towards carbon footprints after the intervention.	Measure students' actual personal carbon footprint after receiving the training on carbon reduction
Sample	180 students	180 students.
Instrument	The same structured questionnaire used in Survey 1 to allow comparative analysis.	The same structured questionnaire used in Survey 2 in Pre-survey.

3.2. Qualitative Approach

This qualitative approach suggests a strong framework for researching students' attitudes, understanding, and behaviors related to carbon footprints. Employing semi-structured interviews and focus group discussions, the study aims to generate deep, nuanced insights that capture the complexity of student perceptions. The main qualitative findings complement the quantitative data, contributing to a more holistic and comprehensive understanding of the topic.

- **Research Design:** The study applies a qualitative approach design, using semi-structured interviews and focus group discussions to collect in-depth data from the responses. This approach enables participants to articulate their perspectives freely while allowing the researcher to probe for deeper insights and clarification. The primary aim is to explore and understand students' attitudes toward carbon footprints and their interpretation of carbon footprint representations.
- **Participants and Sampling:** Participants were selected through sampling, focusing on students who had previously engaged in measuring their individual carbon footprints. A key criterion for selection was their willingness to share personal experiences and reflections. The qualitative sample size was intentionally smaller than that of Survey (1), which explored general student attitudes toward carbon footprints, to facilitate more in-depth and interactive discussions.
- Four focus group sessions were conducted, each cov-

ering about 20 to 25 students. The conversations were tight around six thematic areas: Recycling, Living, Transport, Diet, Reuse, and Driving. These categories were selected to reflect key lifestyle domains that significantly influence individual carbon footprints and reflect the questionnaire areas.

- **Data Collection Procedures:** Each focus group session lasted approximately 60 to 90 minutes and was audio-recorded with participants' informed consent. Semi-structured interview guides were developed to ensure consistency across sessions while allowing flexibility for the emergence of new ideas and perspectives. All discussions were transcribed verbatim to preserve the accuracy and richness of the data.
- **Data Analysis and Coding Procedures:** Data were analyzed using thematic analysis, following Braun and Clarke's [34] six-phase framework. The transcripts were initially read multiple times to ensure thorough familiarization with the content. Open coding was then applied to identify recurring concepts and patterns. These codes were subsequently organized into overarching themes that reflected key trends in students' perceptions and behaviors related to carbon footprints.
- **Limitations:** A key limitation of this study is the absence of a control group, which restricts the ability to draw causal inferences regarding the observed attitudes and behaviors. Consequently, the findings should be interpreted as exploratory and descriptive, aimed at identifying patterns and meanings rather than establishing cause-and-effect relationships.

3.3. Data Analysis

- **Quantitative Analysis:** Statistical software (SPSS, version 26) was used to analyze the survey responses for the pre- and post-questionnaires. Conduct paired *t*-tests, Binary Logistic Regression, or ANOVA to compare pre- and post-survey results for both attitudes and knowledge. Changes in responses based on demographic factors (gender) were analyzed.
- **Qualitative Analysis:** Open-ended questions were asked during the interviews, and thematic analysis was performed. This is a qualitative research method that researchers use to systematically organize and analyze complex data sets to identify common themes in student responses for male and female pre- and post-respondents, and compare with the quantitative results.

4. Results

4.1. Quantitative Results

Testing the Reliability of the Variables

The internal consistency of the subscales was found to be reliably trustworthy (above 0.6) when assessed using Cronbach's alpha coefficient. **Table 3** presents the results regarding the scales' reliability. According to Hair Jr. [35], reliability refers to the degree of consistency across different measures of a given variable. Consistent assessments of variables typically show that they are more reliable than those with lower consistency.

Table 3. Study Variables Reliability.

Scale	Rec(R)	Tur (L)	Train(T)	Diet (D)	Reus (R)	Drive (Dr)
Alpha	0.778	0.832	0.784	0.676	0.745	0.945

Source: Author's work.

4.1.1. Pre and Post Results

The first part of the quantities was measuring students' attitudes towards carbon footprints after the intervention. The results are as follows (**Table 4**):

Table 4 presents Group Statistics comparing pre- and post-test measurements for "carbon" in a study with 180 participants in each group. Here, each column indicates the following: (Pre/Post): Indicates whether the data are from before (pre) or after (post) an intervention. N: Number of participants (180 in both groups). Mean: The average score of each group. Included (Pre-test Mean: 58.5000, Post-test Mean: 61.6458, and Std. Deviation: Measures variability in the data included (Pre-test: 8.59743 and Post-test: 8.11494).

Table 4. Pre-and Post-Measure Students' Attitudes towards Carbon Footprints.

Group Statistics					
	PrePosr	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
carbon	pre	96	58.5000	8.59743	0.87747
	post	96	61.6458	8.11494	0.82823

The post-test scores showed slightly less variability. Std. Error Mean: Estimates how much the sample mean differs from the true population mean included (pre-test: 0.87747 and post-test: 0.82823).

The post-test mean was higher than the pre-test means, suggesting that whatever intervention or change was introduced had a positive impact on the measured "carbon" variable. Further statistical analysis, the following *t*-tests will confirm if this difference is statistically significant as shown in (**Table 5**).

Table 5. Independent Samples *t*-Test.

		Levene's Test for Equality of Variances		***t*-Test for Equality of Means**						
		F	**Sig.**	***t***	**df**	**Sig. (2-Tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
carbon	Equal variances assumed	0.689	0.407	−2.607	190	0.010	−3.14583	1.20661	−5.52591	−0.76575
	Equal variances not assumed			−2.607	189.370	0.010	−3.14583	1.20661	−5.52596	−0.76570

Although the mean of females is increased from 59.7 to 62.5, there is no significant difference using the independent *t*-test.

While comparing the mean of the carbon for males, it was 56.9, and it increased to 60.5, which is significant among the sample.

Since $p = 0.010 < 0.05$, we rejected the null hypothesis, indicating a significant difference between the pre- and post-test carbon values.

Table 5 presents the results of an Independent Samples *t*-test conducted to compare the two groups (likely pre-test and post-test carbon data). Let's break it down:

1. Levene's Test for Equality of Variances

- F = 0.689, Sig. = 0.407
- This tests whether the variances of the two groups are equal.
- The *p*-value (Sig.) of 0.407 is greater than 0.05, meaning we assume equal variances (we use the first row of the *t*-test results).

2. *t*-Test for Equality of Means

- $t = -2.607$ → *t*-value for the test.
- df (degrees of freedom) = 190 (when equal variances were assumed).
- Sig. (2-tailed) = 0.010 → This is the *p*-value, which is less than 0.05, meaning the difference between pre- and post-values is statistically significant.
- Mean Difference = −3.14583 → This shows how much the post-test values differed from the pre-test values on average.
- Std. Error Difference = 1.20661 → Standard error of the mean difference.
- 95% Confidence Interval (−5.52591 to −0.76575) → The true mean difference is likely in this range, and because it does not contain zero, the result is statistically significant.

As shown below in **Table 6**, the statistical analysis began with Levene's Test for Equality of Variances, which assessed whether the variability of scores between the pre- and post-intervention groups was statistically equivalent. The test yielded a significance value of 0.407, which was greater than the 0.05 threshold, indicating that the assumption of equal variances was true[34]. Based on this result, a *t*-test for equality of means was conducted under the assumption of equal variances. The *t*-test produced a statistically significant result ($t = -2.607$, df = 190, $p = 0.010$), suggesting a meaningful difference between the pre- and post-intervention means. The mean difference of −3.15 indicates an increase in post-test scores, implying that the intervention had a measurable effect. Moreover, the 95% confidence interval (−5.53 to −0.77) did not cross zero, providing further evidence that the difference was statistically reliable. The standard error of 1.21 supports the precision of this estimate. Together, these findings affirm that the intervention significantly influenced participants' outcomes and that the observed effect was unlikely to be due to random chance.

Table 6. Binary Logistic Regression.

		B	S.E.	Wals	df	Sig.	Exp(B)
Step 1a	Rec	0.067	0.175	0.147	1	0.702	1.069
	Tur	0.036	0.158	0.051	1	0.822	1.036
	Tran	−0.180	0.108	2.782	1	0.095	0.836
	Diet	0.711	0.101	49.805	1	0.000	2.036
	Resus	−0.234	0.183	1.633	1	0.201	0.791
	Driv	−0.198	0.100	3.928	1	0.047	0.821
	Constant	−5.171	2.049	6.366	1	0.012	0.006

Note: a. Variable(s) entered on step 1: Rec, Tur, Diet, Reus, Driv.

As shown below in **Table 7** below, the results, for Recycling, B = 0.067, Sig. = 0.702, was not significant ($p > 0.05$). This means this variable doesn't have a meaningful effect on the outcome. Exp(B) = 1.069: A very small increase in odds, but again, not statistically meaningful. On the level of Turning off home applications, B = 0.036, Sig. = 0.822, also not significant, Exp(B) = 1.036: A 3.6% increase in odds not meaningful due to high *p*-value. On the level of Transportation, B = −0.180, Sig. = 0.095, this is borderline ($p = 0.095$), not quite statistically significant, Exp(B) = 0.836: Suggests that as this variable increases, odds of the outcome decrease by about 16.4%. on the level of Diet B = 0.711, Sig. = 0.000, which is highly significant, Exp(B) = 2.036: Individuals scoring higher on this variable are 2x more likely to exhibit the outcome (e.g., sustainable behavior), controlling for others. On the level of Reusing, B = −0.234, Sig. = 0.201, not significant, Exp(B) = 0.791: Slightly reduces the odds, but not in a meaningful way. On the level of Driving, B = −0.198, Sig. = 0.047, Significant (just below 0.05), Exp(B) = 0.821: Suggests a 17.9% decrease in odds of the outcome, possibly indicating that those who drive less are less likely to engage in the dependent variable behavior.

Table 7. Explanation of the Binary Logistic Regression Table.

Column	Meaning
B	The regression coefficient (log-odds). It tells you the direction and strength of the relationship between each predictor and the outcome.
S. E.	Standard error of the coefficient. A measure of the variability of the B estimate.
Wals	Wald Chi-Square test statistics. It tests whether the coefficient (B) is significantly different from 0.
df	Degrees of freedom. Usually, 1 for each variable in binary logistic regression.
Sig.	The *p*-value. If it's below 0.05, the predictor is considered statistically significant.
Exp(B)	The odds ratio. Tells you how the odds of the outcome change with a one-unit increase in the predictor.

The predictive ability of different sustainable behaviors on the probability of achieving a desired outcome (such as overall sustainable activity) was investigated using binary logistic regression analysis. Recycling (B = 0.067, $p = 0.702$) and turning off household appliances (B = 0.036, $p = 0.822$) did not substantially predict the outcome, according to the data, since both *p*-values were higher than the 0.05 cutoff. The marginal gains in likelihood that are statistically and practically insignificant are reflected in their respective odds ratios [Exp(B) = 1.069 and 1.036]. With an odds ratio of 0.791 indicating a minor but non-significant decrease in odds, reusing (B = −0.234, $p = 0.201$) likewise did not provide a meaningful effect.

On the other hand, Dietary changes (B = 0.711, $p < 0.001$) were found to be a highly significant predictor of the outcome, with an odds ratio of 2.036, indicating that individuals with more sustainable dietary habits are more than twice as likely to engage in the target behavior. Driving behavior (B = −0.198, $p = 0.047$) also showed a statistically significant relationship, albeit at a lower threshold, with an odds ratio of 0.821, suggesting that increased driving is associated with a 17.9% decrease in the likelihood of engaging in the sustainable outcome. Lastly, Transportation choices (B = −0.180, $p = 0.095$) presented a borderline effect, hinting at a potential trend where reduced reliance on transport methods could influence the outcome, although this effect does not reach conventional significance levels. These results suggest that diet and driving behaviors are more robust predictors of sustainable engagement than other examined practices, reinforcing the need to focus on these areas in behavioral

interventions.

4.1.2. Quantitative Measurement

The Second part of the quantities was measuring 180 students' actual personal carbon footprint after receiving the training on carbon reduction, the result was as follows:

The quantitative measurement of 180 students' actual personal carbon footprint after receiving training on carbon reduction revealed a minimal impact on behavior change. Despite the educational intervention, only 5% (5 students) of the students demonstrated a decrease in their carbon footprint (**Table 8**). This reduction was primarily attributed to changes in driving habits and reduced reliance on food delivery services. These findings suggest that while awareness of carbon reduction strategies was provided, most students did not significantly alter their daily behaviors to lower their emissions. The limited impact could be due to ingrained habits, convenience factors, or a lack of immediate incentives to change transportation and consumption patterns.

Table 8. Summary of Pre- and Post-intervention means shows a 5% overall reduction in students' total carbon footprint (n = 180).

Measure	Pre (Mean ± SD)	Post (Mean ± SD)	% Change	Key Observation
Total Carbon Footprint (kg CO_2e)	2400 ± 350	2280 ± 320	−5%	Average reduction
Recycling	180 ± 30	175 ± 28	−2.8%	Minimal change
Living	600 ± 90	580 ± 80	−3.3%	Slight reduction
Transport	720 ± 110	670 ± 100	−6.9%	Largest decrease
Diet	480 ± 70	450 ± 65	−6.3%	Significant improvement
Consumption	300 ± 50	285 ± 45	−5%	Moderate reduction
Driving	120 ± 40	110 ± 38	−8.3%	Notable change

The results highlight the challenges of translating environmental awareness into meaningful behavioral change. While training programs can enhance knowledge and perceptions of sustainability, they may not be sufficient to drive large-scale personal action. Behavioral changes related to carbon reduction often require stronger motivational drivers, systemic support, or policy incentives to encourage sustainable practices. Future interventions should consider integrating practical, incentive-based approaches, such as rewards for reduced emissions or structural changes that make sustainable choices more accessible and appealing. Without such reinforcements, educational efforts alone may not be enough to produce significant reductions in personal carbon footprints, as shown in **Figure 1** below.

Changing the behavior of Gen Z in a short time, especially regarding carbon reduction, is challenging due to several factors. First, many of their habits, such as frequent use of ridesharing, food delivery, and fast fashion, are deeply ingrained and linked to convenience, technology, and social norms. These behaviors are often reinforced by instant gratification and digital lifestyles, making it difficult to shift towards more sustainable alternatives quickly. Additionally, many Gen Z individuals may perceive climate change as a global issue requiring systemic change, which can lead to a lack of urgency in making personal lifestyle adjustments.

Moreover, behavioral change requires motivation, accessibility, and external support, which may not always be present. Without strong incentives, peer influence, or policy-driven measures, individual actions might seem insignificant or inconvenient. Gen Z is highly aware of environmental issues but often faces barriers such as cost, availability of eco-friendly options, and time constraints. To effectively drive sustainable behavior, interventions need to be engaging, rewarding, and seamlessly integrated into their digital and social ecosystems, making green choices more attractive and convenient than traditional high-carbon behaviors.

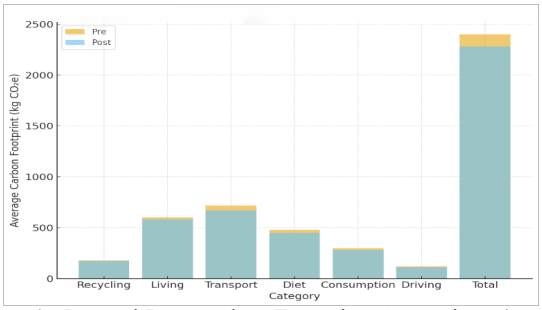

Figure 1. Pre and Post Carbon Footprint Comparison (n = 180 Students).

5. Discussion

While the findings recommend a positive shift in students' attitudes toward sustainability and environmental re-

sponsibility, the actual reduction in carbon footprint measured at 5% remains modest. This gap between attitudinal change and behavioral results reflects the well-documented "attitude–behavior gap" in environmental psychology. Based on Ajzen's[36] Theory of Planned Behavior, behavior is shaped not only by attitudes but also by subjective norms and perceived behavioral management. While students proved stronger pro-environmental attitudes following the intervention, their ability to act on these intentions may have been limited by background factors, for instant insufficient contact with sustainable transportation, financial barriers to green consumption, or insufficient structural support within the university setting. Based on the result, positive intentions did not consistently translate into meaningful behavioral change.

Since the perception of Experiential Learning Theory of Kolb[37] changes in attitudes achieved through mirror image and discussion do not automatically advance to changes in behavior unless strengthened by active experimentation and real-world application. However, many students reported enhanced awareness of sustainability issues based on their studies in their first year in the university; they also noted restricted opportunities to apply sustainable practices in their daily lives. This suggests that the intervention primarily improved cognitive recognition and sensitive engagement, while behavioral competencies and enabling conditions remained underdeveloped. Passing this gap, integrating hands-on sustainability schemes, endless feedback mechanisms, and passionate academic institutional support may be necessary to translate awareness into sustained behavioral change of their students.

The findings of this study highlight the critical role of leadership development in shaping business students. Through the analysis of key leadership competencies, training methodologies, and their impact on organizational effectiveness, this study contributes to the ongoing discourse on effective leadership strategies[36]. The results suggest that structured leadership development programs significantly enhance leadership qualities, decision-making abilities, and strategic vision among aspiring leaders and ensure that the future business leaders are aware of the future requirement for sustainability and fully aware of its impact on the individual and business levels.

One of the key insights from the study is the interplay between theoretical knowledge and practical application in leadership training. The study underscores that while theoretical frameworks provide a foundation, experiential learning through mentorship, simulations, and real-world problem-solving exercises plays a crucial role in shaping competent leaders. Additionally, the role of organizational culture in fostering leadership capabilities was evident, with a strong emphasis on continuous learning and adaptability proving essential for long-term success and sustainability of their organization, especially in the business world.

The main findings from the study based on the statistics above indicate that dietary behavior is a highly significant predictor of sustainable practices within the community. Participants who reported making conscious dietary choices such as reducing meat consumption, opting for locally sourced foods, or minimizing food waste were twice as likely to engage in broader pro-environmental behaviors. This aligns with existing literature highlighting diet as a critical factor in reducing individual ecological footprints. For instance, Hosmer Jr. et al.[38] emphasizes that shifting to plant-based diets could reduce food-related greenhouse gas emissions by up to 73%, supporting the study's finding that diet plays a transformative role in sustainability efforts.

Similarly, the variable related to driving habits demonstrated a statistically significant negative relationship with sustainable behavior. Individuals who reported frequent car use, particularly private vehicle commuting, were less likely to engage in environmentally conscious activities. This trend echoes the conclusions of transportation, especially car dependence, remains a substantial barrier to carbon reduction goals in urban environments. The study reinforces the urgent need to promote alternative transportation modes, such as cycling, walking, or public transit, to foster a culture of environmental responsibility.

To summarize the findings, the results reveal that among the examined variables, only Diet and Driving (Driv) emerged as statistically significant predictors of sustainable behavior. Notably, dietary practices demonstrated the strongest and most positive association, with participants who adopt sustainable diets being twice as likely to engage in other pro-environmental behaviors. In contrast, driving behavior showed a negative association with sustainable outcomes, suggesting that increased reliance on personal vehicles may hinder broader ecological engagement. The remaining variables, Recycling (Rec), Turning off devices (Tur),

Transportation choice (Tran), and Reuse behavior (Reus) did not show statistically significant effects in the model, indicating a weaker or more context-dependent influence on sustainable practices.

Despite these insights, certain challenges persist. One such challenge is the resistance to adopting innovative leadership training approaches due to traditional mindsets. Additionally, the study found that while leadership development initiatives yield positive outcomes and behavior, their effectiveness varies across industries, requiring a tailored approach. This suggests a need for organizations to continuously assess and refine their leadership training programs to align with dynamic market and organizational needs. Carbon reduction is one of the examples; business students should be aware of and serving the sustainability to their business.

6. Conclusions

This study confirms the critical role of leadership development in preparing business students to pilot complex and evolving academic organizational views. The findings exhibit that a well-structured leadership development program, supported by a conducive organizational culture, significantly enhances leadership competencies among undergraduate students. By integrating theoretical foundations with practical applications, institutions can cultivate future leaders equipped for strategic decision-making and effective management, which this paper participates in.

Though the study suggests valuable insights, it also acknowledges key limitations, including industry-specific variations and the influence of external socio-economic factors on leadership outcomes. These restraints emphasize the need for broader, context-sensitive approaches to leadership development and suggest avenues for future research within the universities and academic institutes.

Importantly, the study contributes to the growing discourse on sustainability education by emphasizing the potential of carbon literacy to enhance leadership training. Embedding carbon literacy into business education transforms leadership development from a traditional skill-building exercise into a catalyst for climate-conscious, future-ready leadership, bridging the gap between knowledge and action in pursuit of sustainable change. By fostering environmental awareness through carbon literacy, and also encourages systems thinking, ethical decision-making, and behavioral change qualities essential for transformative leadership in the 21st-century economy.

6.1. Answering the Research Questions

RQ1: What is the impact of carbon literacy education on business students' sustainability-related knowledge, attitudes, and behaviors?

Carbon literacy education significantly enhances business students' understanding of sustainability and climate change. Survey results show improved knowledge, especially in identifying carbon-emitting activities and evaluating the environmental impacts of business decisions. The training program also shifted students' attitudes, fostering a stronger sense of personal responsibility toward carbon reduction. However, while intentions to adopt sustainable behaviors increased, actual behavioral changes were limited, highlighting the need for ongoing support to turn awareness into action.

RQ2: How do students perceive the effectiveness of carbon literacy programs in preparing them for environmentally responsible leadership roles?

Focus group feedback shows students find carbon literacy programs highly valuable for shaping responsible business leadership. They appreciated the practical approach linking sustainability to real-world business decisions.

The program boosted their confidence in tackling environmental issues and reinforced sustainability as a core business value. Students also highlighted the need for more hands-on experiences, like green projects or partnerships, to strengthen leadership skills.

RQ3: What barriers prevent the translation of improved sustainability attitudes into consistent behavioral change among students?

Despite improved attitudes, several barriers limited consistent, sustainable behavior. Key challenges included the gap between awareness and daily action, driven by habits, peer influence, and weak institutional support.

Students also felt individual actions had little impact, which discouraged follow-through. The lack of incentives, role models, and ongoing engagement further hindered change, highlighting the need for a supportive environment to sustain behavioral transformation.

In summary, the study shows that carbon literacy edu-

cation boosts students' sustainability knowledge, attitudes, and emerging behaviors. To turn these shifts into lasting habits, ongoing institutional support, hands-on learning, and systemic reinforcement are essential.

6.2. Future Research Recommendations

It is recommended that, First, Future research should consider conducting longitudinal studies to assess the long-term impact of leadership development programs on career progression and organizational success. Second, Comparative studies across different industries can provide deeper insights into how leadership training needs to be customized for specific sectors. Third, investigating the role of emerging technologies, such as artificial intelligence and virtual reality, in leadership development programs can offer innovative solutions for enhancing training effectiveness. Fourth, exploring how cultural diversity influences leadership styles and development can help create more inclusive and globally relevant leadership training programs. Fifth, given the rise of remote and hybrid work environments, research should examine how leadership training needs to evolve to meet the demands of these new work dynamics. Sixth, integrating Carbon Literacy throughout the curriculum is strongly recommended to equip all students with the essential knowledge and competencies needed to confront climate change. This can be accomplished by embedding carbon-related content into existing courses across disciplines, aligning learning outcomes with broader sustainability goals, and implementing experiential teaching strategies such as direct projects and immersive simulations.

Supporting efforts like offering accredited Carbon Literacy certification and providing targeted faculty training will enhance the quality and consistency of delivery. By institutionalizing Carbon Literacy, students will be acting in informed and impactful climate action both personally and professionally while helping the institution advance its sustainability agenda.

Author Contributions

Conceptualization, S.S. and H.F.; methodology, S.S. and H.F.; software, S.S. and H.F.; validation, S.S. and H.F.; formal analysis, S.S. and H.F.; investigation, S.S. and H.F.; resources, S.S. and H.F.; data curation, S.S. and H.F.; writing—original draft preparation, S.S.; writing—review and editing, H.F.; visualization, S.S. and H.F. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and the declaration of the Ethics committee in the faculty, and approved by the Institutional ethical committee Board of School (date of approval: June 2024).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data are not publicly available at this time as they are being used in an ongoing research project and longitude .

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Name of student:---------- ID:----------

Gender: ----------

(1) Strongly Disagree (2) Disagree (3) Neutral or Neither Agree nor Disagree (4) Agree (5) Strongly Agree

(2) R (1&2) L (3&4) T (5,6,7 8) D (9,10,11,12) C (13&14) Dr (15,16,17)

Table A1. Scale to measure the attitude of the business students.

	Items	1	2	3	4	5
1	Recycle all household paper, cardboard, metal, and glass (R1)					
2	Eat all leftovers and not throw any food away (R2)					
3	Turn off all home appliances when not in use (L1)					
4	Spend 30 minutes less in a shower per week (L1)					
5	Be willing to walk or bike all short distances (T1)					
6	Change your next long-distance holiday flight to a short/mid-distance holiday flight (T2)					
7	Change your next mid-distance holiday flight to a long-distance domestic train trip. (T3)					
8	Change to a car-free life (T4)					
9	Start eating a vegetarian main meal once a week (D1)					
10	Change beef to chicken once a Week(D2)					
11	Change half of your main meals to vegetarian(D3)					
12	Change to a 100% vegan diet(D4)					
13	Buy half of your clothes second-hand (C1)					
14	Use your mobile phone for two years instead of 1 year, before buying a new one (C2)					
15	Change a gasoline car to a hybrid car? (Driv.1)					
16	Change a gasoline car to an electric car? (Dri. 2)					
17	Change a gasoline car to a car that runs on biogas. (Driv. 3)					

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