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Influencing Sustainable Behavior Through Life Cycle Assessment: A Case Study on Single-Use Plastic Pen Consumption at a Teacher Education Institution in Kerala, India

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Abstract

Sustainable campus practices in educational institutions often focus on infrastructure improvements and event-based green initiatives, while the environmental impact of everyday stationery items, particularly single-use plastic (SUP) pens, is frequently overlooked. This study conducts a survey on SUP pen consumption at a teacher education institution affiliated to the University of Kerala, India, followed by a Life Cycle Assessment (LCA) to evaluate their environmental footprint. The findings reveal significant environmental consequences, including global warming and aquamarine ecotoxicity, due to unmonitored usage driven by a heavy reliance on written assessments. After presenting the LCA report at the institution, the study assesses changes in user behavior, exploring the effectiveness of LCA as an educational tool for promoting sustainable practices. It is noted that the intervention enables student-teachers to render otherwise intangible forms of pollution, such as carbon emissions, aquatic toxicity, eutrophication, and resource depletion, into tangible representations, thereby enhancing ecological literacy through evidence-based reflection and improving their ability to communicate sustainability concepts to their students. As universities in India are planning to implement the Integrated Teacher Education Program (ITEP) and new syllabi-assessment systems, the research highlights the potential of digital alternatives to reduce environmental impact and foster sustainability.

Keywords: Digital alternatives, life cycle assessment, single-use plastic (SUP) pens, Sustainable campus practices, sustainable curriculum development, sustainability in education, teacher education institutions.

Introduction

Sustainable campus practices have gained significant attention in recent years, with educational institutions increasingly prioritizing infrastructure improvements such as energy-efficient buildings, solar panel installations, and rainwater harvesting systems. Additionally, event-based green protocols, including plastic-free campus initiatives, eco-friendly event decorations, and waste segregation drives, have become commonplace. For example, many universities mandate the use of reusable cutlery in cafeterias, promote digital documentation to reduce paper consumption, and organize tree-planting drives to offset carbon emissions. However, despite these commendable efforts, plastic waste from everyday stationery items, particularly single-use plastic (SUP) pens, remains largely unaddressed. This oversight persists despite the significant environmental impact associated with their production, use, and disposal.

Single-use plastics, including pens, were originally designed for a modern "throwaway society," leading to their widespread disposal and accumulation in natural environments such as land, air, rivers, lakes, and oceans, posing substantial environmental threats, impacting plant growth, soil invertebrates, terrestrial animals, birds, and marine ecosystems (Chen et al., 2021). In fact, SUPs constitute 60–95% of global marine plastic pollution (Schnurr et al., 2018), contributing to the formation of massive marine garbage patches, including the largest one in the Indian Ocean (Connan et al., 2021). Beyond litter accumulation, SUPs also result in several environmental issues, including anoxic zones in oceans (Thiagarajan & Devarajan, 2025), human and marine toxicity due to chemical leaching (Belmaker et al., 2024), microbial dispersal through plastispheres (Amaral-Zettler et al., 2020), and the infiltration of micro and nano plastics into food chains (Toussaint et al., 2019). Additionally, uncontrolled incineration of SUPs degrades air quality (Nagy & Kuti, 2016), while their decomposition disrupts soil ecosystems (Iqbal et al., 2020) and contributes to eutrophication and acidification in land-based water bodies (Moiseenko, 2016).

The evolution of SUP materials from thermoplastics like polypropylene (PP), polystyrene (PS), and Acrylonitrile Butadiene Styrene (ABS) to thermosetting plastics such as Phenol-Formaldehyde (Bakelite), Epoxy Resins, and Melamine-Formaldehyde has resulted in more durable and heat-resistant products (Parry, 1971). However, these advancements have also raised concerns about their sustainable nature due to their non-biodegradable properties, environmental persistence, and non-reusability. Despite these challenges, SUP pens continue to be extensively used in educational institutions due to their affordability and convenience, particularly in teacher education institutions in Kerala, India, where written assessments like assignments, records, and chart-making are integral to academic activities.

Life Cycle Assessment (LCA) is an effective tool for evaluating the environmental impact of products throughout their life cycle, from raw material extraction to disposal (Guinée et al., 2011). It helps identify opportunities to reduce waste, pollution, and energy consumption by examining each stage of a product's life (Finnveden et al., 2009). LCA is widely adopted in developed countries like Australia, the United States, and the Netherlands for sustainable product design and infrastructure development.

In higher education institutions (HEIs), particularly in Western contexts, LCA studies predominantly focus on assessing the environmental impacts of buildings (53.33%) and energy facilities (36.30%), with climate change, acidification potential, depletion of abiotic resources, and eutrophication potential being the most commonly evaluated categories (Qiu & Dong, 2024). Additionally, LCA has been utilized to identify gaps in sustainability assessments and enhance environmental literacy within academic curricula (Jürgens et al., 2023; Viere et al., 2020).

In recent years, there has been growing recognition of the role of higher education in addressing sustainability challenges through curriculum transformation. LCA, as a critical sustainability tool, has gained traction within academic institutions seeking to cultivate life cycle thinking among future professionals. Viere et al. (2021) propose a robust framework for integrating LCA into higher education, urging institutions to ensure a minimum level of “life cycle literacy” across academic programs. This shift reflects a broader trend of embedding systems thinking and holistic analysis into university curricula to prepare students to confront complex environmental issues. In the context of teacher education, such integration is particularly urgent, as student teachers are positioned not only as learners but also as social role models whose behaviors shape broader community attitudes toward sustainability (Vukelić & Rončević, 2021).

Furthermore, recent research underscores the strategic importance of aligning teacher education with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4, which emphasizes the transformative potential of educators in promoting sustainability values (Khalifatulloh et al., 2023). Embedding sustainability education, including LCA-based exercises, within teacher-training programs therefore supports both the development of reflective practitioners and the diffusion of sustainable practices through school systems. Open and accessible models of LCA education serve to demystify environmental analysis, allowing future teachers to not only understand but actively teach the implications of consumption, waste, and circularity. As Miller (2022) and Nordahl et al. (2024) emphasize, LCA offers a comprehensive lens to evaluate the full impacts of plastics and other materials, encouraging not just recycling but a critical examination of consumption itself.

In India, the application of LCA in HEIs has been primarily limited to infrastructure, energy consumption, and municipal solid waste management. Studies have focused on reducing greenhouse gas emissions through green energy adoption, optimizing waste management, and promoting circular economy principles (Bakos & Schiano-Phan, 2021; Jaglan et al., 2022; Prasad & Deswal, 2024; Sharma et al., 2011; Sharma et al., 2012; Sharma & Chandel, 2016).

However, there is a notable gap in the literature concerning the life cycle assessment of single-use plastic products, particularly within educational institutions, where environmental audits often stop short of being used as tools for pedagogical or behavioral transformation. Most existing studies tend to focus either on broader campus sustainability metrics or the environmental impacts of commonly audited items, with limited emphasis on translating audit data into actionable insights that foster behavioral shifts among students and staff. This study aims to bridge that gap by not only conducting a Life Cycle Assessment of single-use plastic pens at a teacher education institution in Kerala, India, but also by leveraging the findings to initiate reflection and behavioral change. The institution, characterized by its intensive writing requirements for assignments, examinations, and lesson planning, exhibits substantial SUP pen usage. By systematically auditing consumption patterns and analyzing the environmental impact through LCA, this research moves beyond assessment to advocacy, using empirical evidence to prompt awareness, critical discussion, and adoption of sustainable alternatives among pre-service teachers. In doing so, it aligns with global sustainability education goals while fostering change among future educators to lead by example.

The study progresses with the following hypotheses:

- **H1:** The usage of SUP pens in the teacher education institution is significantly high, contributing to a substantial environmental impact that is largely unmonitored and overlooked.
- **H2:** Presenting the LCA findings of SUP pens to student-teachers will lead to a behavioral shift in SUP pen usage, with participants becoming more open to adopting sustainable alternatives and sustainable practices, as they gain a deeper understanding of the environmental consequences associated with their use.

Methodology

Research Method

This study adopted an experimental pre–post survey method to examine the influence of an LCA-based educational intervention on students' awareness and behaviour regarding SUP pen usage.

Research Design

The research design consisted of three main phases outlined further in the section.

Phase 1: Pre-Intervention Survey

A survey method was employed to collect both quantitative and qualitative data, providing a comprehensive understanding of students' existing practices related to SUP pen consumption and their environmental attitudes. The pre-intervention survey established baseline behaviours, usage patterns, and levels of environmental awareness.

Phase 2: LCA-Based Educational Intervention

Life Cycle Assessment: After collecting the pre-intervention survey data, an LCA was conducted to evaluate the environmental footprint of SUP pen usage, with the following specifications:

- Functional Unit and System Boundary: The functional unit was defined as one single-use plastic ballpoint pen with an average mass of 0.01 kg. A cradle-to-gate system boundary was adopted, covering raw material extraction, material processing, and manufacturing stages. The use and end-of-life phases were excluded due to data limitations and the study's focus on production-related impacts.

- Software and Databases: The LCA was performed using OpenLCA software, utilizing the ELCD 3.2 database and OpenLCA LCIA methods 1.5.7 to enable a detailed environmental impact assessment.
- Impact Assessment: The CML-IA baseline method was applied to quantify key environmental indicators, including: Global warming potential, Photochemical oxidation, Acidification potential, Eutrophication, Human toxicity, Marine Aquatic and terrestrial ecotoxicity.

Educational Intervention: The LCA report was presented to participants in two formats: a detailed written document (available by contacting the author of the article) and an oral presentation. This dual-mode approach was designed to enhance accessibility, facilitate understanding, and promote deeper engagement with the environmental implications of everyday materials.

Phase 3: Post-Intervention Survey

A follow-up survey was conducted three weeks after the presentation to assess changes in students' behavioural intentions and practices. The three-week interval was deliberately selected as an optimal time frame to evaluate the persistence of the intervention's impact. Environmental education interventions are often associated with immediate but short-lived effects on attitudes and behaviours; therefore, introducing a temporal gap enables a more meaningful assessment of whether observed changes are sustained beyond the initial exposure and reflect more enduring behavioural transformation (Abrahamse et al., 2005; Steg & Vlek, 2009). This survey focused on their willingness to adopt sustainable alternatives, reported reductions in SUP pen usage, and shifts in environmental awareness.

By comparing pre- and post-intervention responses across these phases, the study evaluates the effectiveness of LCA as both an analytical and pedagogical tool in promoting sustainability-oriented behavioural change among prospective teachers.

Population

The study population comprises first-year and second-year B.Ed. students from the Teacher Education Institution, affiliated to the University of Kerala, Kerala, India, which hosts a total of 110 trainee teachers every academic year. This group was specifically selected due to their significant academic writing requirements, such as assignments and lesson planning, which led to the use of a large number of pens. As a result, this group was considered ideal for examining the impact of SUP pen usage in an educational context and exploring potential behavioral changes toward sustainability.

Sample

The sample for this study consisted of 65 students who voluntarily participated in both surveys. Participants were selected using convenience sampling, which allowed for an efficient way to access a group that was readily available and willing to participate.

The sample size of 65 participants is well within the acceptable range for an experimental study. In experimental research, particularly when using surveys, a sample size between 30 and 100 is generally deemed sufficient to identify trends, detect differences in behavior, and perform reliable statistical analyses (Lakens, 2022). With 65 participants, this study is adequately powered to measure changes in students' attitudes and behaviors regarding SUP pen usage after the LCA presentation, while ensuring that the data are representative of the student population at the selected teacher education institution. Additionally, the use of a convenience sampling method allows for a practical yet effective approach to gathering data from the population of interest, further ensuring that the sample size aligns with the research goals and objectives. This sample size strikes a balance between practicality and statistical relevance, ensuring that the results of the experiment can be used to draw meaningful conclusions about the potential impact of the LCA intervention on student sustainability behaviors.

Ethical Considerations

As the University of Kerala does not have a formal Institutional Review Board (IRB) or ethics committee for independent student-led projects (Sankar, 2026), this study was conducted under the researcher's ethical responsibility and in adherence to widely accepted research ethics guidelines. The study followed ethical guidelines to ensure participants' rights were protected. Informed consent was obtained from all participants, ensuring they understood the nature of the study, its objectives, and the voluntary nature of participation. The study also emphasized privacy and confidentiality, with participants' responses anonymized to ensure that personal data were securely stored and not shared beyond the researcher. Additionally, participants were assured that they could withdraw from the study at any point without consequences.

Data Collection Tools

The data for this study were collected, in 2025, using two online questionnaires, each consisting of 10 items. These items included a combination of multiple-choice questions, multi-select questions, and qualitative feedback questions. This varied format was chosen to capture both quantitative data, such as the frequency of SUP pen usage, and qualitative insights that allowed participants to share their thoughts on sustainability. To ensure the questionnaires' content validity, they underwent an expert review, where 5 professionals assessed the clarity and relevance of each item, ensuring they measured the intended constructs. Additionally, a pilot study was conducted with 10 B.Ed. students from a different teacher education institution affiliated to the University of Kerala. This pilot study helped further refine the questionnaire by testing its clarity and appropriateness, establishing face validity. The feedback from the pilot study enabled the researcher to adjust the tool (available by contacting the author of the article) to better obtain the desired data for the main study.

AI Usage Acknowledgement

The author acknowledges the use of ChatGPT (OpenAI) for language refinement to improve the clarity and readability of this manuscript, as English is not the author's first language. Additionally, ChatGPT was used to generate an image included as the cover page of the intervention report (LCA report). All intellectual content, analysis, and interpretations presented in this study are solely those of the author.

Life Cycle Assessment

Once the survey data were collected, LCAs were conducted to evaluate the environmental footprint of SUP pen usage. The LCAs were performed using OpenLCA software, a widely used tool for environmental modelling and impact analysis. The software allowed for a detailed assessment of the environmental impacts associated with the production, use, and disposal of SUP pens. Using the data obtained from the survey, the LCA focused on key environmental indicators such as global warming potential, photochemical oxidation, acidification potential, eutrophication, human toxicity, and aqua-marine ecotoxicity. The findings from the LCA provided critical insights into the environmental consequences of SUP pen usage within the institution and formed the basis for assessing potential shifts in behavior and adoption of sustainable alternatives, on presenting the report. By combining survey data with LCA, this study aimed to not only measure the environmental impact of SUP pens but also to understand how providing environmental impact information could influence students' behaviors and attitudes toward sustainability in academic settings.

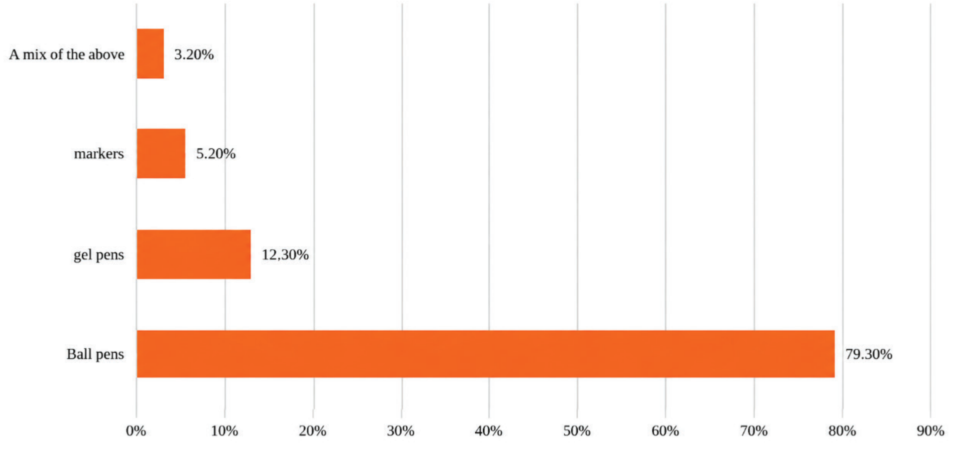
Results and Discussion

Pre-Intervention Survey

The pre-survey conducted with 65 first-year and second-year B.Ed. students, using the Pre-Intervention Questionnaire, revealed significant insights into the usage patterns, perceptions, and disposal behaviours related to single -use plastic ball point pens. A striking 64.6% of respondents reported using more than 10 pens per month, with a clear preference for SUP ballpoint pens.

Figure 1

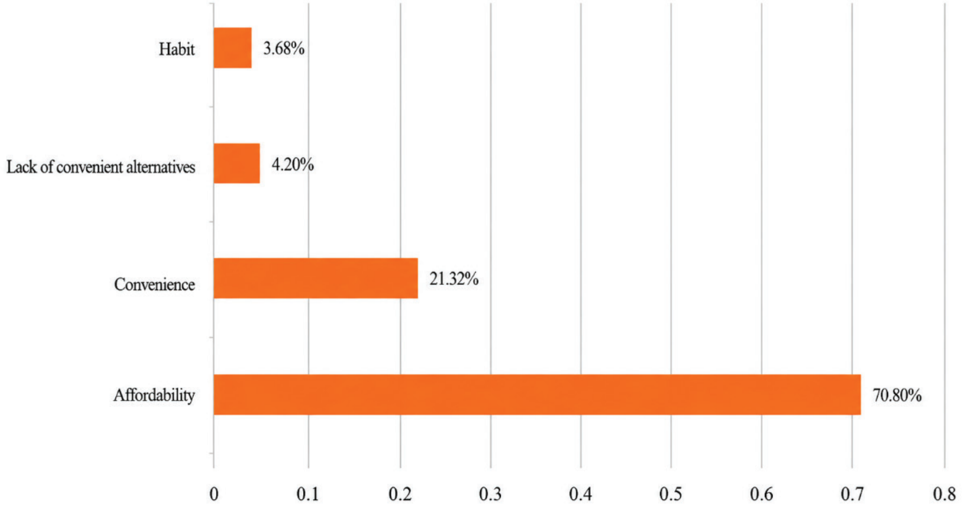
Percentage Distribution of Commonly Used Types of Pens



The primary reasons cited were affordability (70.80%) and convenience (21.32%), as in Figure 2. These findings align with existing literature that highlights cost and ease of use as major drivers of SUP consumption in educational settings (Chen et al., 2021).

Figure 2

Distribution of Students Based on the Primary Reason for Choosing Their Current Type of Pen



Despite the widespread use of SUP pens, an overwhelming 96.9% of participants stated that they were aware of the environmental impacts of SUP products, including pollution and long-term ecological harm. This level of awareness contradicts their reported behavior, as 83% expressed unwillingness to switch to sustainable alternatives, such as metal or ink pens. It appears that while students recognize the environmental consequences, their decisions are primarily influenced by cost and convenience, reflecting the limitations of awareness campaigns that do not address economic or functional benefits (Liobikienė & Poškus, 2019).

The qualitative feedback collected from the pre-survey provided valuable insights into the reasons behind students' reluctance to switch from SUP ballpoint pens to ink pens, despite their awareness of the environmental impacts. The primary concerns highlighted were related to usability and convenience, which significantly influenced their writing tool preferences. Several students expressed dissatisfaction with the writing experience offered by ink pens, noting that they tend to spread ink on the sheet, leading to a messy appearance, particularly when preparing records or assignments. Aesthetic considerations were also highlighted, with some students mentioning that their handwriting did not look as neat with ink pens compared to gel or ballpoint pens. This aligns with the fact that the importance of neatness and legibility in academic work is a key factor influencing writing tool choices (Stuart et al., 2024). Additionally, participants reported that ink pens are unsuitable for exam situations due to the risk of smudging, which could hinder the readability of their answers and potentially impact their performance. This functional disadvantage presents a significant barrier to the adoption of ink pens for academic purposes.

Concerns about durability also emerged as a recurring theme. Respondents mentioned that ink from these pens tends to fade over time, raising doubts about the longevity of written content. Furthermore, students expressed concerns about the possibility of ink spills, which they feared could ruin important documents entirely. This risk of accidental damage contributes to a general perception of ink pens as unreliable compared to the consistency offered by SUP ballpoint pens.

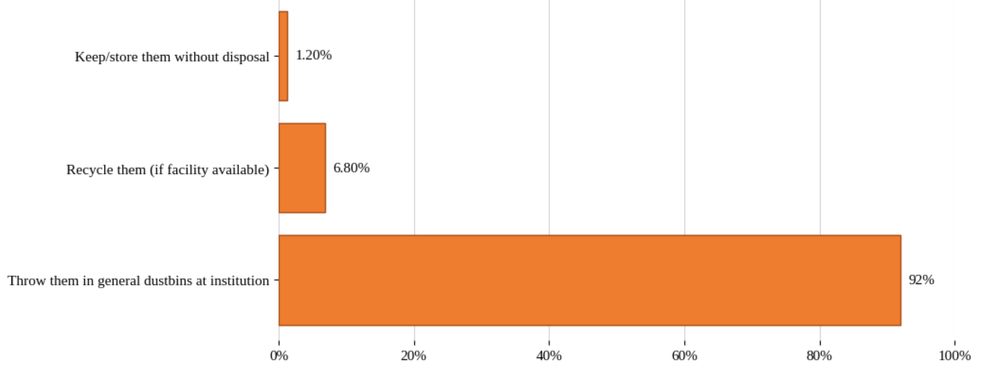
The preference for SUP pens was also linked to comfort and familiarity. As one student stated, "No, because I'm comfortable with plastic pens." This indicates that habitual use and ease of writing significantly influence their choices. This aligns with behavioral research suggesting that comfort and familiarity are powerful drivers of consumer habits, often outweighing environmental considerations (Touchette & Nepomuceno, 2020). Despite some students acknowledging a liking for ink pens, they still preferred SUP pens for exams due to concerns about smudging and neatness. This indicates a conditional acceptance of sustainable alternatives, contingent on specific use cases.

These findings underscore the complex interplay of practical, aesthetic, and emotional factors influencing pen choice among students. Moreover, this reluctance to adopt ink pens despite environmental awareness illustrates the attitude-behavior gap in sustainable consumption, where knowledge does not always translate into action (Eilam, 2025; Vermeir & Verbeke, 2006). This gap is often influenced by perceived inconvenience and emotional attachment to familiar products. While awareness campaigns are necessary, they are insufficient on their own to drive behavioral change, without proper statistical evidence on the environmental footprint. To bridge this gap, educational programs should incorporate experiential learning and practical demonstrations, enabling students to visualize environmental impact and thereby lead to sustainable behavior development.

The survey also revealed that the most common disposal method for SUP pens was placing them in institutional dustbins (92%), as shown Figure 4, with the majority of students (95.4%) admitting they did not know the ultimate fate of these pens. This points to a significant knowledge gap in waste management practices and the end-of-life implications of plastic products. It suggests a need for targeted educational interventions that not only raise awareness but also provide actionable knowledge about sustainable disposal methods and circular economy practices (Fernández et al., 2023; Kirchherr et al., 2017).

Figure 4

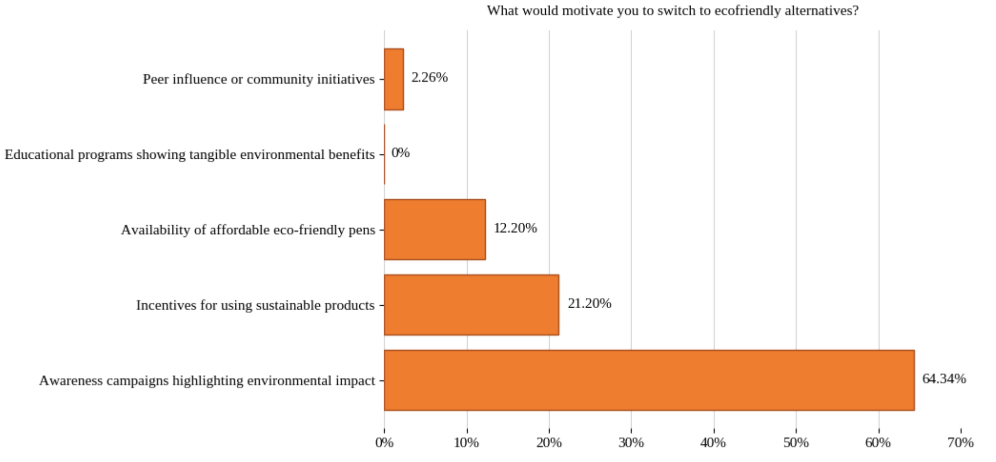
Distribution of Students' Usual Methods of Disposing Used Pens



Interestingly, when asked what would motivate them to switch to eco-friendly alternatives, most students (64.3%) preferred awareness campaigns, as shown in Figure 5. This response highlights a contradiction, as they had earlier claimed awareness of the environmental impact of SUP pens. This suggests a superficial level of awareness, lacking in-depth understanding of environmental consequences or the tangible benefits of adopting sustainable alternatives. This phenomenon, often termed "cognitive dissonance" in environmental psychology, indicates the need for more impactful educational strategies that move beyond general awareness to foster a deeper emotional connection and personal responsibility (Kollmuss & Agyeman, 2002).

Figure 5

Distribution of Students' Selected Motivating Factors for Switching to Eco-Friendly Pen Alternatives



LCA-Based Educational Intervention

Life Cycle Inventory and Product Modelling

The single-use plastic (SUP) ballpoint pen was modelled as a multi-component product, primarily composed of polypropylene-based plastic elements, including the barrel, cap, and refill tube. Minor metallic components, such as a steel spring and a brass/tungsten alloy tip, were also included, along with the ink formulation, consisting of dyes, solvents, and additives. This component-based modelling enabled a comprehensive representation of the material composition and associated environmental impacts across the product's life cycle.

A typical SUP pen was assumed to have a total mass of 0.01 kg, with plastic components accounting for approximately 85–90%, and smaller contributions from metallic elements and ink. Component-wise mass distribution was estimated based on standard product approximations in the absence of manufacturer-specific data.

Table 1

Material Composition and Mass Distribution of a Single-Use Plastic Ballpoint Pen

Component	Material	Weight (kg)	Percentage (%)
Barrel (outer body)	Polypropylene (PP)	0.004	40%
Ink refill tube	PP / PE	0.0015	15%
Ink	Dye + solvent mixture	0.001	10%
Cap / Click parts	PP / PS	0.002	20%

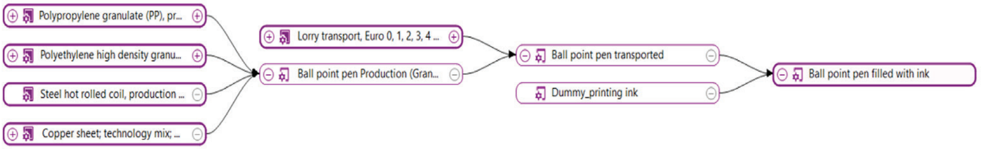
See next page for continuation of table

Continuation of Table 1

Tip	Copper-based alloy (proxy for brass)	0.0005	5%
Spring	Steel	0.0003	3%
End plug / small parts	Plastic	0.0007	7%
Total	—	**0.01**	**100%**

Figure 6

Model Graph of Cradle to Gate Life Cycle Inventory for a One Single-Use Plastic Pen



Modelling of Materials

- Plastic components were modelled using polypropylene datasets.
- Metallic components were represented using copper (proxy for brass) and steel datasets, with the spring modelled using a rolled coil steel dataset.
- Ink was represented using a proxy dataset for printing ink/organic solvent, reflecting its composite nature.
- Assumptions
- Proxy datasets were used due to the lack of specific LCA datasets for ballpoint pen components.
- These assumptions are unlikely to significantly affect results, as the study emphasizes relative environmental impact patterns rather than absolute precision.
- Transport and Usage Scaling
- After assembly, the pen was assumed to be transported by lorry over 500 km to the factory.
- To reflect real-world consumption patterns, the LCA model was scaled to monthly usage, assuming 10 pens per student across the study cohort, resulting in a total product mass of 4.2 kg per month.

This inventory forms the basis for subsequent LCA impact assessment and the educational intervention, linking material-level impacts to student consumption behaviours.

Note on Scope of Impact Assessment

Only the environmental impact of the 42 students who reported using more than 10 pens per month was evaluated, approximating pen usage to 10 pens per month. While a full assessment would ideally include students with exact pen consumption of students using more than 10 pens per month and also students with lower consumption levels (e.g., those using 3–5 pens per month), the focus here was on an approximate high-consumption of users to maximize the effectiveness of the intervention and clearly demonstrate the potential environmental consequences of intensive SUP pen usage.

Impact Assessment

The Life Cycle Assessment of a typical SUP pen, with an average mass of 0.01 kg and composed primarily of polypropylene and polyethylene, revealed notable environmental impacts across multiple categories. The analysis identified key contributing stages, including raw material production (particularly polypropylene granulate), energy-intensive manufacturing processes, and transportation (e.g., lorry transport), as major sources of environmental burden.

The results indicate that climate change potential and marine aquatic ecotoxicity are the most significant impact categories. The breakup of each major impact contribution was also calculated. These impacts are largely attributable to fossil fuel-based plastic production and the presence of chemically intensive materials in the product system. Other impact categories, including acidification, eutrophication, photochemical oxidation, and human toxicity, were also observed but contributed comparatively less to the overall environmental footprint (see Table 2). The findings highlight that even small, low-cost consumer products such as plastic pens can contribute to cumulative environmental impacts when considered at scale.

Table 2

LCA Impact Assessment: Comparative Results for SUP Pens (Single Unit vs. Monthly Usage for 42 Students)

Indicator	Option 1 (1 Pen)	Option 2 (420 Pens)	Unit
Acidification potential - average Europe	1.78145e-3	7.48209e-1	kg SO2 eq.
Climate change – GWP100	3.64842e-1	1.53234e+2	kg CO2 eq.
Depletion of abiotic resources - elements, ultimate reserves	2.68151e-7	1.12623e-4	kg antimony eq.
Depletion of abiotic resources - fossil fuels	5.24603e+0	2.20333e+3	MJ
Eutrophication – generic	3.68676e-4	1.54844e-1	kg PO4--- eq.
Freshwater aquatic ecotoxicity – FAETP inf	4.80396e-4	2.01766e-1	kg 1,4-dichlorobenzene eq.
Human toxicity – HTP inf	2.19718e-2	9.22816e+0	kg 1,4-dichlorobenzene eq.
Marine aquatic ecotoxicity – MAETP inf	1.15674e+1	4.85830e+3	kg 1,4-dichlorobenzene eq.
Ozone layer depletion – ODP steady state	4.66742e-9	1.96032e-6	kg CFC-11 eq.
Photochemical oxidation – high Nox	8.32051e-5	3.49461e-2	kg ethylene eq.
Terrestrial ecotoxicity – TETP inf	2.97645e-4	1.25011e-1	kg 1,4-dichlorobenzene eq.

These findings formed the basis of the LCA report presented to students, highlighting the broader ecological implications of everyday pen consumption. By providing visual quantitative calculations, the report made previously abstract environmental impacts tangible, helping students directly perceive the consequences of their SUP pen usage and fostering a stronger sense of the need to adopt sustainable alternatives.

Life Cycle Assessment Intervention

The findings were compiled into a detailed LCA report, which was presented to the participants both as a written document (available by contacting the author of the article) and through a 30-minute oral presentation. During the presentation, each environmental impact was explained, illustrating how SUP pen usage affects various ecological and human health parameters. This dual-format delivery served as the primary intervention to raise awareness and encourage reflection on sustainable alternatives.

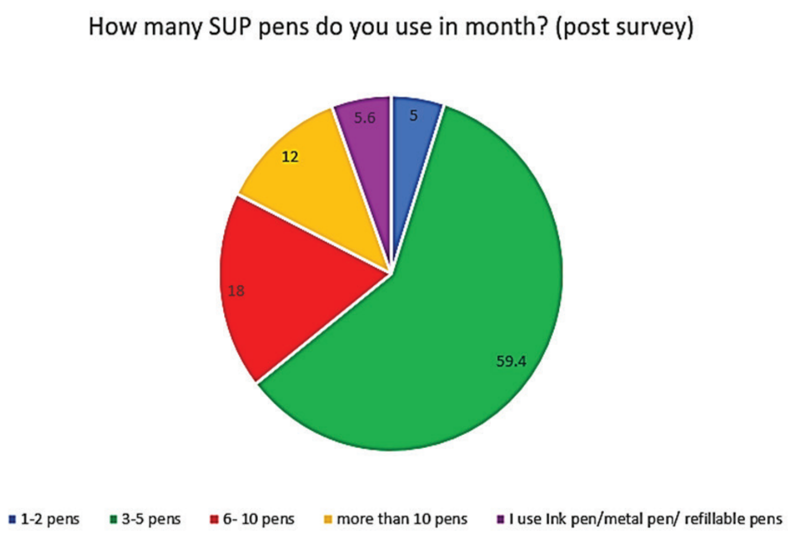
Post-Intervention Survey

Three weeks after presenting the LCA report on SUP ball point pens, a structured post-intervention survey was administered to the same cohort of 65 B.Ed. students, using the post-intervention questionnaire that consisted of both closed-ended and open-ended questions designed to assess changes in pen usage, emotional responses, environmental awareness, and proactive behavioural shifts. This mixed-methods approach enabled a comprehensive understanding of the impact of the educational intervention.

Only 12% of students reported using more than 10 SUP pens per month, as shown in Figure 7, a marked reduction from the 64.6% reported in the pre-survey, and there was even a new distribution representation of metal/ink/refillable pen users. This suggests that the increased awareness of the environmental consequences of SUP pens can effectively influence consumption behavior. The findings align with previous research suggesting that educational interventions can foster pro-environmental behavior by enhancing awareness and emotional engagement (Touchette & Nepomuceno, 2020).

Figure 7

Distribution of Students Across Different Levels of Pen Usage, After Intervention

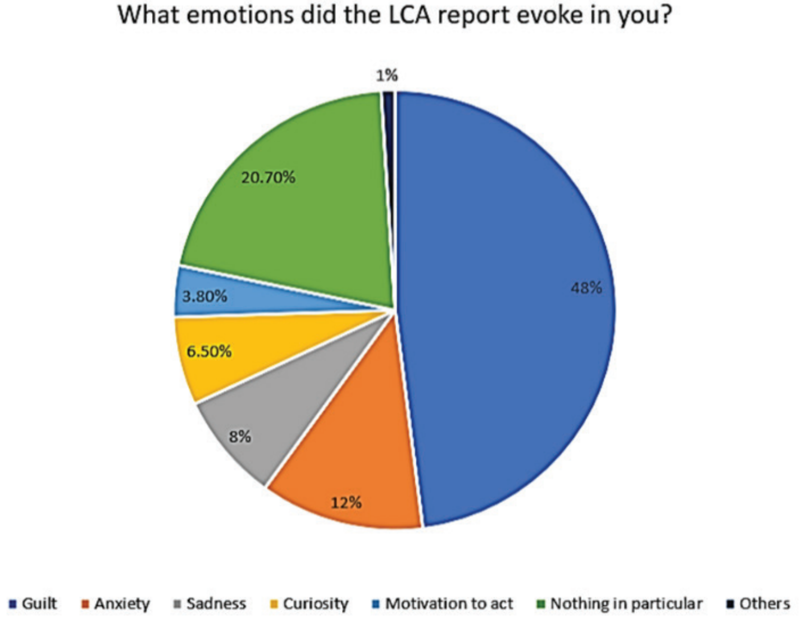


The post-intervention survey also revealed a complete shift in environmental awareness, with 100% of participants acknowledging the environmental impact of plastic pens, compared to 96.9% in the pre-survey. More importantly, 92% expressed a willingness to switch to sustainable alternatives indicating that the LCA report effectively challenged pre-existing perceptions and motivated action. This suggests that presenting tangible, relatable data can enhance environmental literacy and openness to sustainable practices.

Participants reported that the LCA findings elicited feelings of guilt (48%), anxiety (12%), sadness (8%), and curiosity (6.5%), as shown in Figure 8. This emotional response, linked to a form of eco-anxiety, appears to have played a crucial role in motivating behavioral change. The emergence of eco-anxiety is consistent with studies showing that environmental awareness can trigger emotional responses that lead to more sustainable decision-making (Cortázar et al., 2025; Pihkala, 2020). In this case, the emotional impact of the report fostered a heightened sense of responsibility and the need for change.

Figure 8

Distribution of Student Emotions Evoked by LCA Report

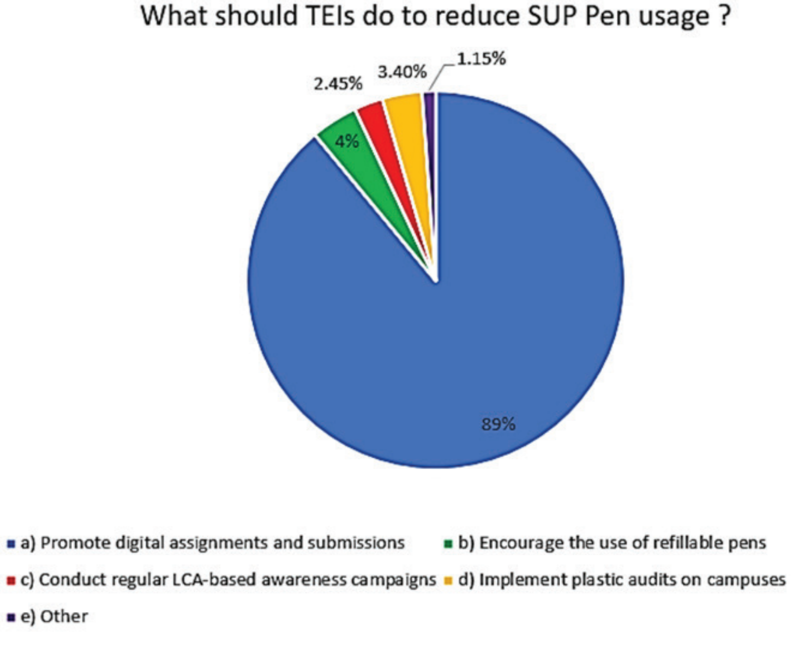


Qualitative feedback provided further insights into the cognitive shift among participants. Statements, such as *"I thought carbon footprint was just CO_2 emissions; I didn't know there were other emissions involved"* and *"This report was eye-opening; we usually don't see pollution other than smoke and hence tend to be dismissive. This showcased what was really going on, and I felt so much guilt"*, illustrate how the LCA findings broadened participants' understanding of environmental impacts. These responses highlight the value of comprehensive environmental education in dismantling misconceptions and fostering more nuanced ecological awareness. In the post-intervention discussions, some students raised the point that even pen refills are packaged in plastic, which could contribute to carbon emissions. However, a counter-argument emerged from within the group: the current SUP pens widely available in the market are made of thermosetting plastics, which are non-recyclable, whereas most refills and their packaging are made of thermoplastics that can be remolded and reused if proper recycling processes are followed. Such exchanges indicated that students had begun to approach the issue with a more critical perspective. Participants also expressed a desire for broader systemic changes, including the implementation of segregated waste management on campus and informed decision-making about the disposal of plastic waste, ensuring that it follows the most sustainable pathways possible.

Additionally, participants provided practical suggestions for promoting sustainability. They emphasized the importance of governmental policies, circular economy practices, and extended producer responsibility, highlighting a growing awareness of systemic solutions to environmental issues. The call for digitizing written assignments, as shown in Figure 9, indicates a proactive attitude toward reducing SUP pen consumption, reflecting a willingness to adopt sustainable practices within educational contexts. Some students also suggested buying only pen brands with available refills, demonstrating a shift towards more mindful purchasing behaviors.

Figure 9

Distribution of Student Suggestions on What Teacher Education Institutions Under the University of Kerala Should Do to Reduce SUP Pen Usage



These findings demonstrate the potential of LCA as an educational tool for influencing behavioral change. The integration of LCA findings into educational curricula could enhance students' environmental literacy and motivate sustainable consumption patterns. Moreover, the shift in students' attitudes and behaviors illustrates the effectiveness of using evidence-based communication strategies to cultivate responsible environmental citizenship.

Overall, the significant reduction in SUP pen usage, increased environmental awareness, and proactive suggestions for sustainability underscore the importance of targeted educational interventions. This study contributes to the growing body of literature on environmental education by demonstrating how LCA can be leveraged to promote sustainable behaviors within educational institutions.

This study has several limitations that should be acknowledged. First, the LCA relied on the OpenLCA database and proxy datasets that are primarily contextualized for European, Australian, and New Zealand production systems rather than Indian manufacturing conditions. Due to a lack of India-specific datasets for SUP pens and their components, the analysis necessarily adopted proxy modelling approaches. While this limits the precision of absolute environmental impact values within the Indian context, the study remains valuable in identifying relative environmental burden patterns and demonstrating the broader ecological implications of intensive SUP pen consumption in educational settings. Second, the study was conducted within a single teacher education institution in Kerala, India, using a localized sample and context-specific intervention. As a result, the findings may not be fully generalizable to all higher education institutions or student populations. However, this contextual specificity also represents a key strength of the study, as it reveals a globally relevant blind spot in campus sustainability initiatives: the neglect of everyday academic consumables such as single-use plastic pens within sustainability audits and educational policy discussions. Thus, while the behavioural patterns observed may vary across contexts, the underlying issue identified by the study has broader international relevance.

Conclusion

This study demonstrates the often-overlooked environmental impact of SUP pens within higher education institutions, specifically in the context of a teacher education program in Kerala, India. Through a combined methodology of pre- and post-intervention surveys and a detailed LCA, the research brings attention to the cumulative ecological burden posed by routine academic consumables and explores the transformative potential of evidence-based environmental education.

The findings reveal a paradox commonly observed in sustainability research: while students exhibited high levels of environmental awareness, their behaviors were primarily governed by cost, convenience, and habit. This disconnect between knowledge and action, termed the attitude–behavior gap, was effectively addressed through the LCA intervention. By presenting students with tangible, quantifiable data on the carbon emissions, aquatic toxicity, and other environmental harms associated with SUP pens, the intervention fostered emotional engagement and catalyzed a measurable shift in behavior.

The dramatic reduction in high-usage rates (from 64.6% to 12%) and the substantial increase in willingness to adopt sustainable alternatives (92%) underscore the capacity of LCA to serve not only as an analytical tool but also as a powerful educational tool.

From an educational policy perspective, the study highlights the urgent need for institutions to reconsider traditional assessment practices that inadvertently encourage the consumption of disposable plastics. Transitioning toward digital assessment methods, embedding sustainability modules within teacher education curricula, and integrating LCA-based learning activities can contribute to cultivating a new generation of environmentally responsible educators.

More specifically, these recommendations can be structurally aligned with the Integrated Teacher Education Program introduced under India's National Education Policy (NEP) 2020. The multidisciplinary and experiential learning orientation of Integrated Teacher Education Program provides opportunities to incorporate sustainability-oriented pedagogies across curriculum transactions. For instance, LCA-based activities may be embedded within Environmental Education, Enhancing Professional Capacities courses, action research components, practicum activities, and community engagement programs already prescribed within teacher education frameworks. Importantly, OpenLCA reports can help student-teachers visualize otherwise abstract forms of pollution, such as carbon emissions, aquatic toxicity, eutrophication, and resource depletion, by translating complex environmental impacts into understandable and relatable forms. This makes hidden ecological consequences more visible, strengthens ecological literacy through evidence-based reflection, and equips future teachers to translate these sustainability concepts meaningfully to their own students.

Similarly, digital submission of assignments, reflective journals, and lesson plans can be integrated into existing assessment reforms promoted under NEP 2020, reducing dependency on single-use plastic stationery while simultaneously strengthening digital pedagogical competencies among future teachers. Furthermore, the study supports the broader NEP 2020 emphasis on experiential, inquiry-based, and socially relevant learning by demonstrating how localized environmental audits can function as pedagogical tools for behavioural transformation. In this sense, sustainability education need not remain confined to theoretical discussions but can be operationalized through institution-level practices that directly engage student-teachers with the environmental consequences of everyday academic consumption.

At the institutional level, this study advocates for systematic environmental audits of everyday campus practices and the adoption of circular economy principles in procurement and waste management. SUP pens, though seemingly insignificant, serve as a microcosm of broader consumption patterns. Addressing their usage presents a practical entry point for initiating sustainable behavioral change across academic settings.

In contributing to the *Journal of Teacher Education for Sustainability* (JTES) action research tradition, this study demonstrates how researcher-driven reflection, participant engagement, and context-specific data can reorient educational practices toward sustainability. Although situated in Kerala, the implications extend globally, as SUP pen usage is a shared challenge across education systems worldwide. By situating this case within the wider discourse on sustainable education, the research provides both a replicable methodology and actionable insights for fostering systemic change in teacher education internationally.

Ultimately, the study demonstrates that sustainability in teacher education is not only a matter of curriculum content, but also of critically re-evaluating the material cultures and everyday practices embedded within educational institutions themselves.

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