



**Restoring Balance: Earth Overshoot Day as a Framework for
Teacher Education**

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Restoring Balance: Earth Overshoot Day as a Framework for Teacher Education

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Purpose - This study examines how pre-service teachers (PSTs) develop awareness and understanding of Earth Overshoot Day (EOD) through a structured educational intervention (EI), focusing on shifts in knowledge, attitudes, and behavioral intentions, and their roles as future educators.

Design/methodology/approach - A descriptive phenomenological design was employed with 27 PSTs participating in a four-week EOD-focused training program. Data were collected through semi-structured interviews and reflection journals. Thematic analysis was used to identify patterns in participants' knowledge, attitudes, and intended behaviors, framed by Social Cognitive Theory (SCT) and Theory of Planned Behavior (TPB).

Findings - The EI significantly enhanced participants' awareness, with 96% accurately defining EOD post-intervention. Participants identified overconsumption, energy waste, and ecosystem damage as key contributors and highlighted consequences such as resource depletion, climate change (CC), and biodiversity loss. PSTs emphasized integrating sustainability into education through experiential learning, creative activities, and role modeling.

Originality - This study addresses a gap in the literature concerning EOD within sustainability education (SE). It demonstrates the potential of targeted interventions to enhance environmental literacy among PSTs and better prepare them to tackle sustainability challenges in their future classrooms.

Practical implications - Teacher education programs can integrate EOD into curricula through creative and interactive pedagogical approaches, thereby fostering critical thinking and pro-environmental behaviors.

Social implications - Educating PSTs about EOD may influence broader societal behaviors, contributing to the achievement of global Sustainable Development Goals (SDGs).

Research limitations/implications -The study is limited by its qualitative design and sample size. Future research could incorporate quantitative and longitudinal methods to provide a more comprehensive understanding of intervention outcomes.

Keywords: Ecological Footprint, Earth Overshoot Day, Educational Intervention, Environmental Education, Environmental Literacy, Sustainability Education, Sustainable Development Goals (SDGs), Teacher Education.

Paper type: Research paper

Introduction

Earth Overshoot Day (EOD) marks the date when humanity's annual demand on nature exceeds what Earth's ecosystems can regenerate in that year (Global Footprint Network [GFN], 2024). It serves as a stark indicator of the growing imbalance between human consumption and the planet's ecological capacity. Since its inception in the early 1970s, EOD has been occurring progressively earlier each year, highlighting an unsustainable trajectory of resource depletion (GFN, 2024). EOD in 2024 fell on 1 August, signalling that humanity was using resources at a pace that would require roughly 1.75 Earths to sustain (GFN, 2024). This stark marker underscores the urgent need to confront the systemic problem of ecological overshoot, which threatens biodiversity, ecosystem integrity, and human well-being.

The ecological footprint (EF) quantifies environmental pressure as the biologically productive land area and water area required to supply a population with resources and to assimilate its waste (Wackernagel and Rees, 1996). EOD calculations are derived from the EF and indicate how much more than the earth's biocapacity humanity is (Wiedmann *et al.*, 2020). This long-term overshoot accelerates loss of biodiversity, climate change (CC), and enhances environmental degradation. Therefore, a balance of human consumption with ecological limits is urgent (Steffen *et al.*, 2015).

Confronted with these obstacles, it will require more than technological innovation and sound policy; it will also depend on shifts in individual and collective behaviour and attitudes (Leiserowitz *et al.*, 2006). Education is at the heart of this process: by helping to instil the values, knowledge, and skills required for sustainable action, it can create ecological awareness and support low-footprint living (Sterling, 2011; UNESCO, 2017). Environmental education programs specifically aim to transform consciousness of such concepts as EOD into real pro-environmental behavior (Monroe *et al.*, 2019); e.g., the addition of EF within educational curriculum has been shown to inspire students to reduce their own traces (Redman *et al.*, 2021).

Pre-service teachers (PSTs) occupy a pivotal role because they will become future catalysts for sustainability mindset in schools. Only through well-prepared educators can sustainability values be effectively transmitted to new generations (Anderson, 2012). Furthermore, cultivating a school culture of environmental stewardship hinges on PSTs' understanding of ecological limits, including the significance of EOD (Mochizuki and Bryan, 2015). Yet research indicates that many PSTs enter programs with limited knowledge and low self-efficacy for teaching sustainability (Goldman *et al.*, 2014), a gap that teacher-education must urgently address.

This study will contribute towards the current literature by looking at how PSTs are exposed and made aware of EOD in a designed educational intervention (EI). In the study, the theoretical basis is rooted in Social Cognitive Theory (SCT; Bandura, 1986), and Theory of Planned Behavior (TPB; Ajzen, 1991) that study constructs interacting with behavior. The study thus offers a detailed theoretical underpinning of awareness, attitude and intention formation with regards to sustainability enabled by education. Moreover, it explores the implications of the results on pedagogy highlighting the nature of future teacher training programs to support sustainable awareness and prescriptive behaviors.

Literature Review

Sustainability education (SE) research has explored various EIs aimed at fostering environmental learning among PSTs. Studies by Goldman *et al.* (2014), Monroe *et al.* (2019), García-González *et al.* (2020), and Redman *et al.* (2021) demonstrate that well-designed EIs can enhance knowledge, attitudes, and self-efficacy regarding sustainability. However, few of these investigations have specifically targeted awareness or behaviors linked to EOD, leaving a gap that the study addresses.

Role of Higher Education Institutions in Sustainability Education

Higher education institutions (HEIs) serve as critical agents for implementing Sustainable Development Goals (SDGs) and embedding sustainability competencies (SCs) into curricula (Leal Filho *et al.*, 2021). Albareda-Tiana *et al.* (2018) identified both structural barriers and effective strategies for integrating SDGs into undergraduate programs, emphasizing the need for institutional support and faculty development. More recently, Conroy *et al.* (2024) introduced a Six-Dimensional Interdisciplinary Sustainability Framework, which has facilitated improvement by promoting cross-disciplinary collaboration and experiential learning.

Ecological Footprint

EF was initially developed by Wackernagel and Rees (1996). It has since been applied by HEIs to take abstract notions of sustainability and convert them into measurable terms. Interactive EF calculators are at the forefront of such an application. Collins *et al.* (2018) illustrated how such applications raise students' consciousness about how all mundane activities ultimately contribute towards mounting global pressure on resources. Fernández *et al.* (2020), however, came across a discrepancy between Spanish university students' environmental consciousness and actual footprints, necessitating experience-based action-learning. In response to this need, Colibaba *et al.* (2022) designed Reducing the Ecological Footprint through Eco-Awareness (REFE) project, founded on interactive, experience-based modules to develop ecological literacy. Subsequently, Douglas *et al.* (2024) came up with a sustainability-education course incorporating fieldwork and reflective practice and found that the former enhances long-term pro-environmental behavior.

Earth Overshoot Day in Sustainability Education

EOD presents an exciting educational concept that illustrates ecological overshoot, the moment in each year when people's consumption surpasses the Earth's regenerative ability (GFN, 2024). Maurer and Bogner (2020) found that university students struggle to differentiate key ecological terms and use "nature" and "environment" interchangeably. Their study indicates that coherent communication of sustainability themes consolidates students' conceptual knowledge about sustainability and encourages active behavior. Similarly, Redman *et al.* (2021) showed that students become more active in using particular temporal markers like EOD in constraining abstract environmental issues. Even though these are its strengths, direct application of EOD in teacher-education courses is rare-a gap that the current study aims to fill.

Sustainability Competencies and Pre-Service Teacher Education

PSTs are pivotal in transmitting sustainability values to future generations (Artvinli *et al.*, 2019; García-González *et al.*, 2020). Yet many PSTs report low confidence in teaching sustainability, limited ecological knowledge, and unfamiliarity with sustainability concepts (García-Gonzalez *et al.*, 2020; Goldman *et al.*, 2014). Mochizuki and Bryan (2015) demonstrated that targeted SE interventions significantly increase PSTs' content knowledge, self-efficacy, and pedagogical skills, underscoring the need for structured programs to develop SCs. More recently, Hyytinen *et al.* (2023) identified variation in PSTs' disciplinary interests and SCs profiles, recommending

tailored, discipline-specific pedagogies to foster critical thinking, ethical reasoning, and collaborative skills.

Experiential and Participatory Approaches in Sustainability Education

The benefits of experiential and participatory pedagogies in building SCs have been demonstrated by numerous studies (Douglas *et al.*, 2024; Persson *et al.*, 2023). Participatory methods engage students directly and foster meaningful community interaction, thereby deepening the sustainability learning experience. Combining theoretical principles with real-world activities promotes not only deeper comprehension but also enduring behavioral and attitudinal change (Douglas *et al.*, 2024). It has been demonstrated that EIs specifically created to foster SCs, like the Diploma of Sustainable Living, significantly improve pro-environmental behavior and sustainability knowledge (Douglas *et al.*, 2024). The potential for EIs to have quantifiable effects on learner behavior is further highlighted by Persson *et al.* (2023).

Theoretical Approaches: SCT and TPB in Sustainability Education

For both understanding and influencing behavioral change in SE, SCT and TPB offer complementary views. SCT captures how contexts within which people live and learn—namely teachers who practice sustainable behaviors—motivate environmental behaviors through the emphasis on observational learning, self-efficacy, and reciprocal determinism (Evans, 2019; Moseley *et al.*, 2010). Accordingly, TPB asserts that a specific group of behavioral intentions, which correlate with actual behavior, is driven by a mix of attitudes towards a behavior, subjective norms, and perceived behavioral control. Through the identification of significant levers to induce intentions to behave in a sustainable way, this model enables effective EI design.

SCT and TPB provide a more subtle understanding of social and cognitive foundations of sustainability actions when combined in teacher-education settings. While TPB identifies how changes in attitudes and social norms serve to reinforce PSTs' intentions to adopt sustainable practices in their own classrooms, SCT identifies how mastery experience and modeling build PSTs' skillset and confidence. The theories complement each other in informing the development of curricula that specifically target SCs in PSTs (Persson *et al.*, 2023).

Although the broader SE literature demonstrates the value of EF, experiential/participatory methods, and competency-based frameworks in higher education, there is scant research on embedding EOD specifically within teacher education. By grounding an EI in SCT and TPB and explicitly incorporating EOD, this study addresses that gap. It examines how EOD-focused activities influence PSTs' sustainability knowledge, attitudes, and emerging professional identities—and offers practical guidance for designing SE interventions that equip future teachers to drive societal sustainability transitions (Varela-Losada *et al.*, 2022).

Theoretical Framework

The study is grounded in the integration of EOD and EF with psychological theories of behavioral change, specifically SCT and TPB.

Social Cognitive Theory (Bandura, 1986)

SCT asserts that learning unfolds through the continuous, reciprocal interaction of personal factors, behavior, and the environment. Four central constructs—observational learning, self-efficacy, outcome expectations, and reciprocal determinism—are especially relevant for designing educational interventions that embed EOD and EF concepts.

Observational Learning enables learners acquire new behaviors by watching models—teachers, peers, or mentors—who demonstrate those behaviors. In a sustainability-focused intervention, PSTs observe mentors integrating EOD discussions and EF activities into their teaching. Such

modeling helps PSTs internalize both the content (e.g., the significance of ecological overshoot) and pedagogical strategies for conveying it (Evans, 2019).

Self-efficacy refers to individuals' beliefs in their capacity to organize and execute the actions required to achieve specific goals. When PSTs engage in carefully scaffolded EOD activities such as calculating class EFs and leading discussions-they build confidence in their ability to teach sustainability concepts. Higher self-efficacy, in turn, predicts greater willingness to introduce EOD content into future classrooms (Moseley *et al.*, 2010).

Outcome expectations are learners' beliefs about the likely results of a behavior, which influence their motivation to perform it. If PSTs believe that teaching EOD will foster student engagement, raise ecological awareness, and lead to positive environmental actions, they are more inclined to adopt and sustain such teaching practices.

Reciprocal determinism describes the dynamic interplay among personal factors (e.g., values, knowledge), behavior (e.g., teaching practices), and environmental influences (e.g., institutional support). A supportive faculty culture and access to EOD resources can reinforce PSTs' motivation and efficacy, while PSTs' successful implementation of EOD lessons can, in turn, shape school norms and expectations around sustainability.

By applying SCT's constructs to EOD- and EF-focused interventions, this framework guides the design of activities that not only convey SCs but also strengthen PSTs' confidence, motivation, and ability to enact sustainable teaching practices.

Theory of Planned Behavior (Ajzen, 1991)

TPB proposes that an individual's behavioral intention-the most immediate antecedent of action-is determined by three constructs: attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991).

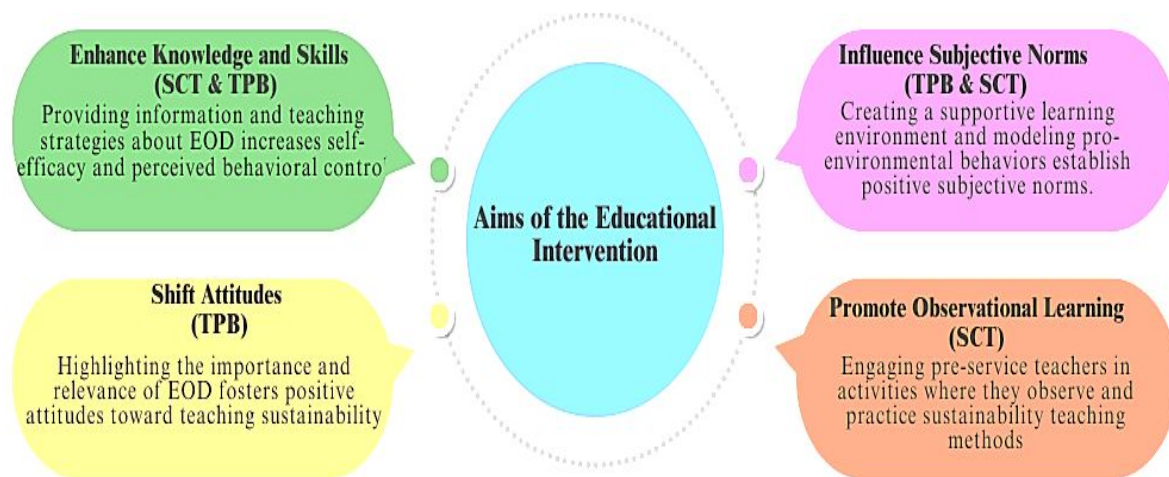
Attitudes refer to one's overall evaluation of performing the behavior (Ajzen, 1991). PSTs hold positive views about teaching EOD and sustainability, they are more likely to form a strong intention to include these topics in their future classrooms.

Subjective norms denote perceived social pressures to perform or refrain from the behavior. If PSTs believe that their peers, mentor teachers, or the institution expect them to address sustainability, their intention to teach about EOD strengthens.

Perceived behavioral control captures one's belief in the ease or difficulty of executing the behavior, reflecting past experience and anticipated obstacles. Confidence in available resources, pedagogical support, and one's own teaching skills closely parallels self-efficacy and directly influences both intention and actual implementation of EOD lessons.

Integrating Theories into the Study

By combining SCT and TPB, the study examines how social influences, personal beliefs, and perceived control contribute to PSTs' awareness and intended behaviors regarding EOD. The EI is designed to enhance self-efficacy, shift attitudes, and positively influence subjective norms, thereby increasing the likelihood that PSTs will integrate EOD into their future teaching practices. Figure 1 illustrates the theoretical model and the EI's specific objectives.



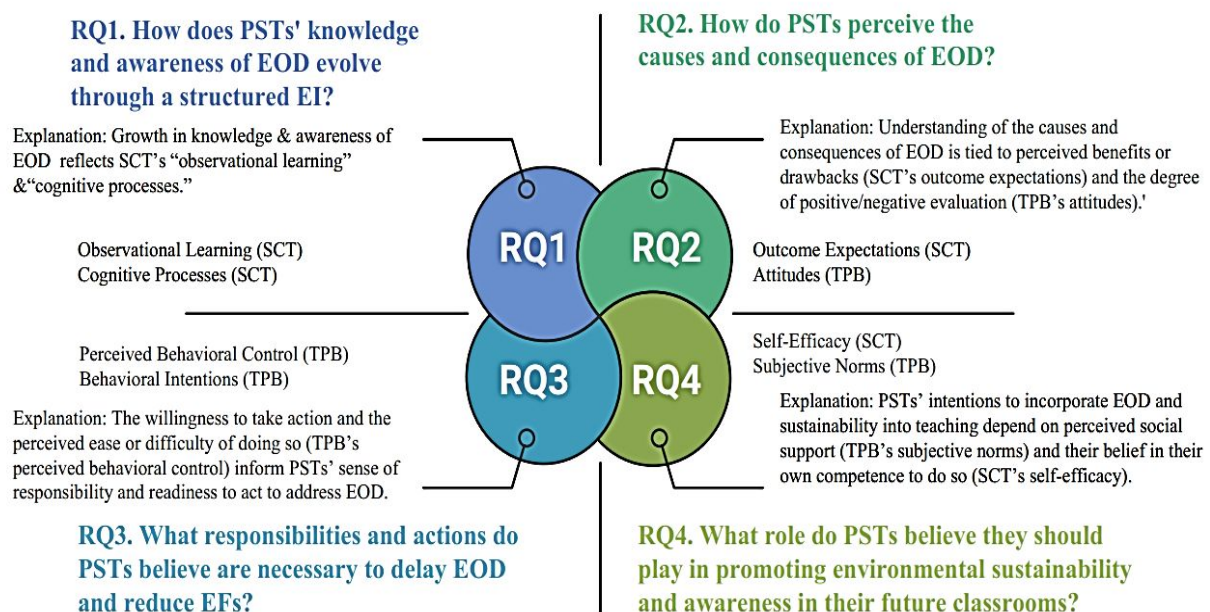
Source: Author own work
Figure 1. Aims of EI

Understanding these theoretical connections not only enhances knowledge about EOD but also facilitates the development of targeted educational strategies that influence the psychological factors driving behavior change. By addressing attitudes, boosting self-efficacy, and leveraging social norms, this study aims to empower PSTs to become advocates for SE.

Purpose

This study primarily aims to investigate how PSTs' awareness and understanding of EOD evolve through a structured EI. It examines the shifts in their knowledge, attitudes, and behavioral intentions related to sustainability. Additionally, the study explores how PSTs internalize these concepts within the context of their emerging professional identities, focusing on their perceptions of responsibility and agency as future educators. Hence, following research questions (RQs) are proposed in accordance of theoretical background as seen in Figure 2.

Mapping Theoretical Connections in Research Questions



Source: Author own work

Figure 2. Map of Theoretical Connections in RQs.

Methodology

A descriptive phenomenology research design was used in the current study to investigate PSTs' experienced phenomena. Phenomenological approach is especially adapted to portray a specific phenomenon's world of living and individual meaning, according to Creswell and Poth (2016). Emphasizing the lived experience of participants, this process allowed for an analysis of the way PSTs absorbed EOD and SE in terms of their emerging professional identity. For these purposes, a descriptive phenomenological approach was taken which revealed the invariant features of PSTs' experience unencumbered by theory leading the investigation. In the field, researchers "bracketed" assumptions so that themes organically emerged from the data (Van Manen, 2016). As behavior change is psychologically dependent, SCT and TPB were applied as interpretive theories throughout the research. SCT and TPB informally determined EI design in that RQs and interview protocols were directly informed by them; for example, EI activities were intentionally aligned with SCT and TPB's main concepts. This systematic integration grounded the data phenomenologically (i.e., thickly in participants' own accounts), with interpretation of results supplemented by the conceptual structures of SCT and TPB.

Participants' descriptions led to deductively derived themes that were then analyzed inductively and mapped onto SCT and TPB constructs (reverse logical deduction). This blend of inductive and deductive analytic procedures added empirical richness and theoretical depth, resulting in analytical insights with precision regarding PSTs' engagement and internalization of concepts related to EOD awareness and SE. Ultimately, this methodological fusion of descriptive phenomenology with SCT and TPB frameworks was an important element in establishing the study's analytic transparency, methodological reliability, and theoretical integrity.

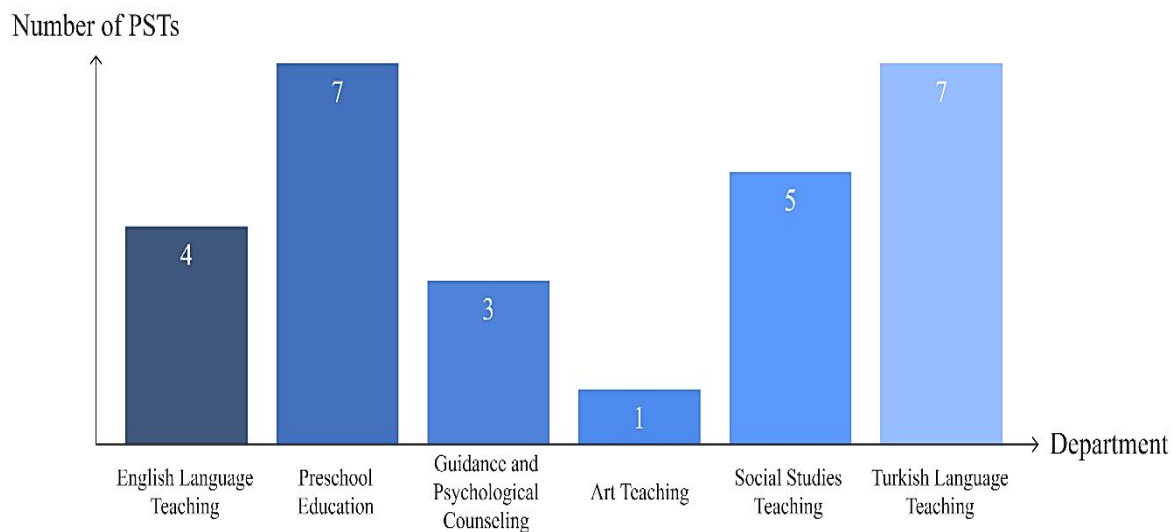
Sampling

The study used criterion sampling, a type of purposeful sampling. This approach allowed the researchers to select participants who could supply detailed, context-rich data that aligned with the study's aims (Suri, 2011). To make the effects of the EI clearly observable, the inclusion criteria were designed to ensure that all PSTs shared a comparable baseline in sustainability education. The criteria were as follows:

- **Enrolling for Elective Course "Extra-curricular Activities in Education":** Participants had to be taking a class that was exclusively environmental literacy, and therefore represented this biometric marker for need of additional environmental awareness. This was intended to confirm all participants had some environmental base level of exposure and interest in the topic, and was important for their experiences.
- **No EOD Training or Specialized Education:** To claim any changes in knowledge, attitude or behavioral intentions to be solely due to intervention, it was necessary that no one had formal education or specialist training in EOD or closely related subjects before the study. This helped make the playing field level, with all participants starting with a similar level of knowledge about sustainability issues as a baseline.
- **Voluntary, Informed Consent:** Participants provided their informed consent for participation in all study activities. In addition, it helped that the data were to be based on users who are real and engaged with generated content.

The final sample comprised 27 PSTs from a state university's Faculty of Education: 24 female and three male students, reflecting gender distribution commonly observed in education programs. 17 participants were third-year students and 10 were fourth-year students. Drawing from various departments provided a broad spectrum of perspectives on sustainability and EOD, enriching the data and enhancing the transferability of the findings. The diverse departmental

representation is shown in Figure 3.



Source: Author own work

Figure 3. Distribution of PSTs' departments

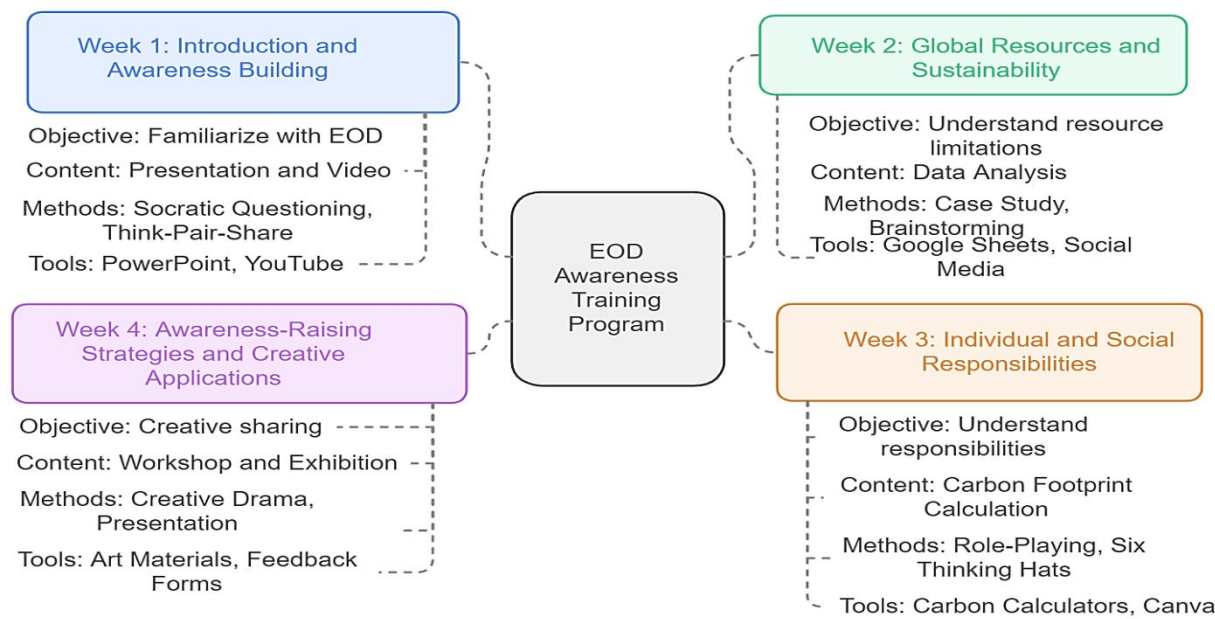
Educational Intervention

A four-week EOD Awareness Training Program was carefully designed and implemented to enhance PSTs' understanding of EOD and broader sustainability issues. The intervention was embedded within an existing elective course to ensure both relevance and accessibility for participants. The structure of the intervention was closely aligned with the study's conceptual framework, incorporating key constructs from SCT and TPB.

Objectives of the Educational Intervention

- To increase participants' knowledge and awareness of EOD, EF, and sustainability.
- To foster positive attitudes toward environmental responsibility and SE.
- To build PSTs' self-efficacy in teaching EOD and integrating sustainability into educational settings.
- To influence behavioral intentions by encouraging personal and professional commitments to sustainable practices.

The program, outlined in Figure 4, was delivered over a period of four weeks (eight instructional hours in total). Each session was designed to build progressively upon previous one, deepening participants' cognitive engagement and emotional connection with sustainability concepts.



Source: Author own work

Figure 4. Design of EOD awareness training program

Week 1: Introduction and Awareness Building

The first week aimed to familiarize students with the concept of EOD and foster initial awareness. A presentation introduced the history, purpose, and global importance of EOD, utilizing visuals like graphs and infographics to concretize the topic. Short documentaries, videos and planetary boundaries were screened to provide context. Interactive discussions were facilitated using the Socratic questioning method, encouraging students to reflect on questions like "What drives EOD?" and "How can we, as individuals, make a difference?" Think-Pair-Share technique allowed PSTs to reflect on their personal resource consumption habits, exchange ideas with peers, and share insights with the class.

Week 2: Global Resources and Sustainability

In the second week, the focus shifted to increasing understanding of resource limitations and sustainable living. PSTs analyzed real-world data on global resources, EFs, and sustainability, comparing resource consumption across countries. Case study analyses of notable sustainability efforts in local and worldwide were conducted to examine outcomes and best practices. Group brainstorming sessions centered on "What can we do individually for sustainability?" aimed to foster collective problem-solving and idea generation.

Week 3: Individual and Social Responsibilities

The third week emphasized helping PSTs understand their individual and societal responsibilities and develop behavior change strategies. Participants calculated their individual carbon footprints using online calculators, leading to personal insights into their environmental impact. Role-playing activities allowed PSTs to assume various social roles and discuss how resource use impacts sustainability, performing these roles in class to enhance empathy and understanding. Six-Thinking-Hats technique was employed to evaluate the individual and societal dimensions of EOD from different perspectives, encouraging critical thinking and comprehensive analysis.

Week 4: Awareness-Raising Strategies and Creative Applications

The final week aimed to enable PSTs to creatively share what they had learned. Workshops facilitated the creation of awareness-raising projects using methods such as poetry, short skits, or storytelling. An exhibition and presentation of posters and creative products allowed PSTs to showcase their work, receive feedback, and reflect on their learning. Creative drama activities

involved developing and performing short plays and stories to increase awareness of EOD, enhancing communication skills and reinforcing knowledge.

Alignment with Theoretical Framework

The intervention was intentionally designed to reflect the core constructs of SCT and TPB:

- **SCT:** Observational learning was encouraged through videos and modeling activities; self-efficacy was enhanced via mastery experiences such as footprint calculation and peer teaching. Outcome expectations were addressed through class discussions about the potential impacts of sustainable behavior.
- **TPB:** Attitudes were shaped through reflective dialogue and critical analysis; subjective norms were reinforced via collaborative work and social validation; perceived behavioral control was targeted by equipping students with practical strategies, tools, and classroom-ready activities.

Data Collection

To obtain a comprehensive understanding of participants' experiences and to enhance the validity of the findings, multiple qualitative data collection methods were employed. These included semi-structured interviews and reflection journals, both of which allowed for the triangulation of data and enriched the depth of analysis.

Semi-Structured Interviews

Pre-intervention Interviews were conducted both before and after EI to capture shifts in participants' knowledge, attitudes, and behavioral intentions regarding EOD and sustainability. Each of the 27 PSTs participated in two interviews, resulting in a total of 54 interview transcripts.

- Pre-intervention interviews assessed baseline awareness and perceptions related to EOD, EF, and sustainability.
- Post-intervention interviews focused on the impact of the EI, revealing changes in conceptual understanding, attitudinal orientations, and intention to act.

The interviews were recorded with informed consent, literally transcribed, and anonymized to protect privacy. Interview guides were RQ- and conceptual framework-directed (SCT and TPB) to facilitate consistency among participants.

Reflection Journals

During EI, participants were asked to maintain personal reflection journals. At the end of each session, PSTs recorded shifting thoughts, emotions, and critical insights. These journals gave a glimpse into the internal cognitive and emotional processes evoked by EI. They were a secondary source of data that helped uncover shifts in awareness, motivation, and professional identity development over time.

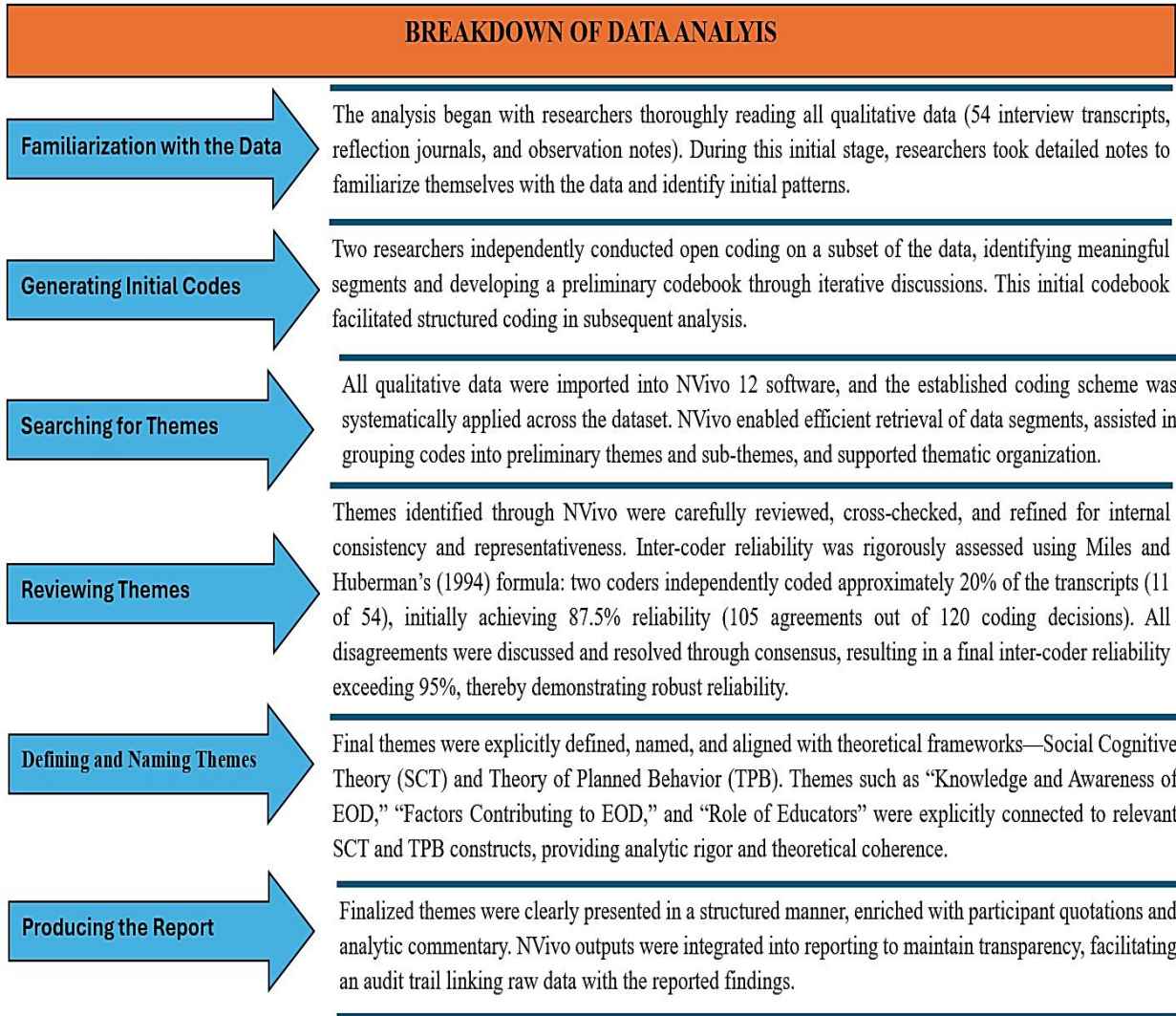
Data Analysis

The study used thematic analysis approach to systematically examine the data in a bid to identify, structure, and interpret the common patterns and themes (Braun and Clarke, 2006). This approach allowed for an open yet systematic analysis that was well-suited for exploring the rich lived experience of PSTs. As seen in Figure 5, the analytical process employed a hybrid model that integrated inductive and deductive techniques:

- **Inductive coding** was first applied to participants' narratives (interviews and journal entries), allowing themes to emerge organically from the data.

- **Deductive mapping** was then used to relate these themes to the theoretical constructs of SCT and TPB enriching interpretation and grounding results in established behavioral theory.

This dual approach enriched theoretical illumination and empirical intensity of the research. Whereas inductive analysis ensured responsiveness to actual voices of the participants and surrounding meanings, deductive view enabled rigorous exploration of how these accounts map onto constructs such as self-efficacy, outcome expectations, and subjective norms.



Source: Author own work

Figure 5. Breakdown of Data Analysis.

Formation of Themes in Relation to Theoretical Framework

The analysis revealed the following thematic structure, which is consistent with RQs and theoretical framework of the study:

1. **Knowledge and Awareness of EOD:** Corresponds to the cognitive learning component in SCT and addresses RQ1 regarding conceptual development post-intervention.
2. **Factors Contributing to EOD:** Linked to outcome expectations (SCT) and attitudes (TPB), related to RQ2.

3. **Consequences of EOD:** Reflects the expansion of ecological consciousness and risk perception; contributes to attitude formation (TPB) and outcome interpretation (SCT); also related to RQ2.
4. **Responsibilities and Actions to Delay EOD:** Relates to perceived behavioral control and behavioral intentions (TPB), corresponding to RQ3.
5. **Role of Educators and Education:** Highlights the influence of subjective norms (TPB) and self-efficacy (SCT), aligned with RQ4.

This structure allowed the findings to be both grounded in participant experience and interpreted through a robust theoretical lens, supporting the study's aim of bridging empirical insight with conceptual clarity.

Ethical Considerations

Ethical approval was obtained from the university's institutional review board, ensuring adherence to ethical standards. Participants provided informed consent after being fully briefed on the study's purpose, procedures, and their rights, including the right to withdraw at any time. Confidentiality and anonymity were maintained by assigning unique codes (K1, K2...K27) to participants and securely storing data. All identifying information was removed from transcripts and reports.

Trustworthiness

To ensure the trustworthiness of the study, several strategies were employed. Credibility was attained by triangulating data sources (interviews, reflection journals) and member checking, in which participants checked the accuracy of summaries of findings; Dependability was established by keeping an audit trail of research decisions and procedures, allowing for replication and scrutiny; Confirmability was enhanced by reflexivity and peer debriefing, which reduced researcher bias and made sure findings were based on the data; and Transferability was made possible by offering rich, in-depth descriptions of the context, participants, and methods, which allowed readers to evaluate the findings' generalizability in different contexts.

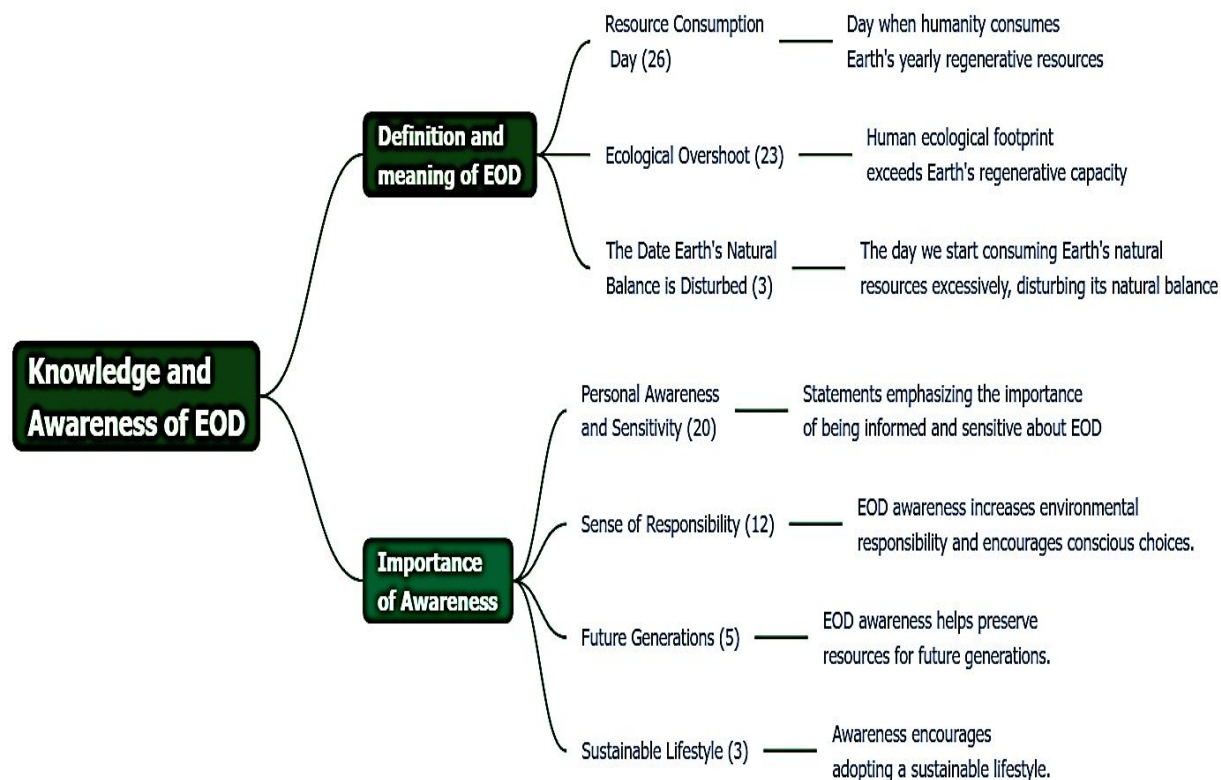
The methodological approach was thoughtfully planned to examine the complex experiences of PSTs with reference to EOD and SE. The study intends to make a significant contribution to the field by using a descriptive phenomenological design, incorporating a strong EI in line with theoretical frameworks, and applying exacting data gathering. The coherence and depth of the findings are improved when themes are in line with the theoretical framework and RQs.

Findings

In the pre-intervention interviews, none of the 27 PSTs had prior knowledge of EOD, indicating a significant gap in environmental literacy among future educators. However, after EI that included discussions, EF calculations, brainstorming sessions, and creative activities, a substantial shift in understanding was observed. The findings are organized around key themes derived from data analysis, reflecting participants' perspectives on the environmental challenges associated with EOD and the role of education in promoting sustainability.

Knowledge and Awareness of EOD

EI proved effective in enhancing the PSTs' understanding of EOD. In the post-intervention interviews, 26 participants (96%) accurately defined EOD as the date when humanity's consumption of natural resources surpasses what Earth can regenerate in a year. Figure 6 summarizes sub-themes, codes, frequencies and summary of quotations.



Source: Author own work

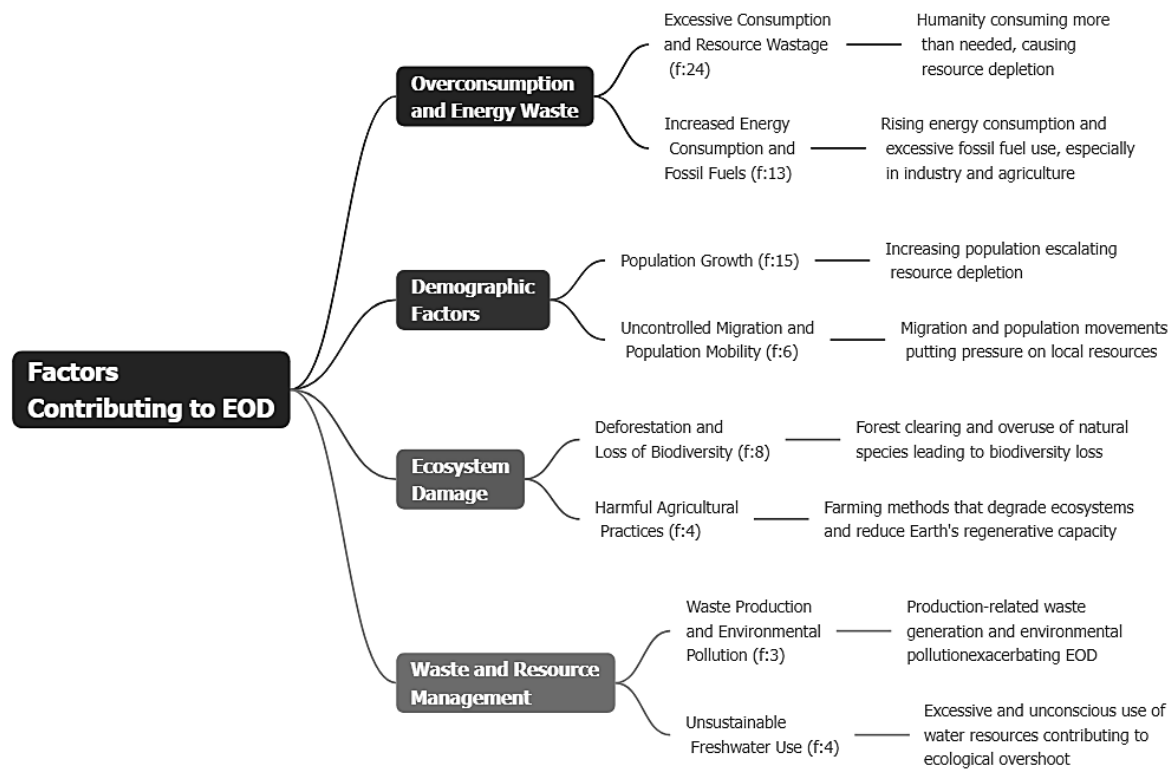
Figure 6. Components of knowledge and awareness of EOD.

Participants demonstrated a foundational awareness of EOD (K1:"when we've used up all the resources Earth can renew in one year";K12:"The day when our consumption surpasses Earth's renewal rate"). However, only a few participants linked EOD to the breakdown of Earth's natural balance (K8:"EOD is point at which we disrupt planet's sustainable balance"). This limited acknowledgment of the broader ecological and temporal implications of EOD suggests that although the educational intervention successfully conveyed the basic concept, further education is needed to deepen understanding of its complexities and historical progression.

PSTs recognized the importance of EOD awareness for promoting sustainable living and protecting resources for future generations. They emphasized personal awareness and sensitivity (K14:"Being aware of EOD helps us manage our planet's natural resources sustainably and encourages us to consume more cautiously"), and linked EOD awareness to heightened environmental responsibility and conscious decision-making (K6:"This awareness allows us to protect our natural resources and prevent exceeding the planet's limits"). These responses indicate that PSTs have developed an understanding of individual and societal significance of EOD, recognizing the role of awareness in fostering ecological responsibility.

Factors Contributing to EOD

After EI, PSTs demonstrated a nuanced understanding of the human-driven factors contributing to EOD. They identified overconsumption, energy waste, demographic factors, ecosystem damage, and waste and resource management as major contributors. Figure 7 outlines the sub-themes, codes and descriptions.



Source: Author own work

Figure 7. Components of factors contributing to EOD

Overconsumption and energy waste significantly contribute to EOD. Participants emphasized humanity's unsustainable resource use (K22: "*People take more from nature than they need*"). Additionally, rising energy demands and fossil fuel overuse were identified as key issues (K23: "*Fossil fuel consumption, especially due to industrialization and modern agricultural methods, has significantly increased demand on natural resources*").

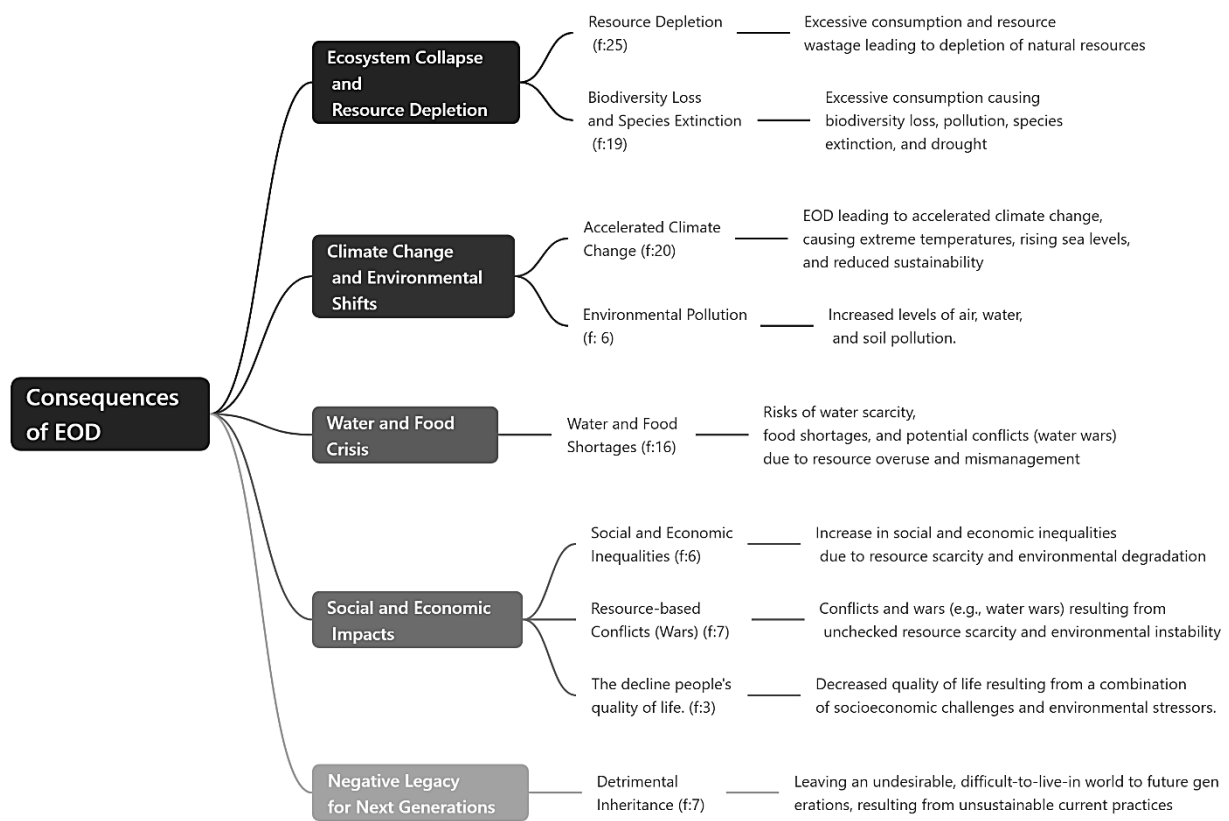
Demographic factors significantly contribute to resource depletion. Participants noted that population growth increases consumption (K2: "*As population grows, consumption increases*") and that uncontrolled migration accelerates resource strain (K4: "*Uncontrolled migration can lead to faster depletion of natural resources in certain regions*"). These insights highlight the impact of demographic pressures on environmental challenges.

Ecosystem damage was another significant theme. Participants emphasize that deforestation and biodiversity loss (K1: "*Overuse of natural species and deforestation contribute to EOD*"). Additionally, unsustainable agricultural practices were identified as detrimental to ecosystems (K3: "*Agricultural practices, deforestation, and waste management contribute to ecological overshoot*"). These responses indicate an awareness of how human activities directly harm ecosystems and reduce Earth's capacity for regeneration.

Waste and resource management issues were underscored by participants. They noted that production waste and environmental pollution contribute to EOD (K6: "*Waste generated during production and environmental pollution contribute to EOD*"). Additionally, unsustainable use of freshwater resources was highlighted as a critical factor (K9: "*Unconscious use of water resources is significant factor*"). These responses emphasize the importance of sustainable resource management in mitigating ecological overshoot.

Consequences of EOD

PSTs developed a deeper appreciation for the far-reaching environmental and social consequences of EOD. They expressed significant concern over issues such as resource depletion, CC, biodiversity loss, water and food crises, social and economic impacts, and negative legacy for next generations. Figure 8 summarizes this theme.



Source: Author own work

Figure 8. Components of consequences of EOD.

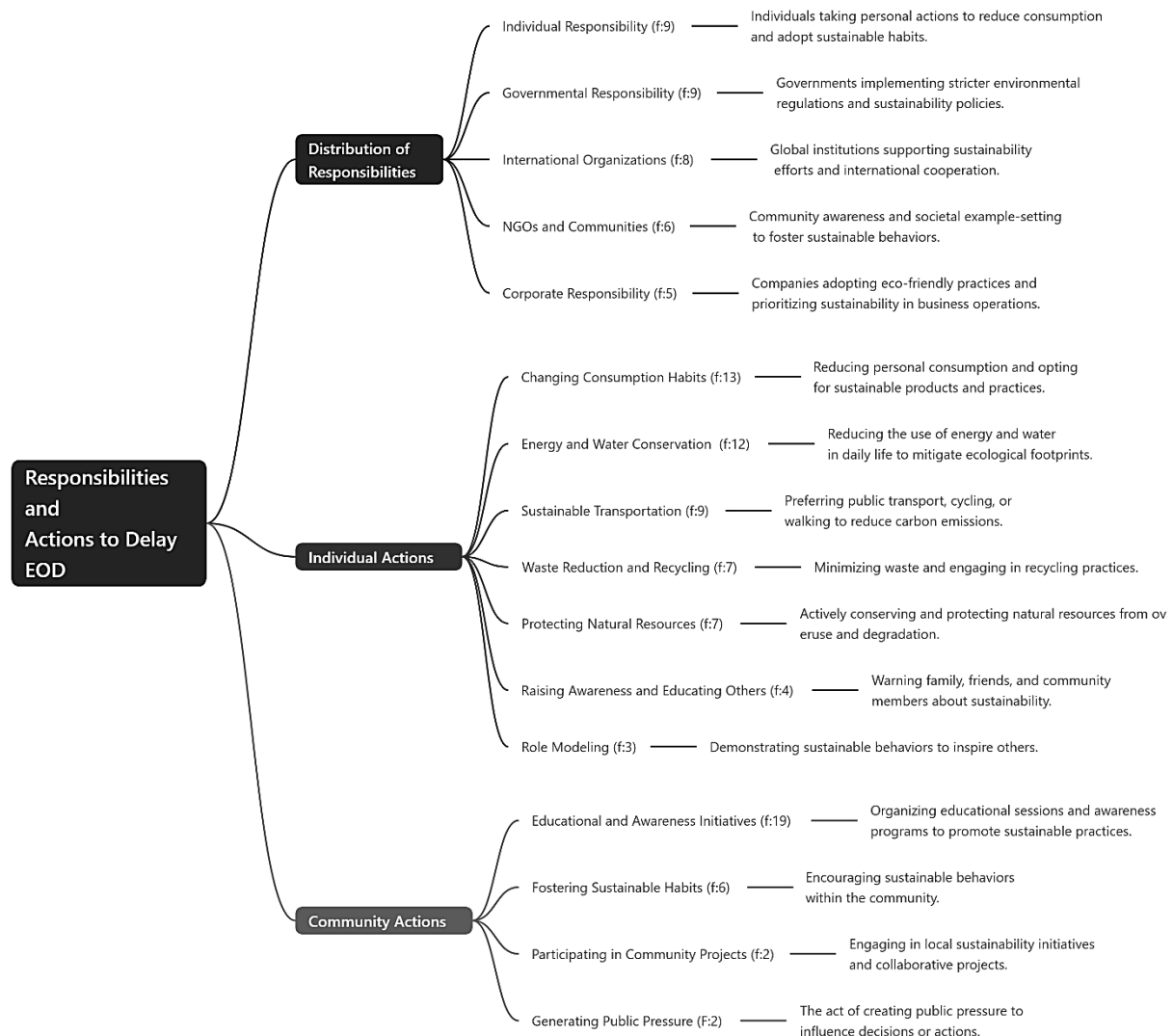
Ecosystem collapse and resource depletion emerged as major concerns. Participants linked EOD to severe depletion of natural resources (K26: "Resource depletion is one of biggest problems") and highlighted biodiversity loss and species extinction (K5: "It can lead to the extinction of animal species, pollution of nature, and drought"). These responses highlight an understanding of the critical state of natural resources and ecosystems. CC and environmental shifts were highlighted and were connected EOD with accelerated CC effects (K3: "CC due to EOD brings water scarcity, temperature extremes, and rising sea levels") This demonstrates an awareness of how ecological overshoot contributes to global environmental changes.

Water and food crisis emerged as a significant concern. K2 observed, "In a future where EOD is not taken seriously, we will face many problems, primarily scarcity and water wars." This indicates recognition of the potential for resource scarcity to impact human survival and societal stability. Social and economic impacts were also a major concern. Participants anticipated that environmental degradation would exacerbate inequalities and trigger conflicts over dwindling resources (K21: "Social and economic inequalities will increase"; K14: "Unchecked EOD could lead to water wars and create an uninhabitable world plagued by social instability"). These insights underscore the interconnectedness between environmental decline and societal challenges.

Negative legacy for next generations was a concern for participants, who expressed apprehension about leaving a detrimental legacy. (K2 :*"We would leave a worse legacy for future generations."* K7:*"I can't even imagine it; it would become an uninhabitable world."*). These sentiments highlight considerations and intergenerational responsibilities associated with sustainability.

Responsibilities and Actions to Delay EOD

Aligned with theories of social and behavioral change, PSTs emphasized a range of responsibilities and actions to counter EOD, advocating for both individual and collective initiatives. Figure 9 presents components of the theme.



Source: Author own work

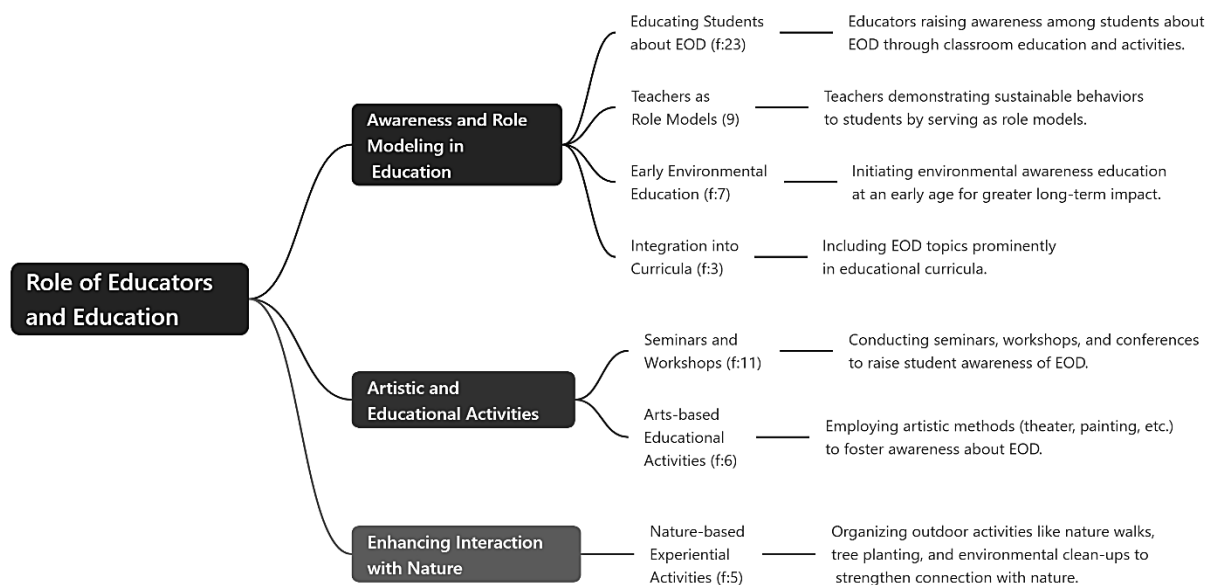
Figure 9. Components of responsibilities and actions to delay EOD

Participants recognized a wide distribution of responsibilities in addressing EOD, highlighting the roles of individuals, governments, international organizations, society, and corporations. They emphasized the importance of individual action, governmental intervention, and corporate accountability in promoting sustainability (K16:*"We can individually contribute by choosing sustainable products and conserving resources in our daily lives."*; K15:*"Governments should implement environmental policies and sustainability measures."*; K20:*"Support from international organizations is necessary."*; K18:*"As a society, we must be conscious consumers*

and set an example for other societies."; K22:"Business world should take steps toward sustainability."). In terms of individual actions, participants advocated for changing consumption habits, conserving energy and water, adopting sustainable transportation, reducing waste, raising awareness, setting an example, and protecting natural resources (K2:"We can develop conscious habits to reduce electricity and water consumption."). These answers demonstrate an awareness of how human actions can lead to EFs and possible influence of individual decisions on postponing EOD. By emphasizing education and awareness campaigns, PSTs also emphasized the value of community actions (K5:"Educational sessions can be held in schools"). These results suggest an understanding of the need for group efforts to encourage sustainable lifestyles and the part that community involvement plays in bringing about change.

Role of Educators and Education

The study underscored the important role played by teachers in generating awareness and sustainability. The participants understood the importance of their role in teaching students about EOD, being role models, and embedding sustainability in the classroom through participatory teaching methods. Figure 10 shows details of this theme.



Source: Author own work

Figure 10. Components of role of educators and education

Under this theme, participants emphasized the need to educate students about EOD (K1:"Educators inform students about EOD and then carry out activities with them"). They also stressed that teachers should model sustainable behaviors (K12:"Educators should be role models for students."), that environmental education should begin at an early age (K9:"Awareness should be created at a young age."), and that EOD should be more thoroughly integrated into curricula (K7: "This topic should be given more space in the curriculum."). Participants also suggested artistic and educational activities as effective means of engaging students (K1:"Activities can be conducted using theater, painting, poetry, etc. ").

Furthermore, enhancing interaction with nature was seen as crucial. Participants recommended activities that promote environmental engagement (K4:"By organizing nature trips, students can learn about the environment and become conscious about protection."). These approaches align with experiential learning theories, emphasizing the importance of direct experiences in fostering environmental awareness.

Discussion

The findings of are discussed in relation to the theoretical frameworks of SCT and the TPB as well as existing literature.

RQ1: How do PSTs' knowledge and awareness of EOD evolve through a structured EI?

Initially, the PSTs lacked awareness of EOD, reflecting a significant gap in EL. This aligns with previous studies indicating low levels of specific sustainability knowledge among university students (García-González *et al.*, 2020; Varela-Losada *et al.*, 2022). Following EI, participants demonstrated a foundational understanding of EOD, recognizing its definition and importance. This increase in knowledge aligns with the knowledge acquisition of SCT, suggesting that EIs can effectively enhance EL. According to TPB, increased awareness can influence attitudes toward sustainable behaviors. The use of interactive and creative pedagogies likely contributed to this enhanced understanding by engaging multiple learning styles and fostering deeper cognitive processing (Redman *et al.*, 2021). This finding also supports transformative learning theory, which posits that critical reflection and experiential learning can lead to profound changes in perspective (Sterling, 2011; Varela-Losada *et al.*, 2022). By challenging previous beliefs and proposing fresh paradigms of analysis, EI brought about a shift from ignorance to interest about EOD and sustainability.

RQ2: How do PSTs perceive the causes and consequences of EOD?

Respondents constructed a sophisticated understanding of the causes of EOD, such as overconsumption, wastage of energy, demographic factors, ecosystem loss, and disposal of wastes. This suggests a comprehension of the system drivers of ecological overshoot (Wiedmann *et al.*, 2020). Comprehension of these drivers relates to the outcome expectations element of SCT, as participants learn the outcomes of human activity for the environment. On the issue of consequences, PSTs indicated issues of resource depletion, CC, biodiversity loss, and social inequalities. This awareness indicates heightened ecological literacy and sensitivity to the interconnectedness of environmental, social, and economic systems—a central aspect of SE (Steffen *et al.*, 2015). This awareness is essential for the development of critical thinking abilities for resolving complex problems of sustainability (Redman *et al.*, 2021).

RQ3: What responsibilities and actions do PSTs believe are necessary to delay EOD and reduce EFs?

PTs emphasized personal and social obligations, urging sustainable consumption, energy and water preservation, waste reduction, government policy, company responsibility, and international collaboration. This is the articulation of perceived behavioral control and subjective norms aspects of TPB, implying that PTs recognize their ability to make a difference in environmental outcomes and are aware of external pressure regarding sustainability expectations. Existing studies have established the effectiveness of intervening on these variables in promoting pro-environmental behaviors (Bamberg *et al.*, 2021). The emphasis on multi-level interventions aligns with socio-ecological models that consider individual behavior within broader social and institutional contexts. Literature suggests that addressing environmental issues requires integrated strategies that encompass personal actions and systemic changes (Otto *et al.*, 2021). PSTs' holistic approach underscores the need for collaborative efforts to effectively mitigate EOD.

What role do PSTs believe they should play in promoting environmental sustainability and awareness in their future classrooms?

Participants recognized their role as educators in promoting sustainability, emphasizing the importance of raising awareness, serving as role models, and integrating sustainability into

education through interactive methods. This aligns with the observational learning and self-efficacy constructs of SCT, suggesting that by modeling sustainable behaviors and integrating sustainability into their teaching, educators can influence students' attitudes and behaviors, contributing to a culture of environmental stewardship (Evans, 2019). According to TPB, participants' intentions reflect the behavioral intentions component, indicating a commitment to incorporating sustainability into their teaching. This finding is consistent with the concept of teachers as agents of change (UNESCO, 2017). SE must be carried out multidisciplinary, action-oriented, and participatory methods (Monroe *et al.*, 2019). The integration of EOD in teacher education can encourage increased recognition and reveal instances of real, real-world global sustainability issues (Leal Filho *et al.*, 2021).

To develop greater practice and consciousness towards environmental sustainability in PSTs, participants advocated the incorporation of EOD in environmental education. They suggested the implementation of experiential and innovative pedagogies, such as workshops, art, and hands-on activities that correlate with higher-order thinking models and active learning (Morris, 2020). These approaches have been found to boost motivation and internalization of SCs, eventually influencing subsequent teaching practices (Anderson, 2012; Lambrechts *et al.*, 2018). Moreover, more recent research identifies the preponderant significance of environmental competence and teacher self-efficacy in effective SE (Albareda-Tiana *et al.*, 2020). Thus, it is imperative that teacher education programs embrace pedagogies that build PSTs' competence and confidence (Evans, 2019).

Conclusion

This research demonstrates that targeted environmental education empowers PSTs with increased awareness, knowledge, and attitudes towards the most paramount issues of sustainability-specifically EOD. Through the integration of EOD in the curriculum through experiential and interactive pedagogies, teacher educators can confirm ecological consciousness and prepare future teachers to instruct environmental stewardship with confidence. The EI was key to building the knowledge of PSTs in EOD and bridging gaps in environmental literacy. Students who had no prior knowledge in EOD studied it holistically as a manifestation of resource scarcity and nature imbalance. The EI influenced not only knowledge but also attitude and intention to act: students gained increased sense of urgency and sense of responsibility in terms of sustainability. Although direct behavioral change measurement was not achieved, PSTs expressed intention to implement-percentage suggesting ways of reducing EF and instructing with SCs-a finding consistent with TPB. PSTs adopted sustainability as a professional identity in that they self-identified as environmental educators with the role of advancing ecological knowledge. This alignment between professional identity and personal values substantiates teacher education in building sustainability champions. Finally, carefully designed EIs are effective platforms for building PSTs' sustainability literacy and empowering them to apply such fundamental concepts in their own classrooms towards an even more sustainable future.

Practical Implications

For teacher educators in HEIs who struggle with integrating sustainability into their curriculum, this research offers practical recommendations. Environmental literacy and self-efficacy of PSTs enable them to employ pedagogies that activate students' critical thinking and action competences (Albareda-Tiana *et al.*, 2020). By incorporating EOD and related sustainability concerns, PSTs can develop pedagogical and environmental literacy competencies, positioning them to educate future generations about sustainability issues (Shephard *et al.*, 2019).

Innovative and interactive pedagogies facilitate student engagement through the formation of critical thinking and pro-environmental behavior (Lambrechts *et al.*, 2018). HEIs' provision of professional development and resources is needed to support teachers in using such approaches.

End-to-end support for implementation-inclusive of step-by-step models and context-specific trainer guides-maximizes the scalability and feasibility of such interventions in diverse school settings. This support not only facilitates integration of EOD material into teacher-education courses but also to the broader field of SE by making flexible methodologies according to local situations. This support is of great worth in equipping PSTs with knowledge and competencies necessary for them to play an active role in promoting sustainability in their teaching.

Social Implications

Both PSTs and teachers have potential to influence the attitude and behavior of next generation. Education for EOD and sustainability in PSTs, therefore, has broader social implication (UNESCO, 2017). Educating them on environmental education and ethics carries a multiplier effect that can extend from students to society and broader community (Albareda-Tiana *et al.*, 2020; Evans, 2019). It is an SDG-aligned approach, specifically with SDG-13 (Climate Action) and SDG-4 (Quality Education), which highlight the essential role of education in combating CC and advancing global citizenship. Addressing environmental challenges such as biodiversity loss, resource depletion, and CC, and achieving SDGs can be underpinned by spanning environmental literacy gaps and facilitating SE (Leal Filho *et al.*, 2021; Otto *et al.*, 2021).

Limitations and Future Research

This study examines PSTs' knowledge, attitudes, and intentions related to EOD using only qualitative data, which indicates a lack of a quantitative perspective. Future research could combine both qualitative and quantitative methods to give a more complete picture of the intervention's impact. The other limitation is about sampling. Small sample size and high number of female participants, which may affect generalizability. To better understand the effectiveness of EOD education and to guide the development of global SE policy, it is also essential to see how these approaches are used in various cultural contexts. The long-term impacts of SCs on teaching methods might be clarified by longitudinal studies and bigger, more representative samples. The author has introduced "Ecological Footprint" elective course in subsequent academic terms at the state university, which incorporates EF & EOD based EI in longer period. This strategy will make it possible to gather longitudinal data in order to examine how PSTs' changing views on EF and EOD translate into SE and also once they start in-service teaching. Future studies will use this expanded data to investigate the persistence of behavioral and attitudinal changes induced by EI, even if they are not included in the current study.

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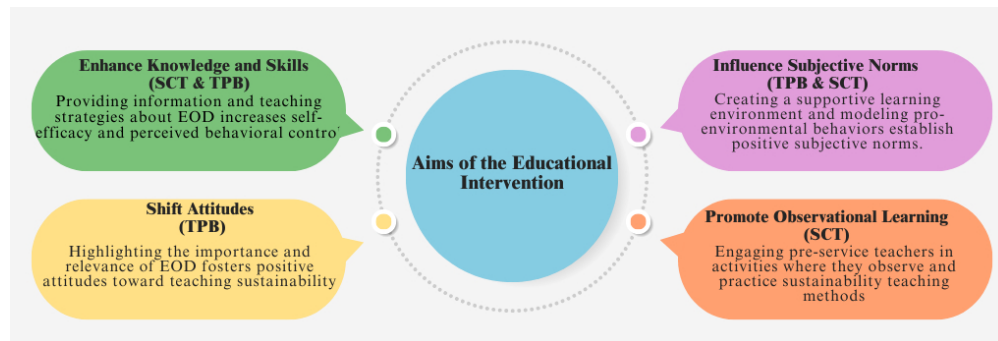
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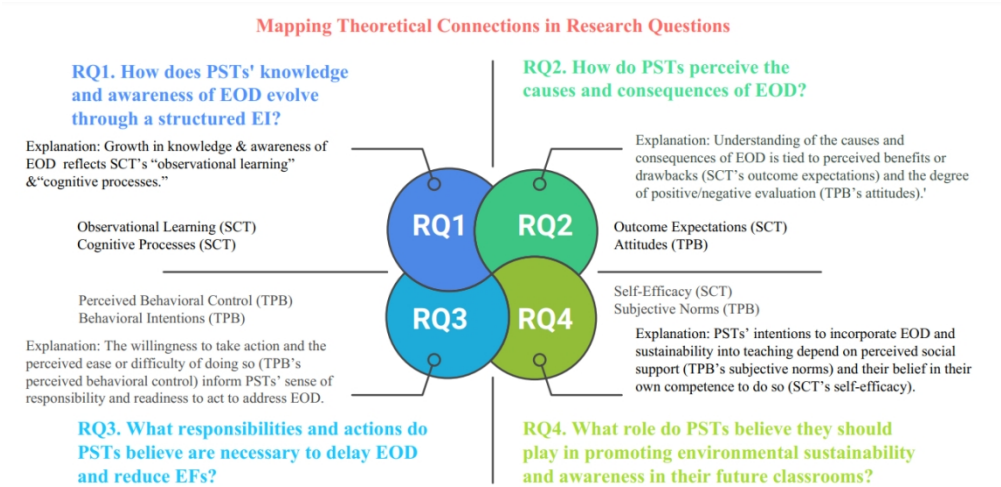
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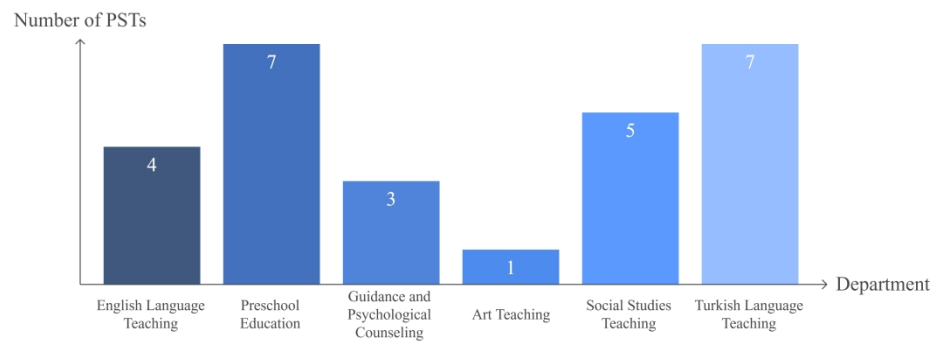
The aims of EI

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Map of Theoretical Connections in RQs

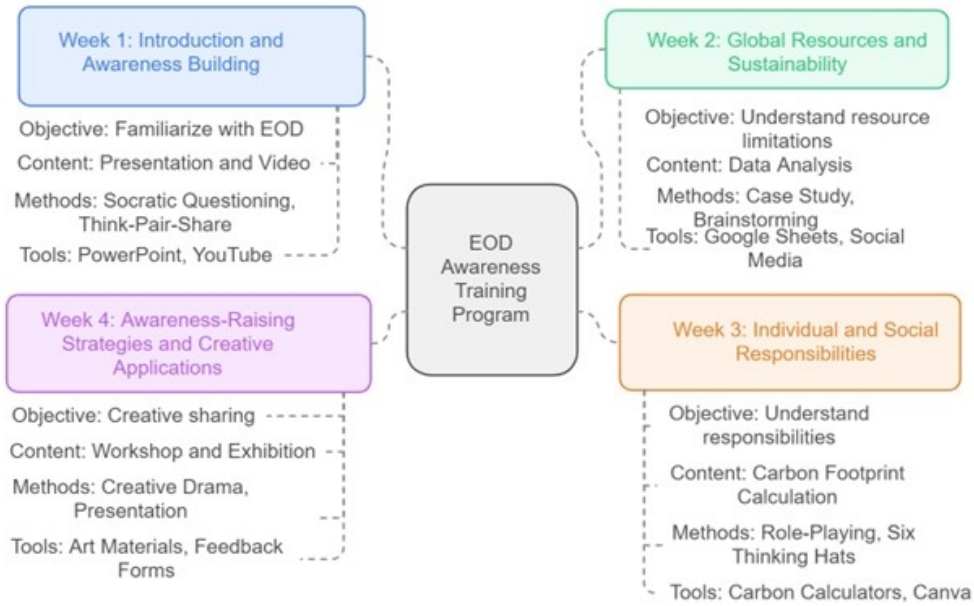
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Distribution of PSTs' Departments

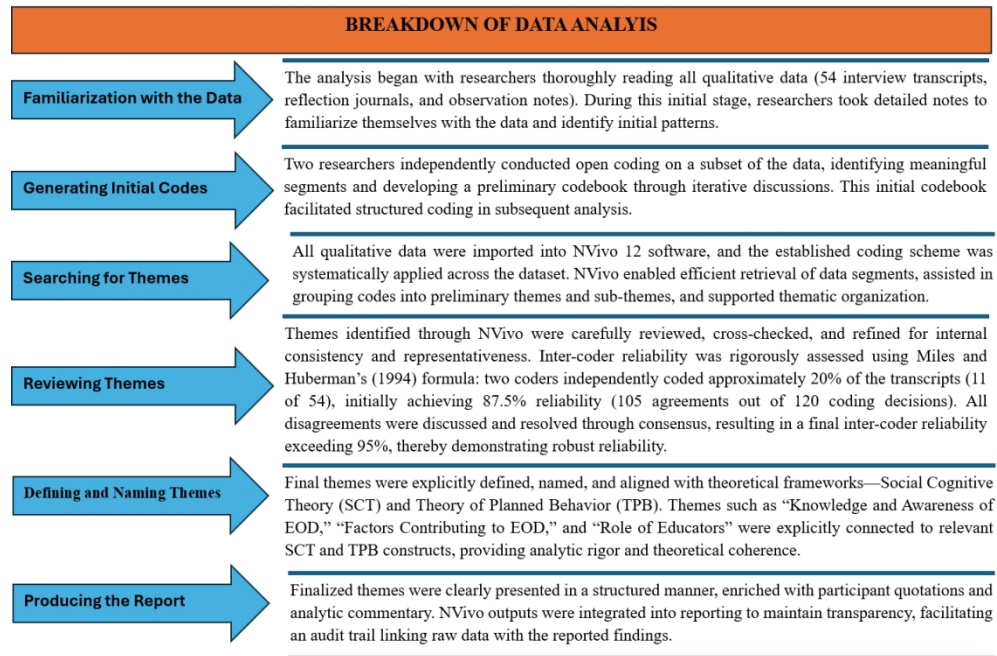
Distribution of PSTs' departments

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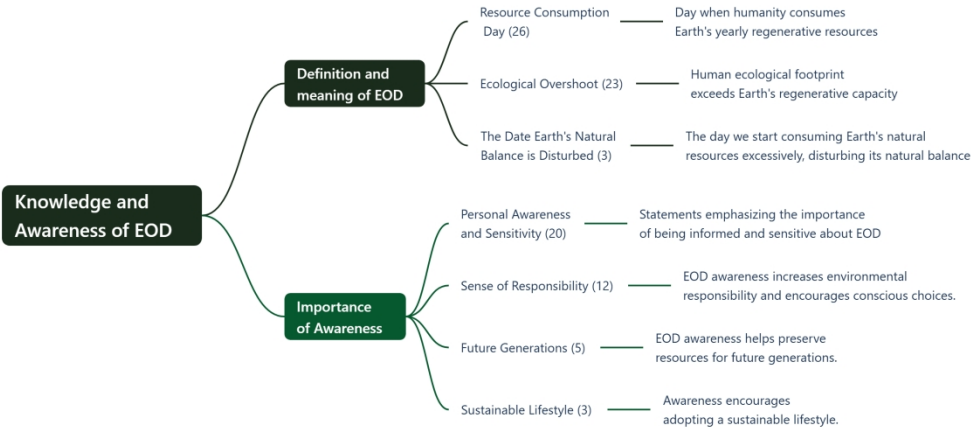
Design of EOD awareness training program

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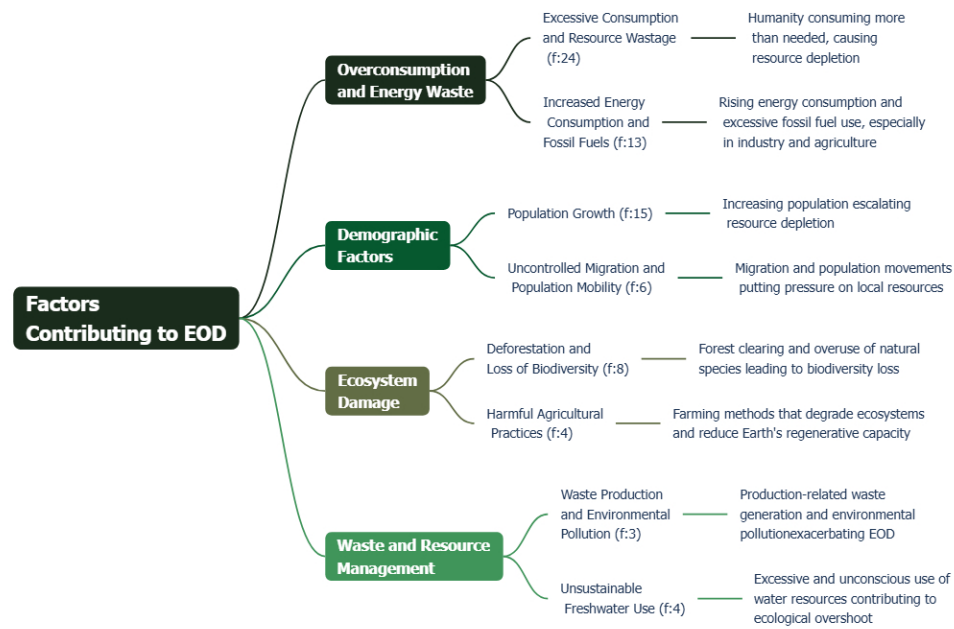
Breakdown of Data Analysis

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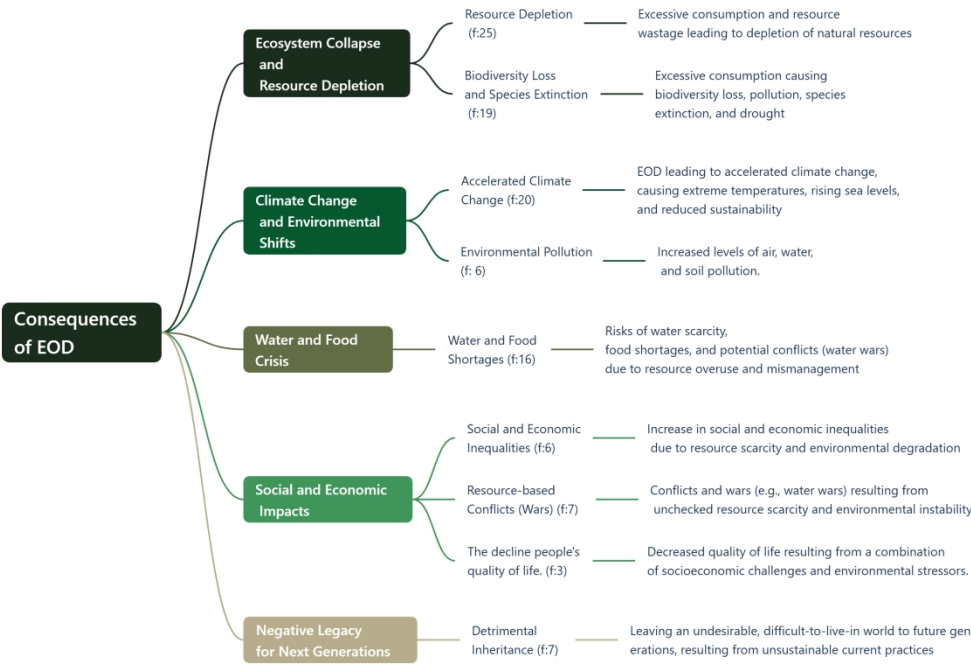
Components of knowledge and awareness of EOD theme.

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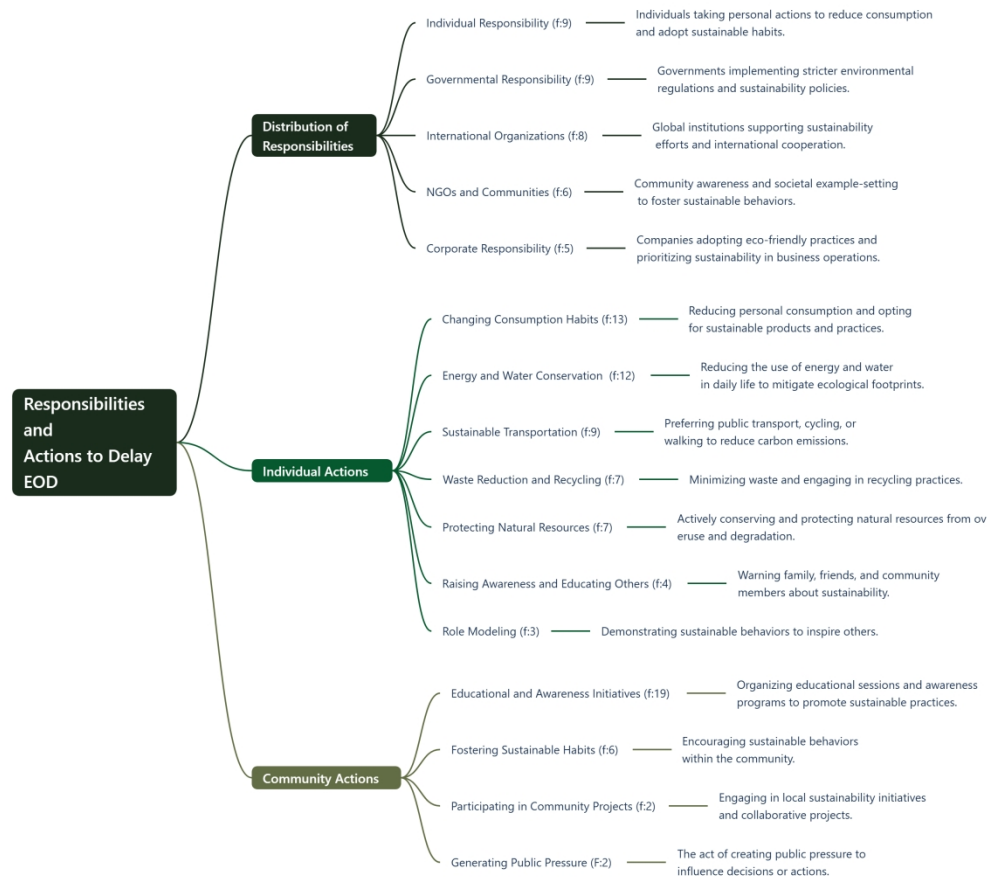
Components of factors contributing to EOD

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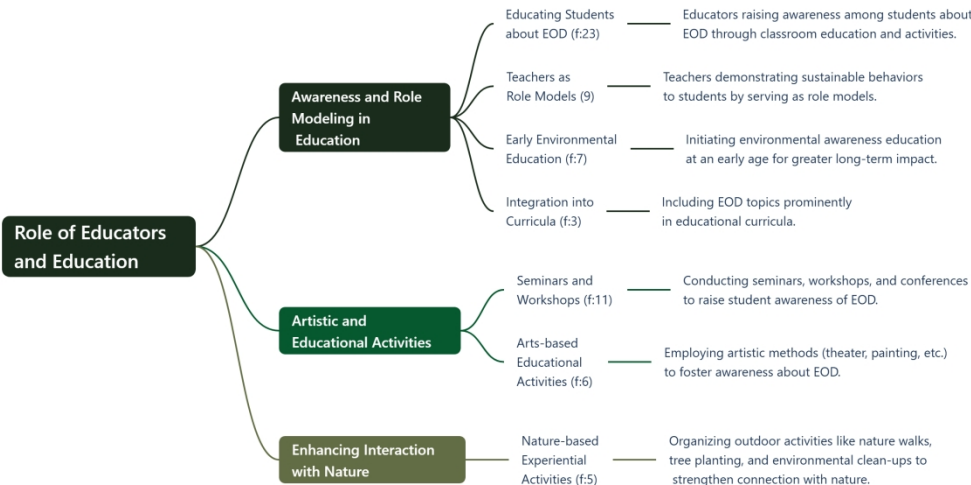
Components of consequences of EOD.

896x606mm (72 x 72 DPI)



Components of responsibilities and actions to delay EOD

977x872mm (72 x 72 DPI)



Components of role of educators and education

881x444mm (72 x 72 DPI)

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Dr. Adem Kenan is an academic in science education at a faculty of education in Turkey, specializing in the training of pre-service teachers. His research interests include sustainability education, climate change education, mathematical modeling, and STEAM approaches. He focuses particularly on examining teachers' and pre-service teachers' ethical awareness of artificial intelligence and their practices related to climate change education. Additionally, he investigates how concepts such as Earth Overshoot Day and ecological footprints can be utilized in teacher education to contribute to the advancement of sustainability education. Adem Kenan can be contacted at [akenan@erzincan.edu.tr].