UNIVERSITY OF PIRAEUS

SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGIES

DEPARTMENT OF INFORMATICS

PHD THESIS

Thesis Title:	**Embedding Sustainability in Information and Communication Technology (ICT) Education** **Ενσωμάτωση της Βιωσιμότητας στην Εκπαίδευση της Τεχνολογίας Πληροφοριών και Επικοινωνίας (ΤΠΕ)**
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Statement of Originality

I hereby declare that this PhD Thesis is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

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Περίληψη

Η Εκπαίδευση για τη Βιώσιμη Ανάπτυξη (ΕΒΑ) θεωρείται ως η εκπαίδευση που μπορεί να βοηθήσει και να υποστηρίξει τα νέα άτομα να αναπτύξουν στάσεις, δεξιότητες και γνώσεις προκειμένου να είναι σε θέση να λαμβάνουν καλά τεκμηριωμένες αποφάσεις για ένα βιώσιμο μέλλον. Η Πληροφορική διαδραματίζει θεμελιώδη ρόλο στην ΕΒΑ, καθώς υποστηρίζει σημαντικά την πρόσβαση σε πληροφορίες για τη βιωσιμότητα, και την ανάπτυξη καινοτόμων προϊόντων, εργαλείων και υπηρεσιών για αυτό το σκοπό. Ως εκ τούτου, η πρόκληση της σύνδεσης της βιωσιμότητας με την εκπαίδευση της Τεχνολογίας Πληροφοριών και Επικοινωνίας (ΤΠΕ) είναι επιτακτική για την ενίσχυση της μετασχηματιστικής μάθησης προς την ΒΑ. Για την αντιμετώπιση αυτής της πρόκλησης, ο γενικός σκοπός αυτής της διατριβής είναι να διερευνήσει και να συνεισφέρει νέα και γενικεύσιμα συμπεράσματα σχετικά με τις επιπτώσεις της ενσωμάτωσης της βιωσιμότητας στην εκπαίδευση ΤΠΕ στο ελληνικό εκπαιδευτικό σύστημα, συμπεριλαμβανομένης της ανώτερης δευτεροβάθμιας και τριτοβάθμιας εκπαίδευσης. Τα αποτελέσματα διερευνώνται μέσω δύο πρωτογενών ερευνών. Η πρώτη μελέτη ασχολείται με την άτυπη εκπαίδευση στην Ελλάδα. Ο στόχος είναι να διερευνήσει τον αντίκτυπο της χρήσης των εφαρμογών μεταφοράς για κινητές συσκευές στην ΕΒΑ μεταξύ των νέων ατόμων, τη δυνατότητα ενίσχυσης της περιβαλλοντικής συνείδησης και την πρόθεση ενεργού συμμετοχής σε βιώσιμες ταξιδιωτικές πρακτικές. Τα αποτελέσματα της μελέτης δείχνουν ότι υπάρχει μια θετική στάση από τα νέα άτομα απέναντι στην καθημερινή χρήση των εφαρμογών αυτών και μια προθυμία να αλλάξουν τις ταξιδιωτικές τους συνήθειες προς πιο βιώσιμες επιλογές. Η έρευνα αποκάλυψε επίσης ότι οι συμμετέχοντες/συμμετέχουσες ήταν πρόθυμοι/πρόθυμες να παρέχουν ανατροφοδότηση και να επιβραβεύονται για να αξιολογήσουν τον αντίκτυπο της συστηματικής χρήσης της εφαρμογής ώστε να βελτιώσουν τις προσφερόμενες ταξιδιωτικές υπηρεσίες. Πιο συγκεκριμένα, καταγράφεται μια ισχυρή σύνδεση μεταξύ της ενεργοποίησης για τη δοκιμή της εφαρμογής και της πιθανής συνέχισης της χρήσης της όταν οι συμμετέχοντες/συμμετέχουσες μπορούν να ανακαλύψουν περισσότερες βιώσιμες ταξιδιωτικές επιλογές και ταυτόχρονα να λαμβάνουν ανταμοιβές. Η δεύτερη μελέτη, ασχολείται με την τυπική εκπαίδευση στην Ελλάδα. Ο στόχος είναι να διερευνήσει τις γνώσεις των νέων ατόμων σχετικά με θέματα βιωσιμότητας, να αξιολογήσει τα αποτελέσματα της ενσωμάτωσης της βιωσιμότητας στα προγράμματα σπουδών ΤΠΕ καθώς και να διερευνήσει την πρόθεσή τους να ασχοληθούν με την πράσινη πληροφορική στην Ελλάδα. Επιπλέον, στοχεύει στη διερεύνηση της συμβολής της εκπαίδευσης στην περιβαλλοντική ευαισθητοποίηση των νέων ατόμων σχετικά με την εξοικονόμηση ενέργειας και τις πρακτικές διαχείρισης των ηλεκτρονικών αποβλήτων μέσα από μια εκπαιδευτική παρέμβαση για το σκοπό αυτό. Αναφορικά με τη δευτεροβάθμια εκπαίδευση η μελέτη δείχνει ότι η εκπαίδευση για την ευαισθητοποίηση σχετικά με την ανακύκλωση ηλεκτρονικών αποβλήτων είναι ζωτικής σημασίας για την απόκτηση περιβαλλοντικών δεξιοτήτων, συμπεριφοράς και στάσεων που συνάδουν με την προστασία του περιβάλλοντος και τη ΒΑ. Αν και οι γνώσεις των μαθητών/μαθητριών σχετικά με τη βιωσιμότητα ήταν ανεπαρκείς, ήταν πρόθυμοι/πρόθυμες να μάθουν περισσότερα και να ασχοληθούν με αυτή. Επιπλέον, οι μαθητές/μαθήτριες έδειξαν θετική αντίληψη για την πράσινη πληροφορική και την ενσωμάτωση της βιωσιμότητας στα προγράμματα σπουδών ΤΠΕ. Η έρευνα επίσης προτείνει ότι τα προγράμματα σπουδών ΤΠΕ θα πρέπει να επανασχεδιαστούν ώστε να ενσωματωθούν οι αρχές της βιωσιμότητας. Αναφορικά με την τριτοβάθμια εκπαίδευση, τα αποτελέσματα της μελέτης υποδηλώνουν ότι αν και η πλειονότητα των φοιτητών/φοιτητριών είχε ελλιπές επίπεδο κατανόησης της έννοιας της βιωσιμότητας λόγω της εμφανούς αδυναμίας ενσωμάτωσης σχετικών θεμάτων στην εκπαίδευση ΤΠΕ στην Ελλάδα, μετά από την εκπαιδευτική παρέμβαση έδειξε σημαντική αύξηση της γνώσης σχετικά με τη βιωσιμότητα και τις περιβαλλοντικές επιπτώσεις της ΤΠΕ. Σε κάθε περίπτωση, τα αποτελέσματα της μελέτης αποκαλύπτουν ότι οι φοιτητές/φοιτήτριες δεν είναι ικανοποιημένοι/ικανοποιημένες με τη συμβολή του πανεπιστημίου στην ΕΒΑ. Επίσης, η έρευνα παρέχει πληροφορίες για τα ελληνικά πανεπιστήμια ώστε να αναπροσανατολίσουν τα προγράμματα σπουδών ΤΠΕ προκειμένου να ενσωματώσουν θέματα βιωσιμότητας. Επιπλέον, τα ευρήματα αποδεικνύουν ότι η άμεση επίδραση της εκπαίδευσης στην πρόθεση των φοιτητών/φοιτητριών να ασχοληθούν με τη βιωσιμότητα ήταν σημαντική. Η πρόθεση αυτή μπορεί να ενισχυθεί μέσω πρακτικών προσανατολισμένων στη βιωσιμότητα που εφαρμόζουν τα πανεπιστήμια και θα μπορούσε να υποστηριχθεί περαιτέρω με την προσφορά και εφαρμογή προγραμμάτων επιβράβευσης των φοιτητών/φοιτητριών.

Abstract

Education for Sustainable Development (ESD) has been viewed as education that can help and support young people to develop the attitude, skills, and knowledge in order to make well-informed decisions in meeting the developmental and environmental apprehension for a sustainable future. In this context, the UN 2030 Agenda aims to achieve SD in an integrated, indivisible and balanced manner through seventeen Sustainable Development Goals (SDGs). The SDG4, according to its target 4.4, intends to promote ESD by increasing the number of young people with relevant skills for labor market competitiveness, including Information and Communication Technology (ICT) skills. ICT has a fundamental role in collaborating for SD as it significantly supports the access to information for sustainability by directly applying tools and technologies developed for this. Therefore, the challenge of connecting and combining sustainability with ICT education is imperative for enhancing transformative learning toward SD through integrating aspects of sustainability issues into ICT curricula. To address this challenge, the overall purpose of this thesis is to investigate and contribute novel and generalizable findings on the effects of embedding sustainability in ICT education in the Greek educational system, including the secondary as well as higher education in terms of the young people's broader consciousness of SD. The effects of embedding sustainability in ICT education are investigated through two primary studies. The first study, Study One, deals with the out-of-school or informal education in Greece. It aims to explore the impact of mobile transit applications (apps) in ESD among young people, the potential to foster environmental consciousness, and the intention to actively engage in sustainable traveling practices. The results of this study indicate that there is a positive attitude from young people toward the daily use of the two designed - for the purpose of Study One – mobile transit apps mockups, and participants are willing to change their travelling habits toward more sustainable options and intend to use these apps for this change. The assessment has also revealed that the participants are willing to regularly provide feedback and get rewards to evaluate the impact of the app's systematic use and improve the travel services offered, as there was a strong connection between triggering for testing the app and the possible continuation of its use when participants could discover more healthy and sustainable travel options and get rewards. The second study, Study Two, deals with the in-school or formal education in Greece and focuses on the secondary and higher education levels. It aims to elicit the students' prior knowledge regarding sustainability issues, assess the effects of integrating ESD into ICT curricula, and explore their intention to deal with green informatics in Greece. Furthermore, it aims to investigate the contribution of ICT education to the students' environmental awareness about energy conservation, attitudinal disposition, and e-waste management practices. Concerning secondary education, the study recommends that education for e-waste recycling awareness is vital in achieving environmental skills, behavior and attitudes consistent with environmental protection and sustainable development. Although the pupils' knowledge about sustainability was insufficient, they were willing to learn more and get involved with it. Moreover, the pupils showed a positive perception of green informatics and of the integration of sustainability into the ICT curricula. The research recommends that the ICT curricula should be redesigned in order to integrate the principles of sustainability. Concerning higher education, the outcomes of the study denote that the majority of the ICT students had a deficient level of understanding of the concept of SDGs because of the apparent weakness in incorporating sustainability issues in ICT education in Greece. On the other hand, they showed a significant increment of knowledge regarding sustainability and the environmental impact of ICT studies. In any case, the study outcomes reveal that the ICT students were unsatisfied with the contribution of the university toward sustainability. The study results also provide insights for Greek universities to reorient the ICT curricula in order to integrate sustainability issues. The findings prove that the direct effect of the educational intervention on the intention of the ICT students to engage in sustainability was significant. This result highlights that intention might be enhanced through sustainability-oriented practices implemented by the HEIs and might be supported further with the implementation of rewarding programs that HEIs offer.

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List of Abbreviations

ACM/AIS – Association for Computing Machinery/Association for Information Systems

ACM/IEEE-CS – Association for Computing Machinery/Institute of Electrical and Electronics Engineers-Computer Society

App – Application

DCs – Data Centers

EE – Environmental Education

EFA – Exploratory Factor Analysis

EfS – Education for Sustainability

EPMA – Eco Persuasive Mobile Application

ESD – Education for Sustainable Development

ESTA – Education in Sustainable Travel urban behavior through mobile Applications

E-Waste – Electronic Waste

GDPR – General Data Protection Regulation

GHG – Greenhouse Gas

GPS – Global Positioning System

GRI – Global Reporting Initiative

HCI – Human-Computer Interaction

HEIs – Higher Educational Institutions

ICT – Information and Communication Technology

IM – Independent Mobility

IQR – InterQuartile Range

ISCN – International Sustainable Campus Network

ISWA – International Solid Waste Association

IT – Information Technology

ITU – International Telecommunication Union

MaaS – Mobility as a Service

NGOs – NonGovernmental Organizations

SD – Sustainable Development

SDGs – Sustainable Development Goals

SDSN Australia, New Zealand & Pacific – The Australia, New Zealand & Pacific Network of the Sustainable Development Solutions Network

SPSS – Statistical Package for the Social Sciences

STEM – Science, Technology, Engineering, and Mathematics

TPB – Theory of Planned Behavior

TTM – Transtheoretical Therapy Model

UCD – User-Centered Design

UN – United Nations

UN DESA – United Nations Department of Economic and Social Affairs

UN-GSDR – United Nations Global Sustainable Development Report

UNEP – United Nations Environment Program

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNITAR – United Nations Institute for Training And Research

UNU – United Nations University

*«Our biggest challenge this new century is to take an idea that seems abstract – **sustainable development** – and turn it into a reality for all the world's people»*

Kofi Annan, Former United Nations Secretary-General, 2001

Preface

I have long been interested in sustainability issues related to Information and Communication Technology (ICT) and how these complex issues can be taught in a meaningful and engaging way. I have also considered environmental concerns regarding the effects of ICT systems in climate change, smart e-waste management systems, and energy supply efficiency, among others, to be of crucial importance. Over the years, this feeling has grown stronger; ICT systems are also intimately connected to many natural resources; they consume raw materials like silicon and copper; and their production and operation consume energy. On the surface, they seem unconnected and spanning lives of their own, yet deep down, they are parts of the same whole; the ways these challenges are tackled are all rooted in sustainability, and put together, they form the mosaic of what is called sustainable development.

Nowadays, the role of ICT in environmental protection and sustainability promotion is at the center of many debates in society, and at the same time, *young people** unite to take collective action for the environment and for their future. As an ICT and Math teacher in upper secondary school, I have approached the teaching and learning of the impact of ICT on the environment in various ways over the years. Those "intuitive experimentations" and experiences made it clear to me that although many students did not have the appropriate knowledge and information about these green ICT issues, they perceived and realized them as important. However, deepening their understanding of the complexity between ICT and sustainable development was challenging.

At the same time, I felt that these issues offered substantial educational potential. I had to figure out how to approach the complexity of these issues and how I could strengthen a meaningful engagement with them. Some students claimed that «there are things in society that we cannot influence or overcome». This students' perception of a limited possibility to contribute to environmental change made me feel unsatisfied and sometimes disheartened. At the same time, I noted that I had to overcome cognitive dissonance in the students' perceptions of sustainable ICT practices. I also had to determine the actions needed to support and establish these practices in the students' daily lives.

When I had the opportunity to start my doctoral studies, I took the chance to focus on ICT education for sustainable development. Since then, I have learned a lot about the complex relationship between ICT and sustainable development, which is not becoming necessarily simpler by learning more. In addition, I have studied the challenges related to ICT education for sustainable development and discovered the opportunities it offers. I realized then that ICT teachers have a role not only in developing the students' disciplinary knowledge in ICT but also in fostering the implementation and adoption of sustainable development experiences in their ICT education.

Consequently, the following questions have captured my interest during the pursuit of my doctoral studies: How can out-of-school or informal education through the use of mobile transit applications (apps) and in-school or formal education through the integration of sustainability issues into ICT curricula support the interconnections between subject disciplines of ICT and sustainable development, and how can students learn, understand, and embrace the issues that include aspects and disciplinary knowledge from the subjects mentioned above? This PhD Thesis is a compilation of the two primary studies (Study One and Study Two) that have been conducted in order for these questions to be answered.

* In this Thesis, the term "young people" covers ages 10 to 24, according to the World Health Organization

Part A

Chapter 1 Introduction

This chapter contains the introduction of the PhD Thesis. It situates the theoretical ground for understanding the broad spectrum of concepts concerning sustainability, sustainable development and sustainability in ICT. It provides background information about the fundamental role of ICT in collaborating for sustainable development as well as the environmental impact of ICT. Then, it presents the support of embedding sustainability in ICT education through the use of mobile transit apps and the integration of sustainability issues into the ICT curricula, which are the subject of this PhD Thesis.

1.1 The Concept of Sustainability and Sustainable Development

The concept of sustainability has deep roots. It was born from the realization that human activities endanger the future of life on the earth (Samuel & Lesley 2007). It encompasses a wide range of social, economic, and environmental considerations that aim to create a balanced and equitable world for the planet's current and future inhabitants. Sustainability is often associated with three main pillars: the environmental, the social and the economic, which are commonly known as the "three pillars of sustainability" or the "triple bottom line" (Purvis et al., 2019). The aforementioned perspective has been conveyed through a visual representation consisting of three overlapping circles (Figure 1).

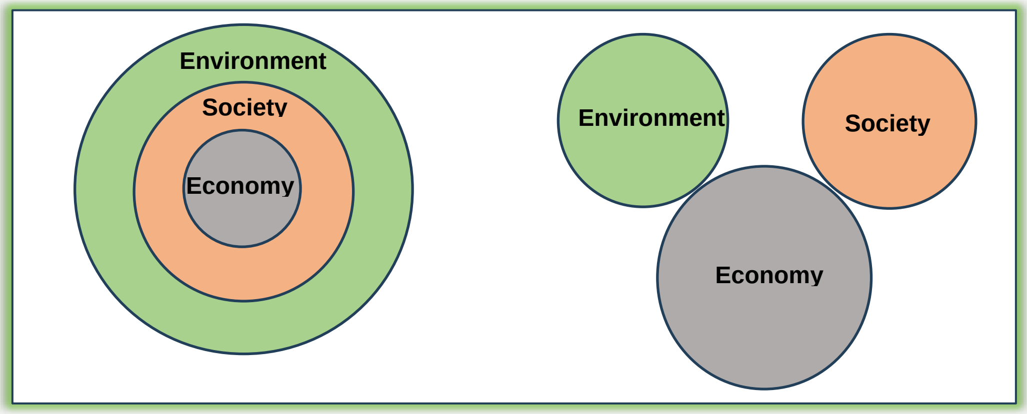


Figure 1. The visualization of the concept of sustainability

This depiction illustrates that the three fundamental aspects of sustainability are not inherently separate from one another but possess the potential to mutually strengthen and support each other. Indeed, the three pillars exhibit interdependence, such that the absence of any one pillar would render the remaining pillars nonviable in the long term.

The three pillars have emerged as a widely recognized foundation for several sustainability standards and certification systems in recent years:

[1] *Environmental Sustainability*: This pillar focuses on preserving and protecting the natural environment, including the conservation of resources, reduction of pollution, and promotion of biodiversity. It involves practices that minimize the negative impact of human activities on the ecosystems and the climate.

[2] *Social Sustainability*: This pillar is concerned with maintaining social well-being and fostering equitable and inclusive communities. It involves promoting social justice, human rights, fair labor practices, and access to education, healthcare, and basic necessities for all individuals, regardless of their background or socioeconomic status.

[3] *Economic Sustainability*: This pillar revolves around creating a stable and thriving economy that supports both the present and the future needs. It involves responsible resource management, sustainable business practices, and ensuring long-term economic growth that benefits society as a whole.

Sustainability is a global challenge that requires collective action and cooperation from individuals, communities, businesses, governments, and international organizations. Achieving sustainability involves making conscious choices and decisions in areas such as energy consumption, electronic waste (e-waste) management, transportation, agriculture, and urban planning. Therefore, sustainability research has emerged as an interdisciplinary research field. Consequently, the knowledge about achieving sustainable development has grown (Raw et al., 2018).

The concept of Sustainable Development (SD) was officially introduced in the Brundtland Report in 1987 (United Nations, 1987) as the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". In September 2015, at the United Nations, leaders and stakeholders from all over the world presented and adopted the 2030 Agenda for SD, one of the most emulous and widely accepted agreements in recent history. By 2030, this Agenda, which came into force on January 1st, 2016, aims to guide the world toward a more prosperous and secure future for all. The 17 Sustainable Development Goals (SDGs) serve as the foundation of the Agenda (Table 1).

The SDGs are a set of aspirations and priorities to direct all nations in addressing the most critical challenges of the world, such as eradicating hunger and poverty; ensuring that everyone can enjoy healthy and fulfilling lives; facing climate change, and protecting the planet from degradation; and encouraging fair, peaceful and inclusive societies free from violence and fear (United Nations, 2015). The SDGs, in the form of 17 goals, 169 targets, and 232 indicators, provide a conceptualization or delimitation of sustainability. The overarching goal is to create a world where environmental, social, and economic systems work together harmoniously to meet the needs of the present and future generations without compromising the planet's capacity to support life.

Table 1. The 17 Sustainable Development Goals (SDGs)

SDG 1	End poverty in all its forms everywhere
SDG 2	End hunger, achieve food security and improve nutrition and promote sustainable agriculture
SDG 3	Ensure healthy lives and promote well-being for all at all ages
SDG 4	***Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all***
SDG 5	Achieve gender equality and empower all women and girls
SDG 6	Ensure availability and sustainable management of water and sanitation for all
SDG 7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG 10	Reduce inequality within and among countries
SDG 11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG 12	Ensure sustainable consumption and production patterns
SDG 13	Take urgent action to combat climate change and its impacts
SDG 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG 17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development Finance

SDG 4 focuses on quality education that ensures inclusive and equitable quality education and promotes lifelong learning opportunities for all. Nevertheless, SDG 4 is linked to almost all the SDGs in one way or another. Young people, as well as adults, spend extensive periods of their lives in education in different learning settings: in formal education linked with schools and training institutions; in non-formal education linked with community groups and other organizations; and in informal education, which covers among other opportunities for interactions with friends, family and work colleagues.

Therefore, the role of educational institutions, regardless of their academic level, is crucial in meeting SDGs as they cultivate essential skills development and promote values, behaviors, and lifestyles favorable to a sustainable future and society. At the same time, they can produce and encourage future professionals as change agents and facilitate the creation of spaces where ideas are expressed freely, paradigms are challenged, creativity is promoted, and new SD knowledge is acquired and generated.

1.2 The Concept of Sustainability in ICT – Green Informatics

Over the past few years, there has been a noticeable increase in the use of a range of ICT products, including computers, mobile devices, and sensors. Nowadays, we are entirely dependent on many well-functioning ICT systems, including the infrastructure that connects these systems. Furthermore, the COVID-19 pandemic has had a remarkable effect on the use of electronic devices and digital services. People rely on ICT products to stay connected with family, work, colleagues, and social life (Adejumo & Oluduro, 2021). Although this issue has meant more significant use of technology at home, it has also led to an increased consumption of ICT products. From this perspective, it is absolutely necessary for the users to be conscious of the options for their end-of-life electronics and focus on each user's responsibility in making circularity a certainty for electronic ICT devices.

Simultaneously, ICT has a fundamental role in collaborating for SD as it significantly supports the access to information for SD and the goals of the 2030 Agenda by directly applying tools and technologies developed for this purpose (Latorre-Cosculluela et al., 2023). Such technologies lead to enhanced learning and teaching by using interactive, dynamic, and engaging SD content while helping people worldwide access this content more efficiently and effectively (Basilotta-Gómez-Pablos et al., 2022). Therefore, sustainability in ICT is becoming increasingly important as the digital world continues to expand and the demand for technology-driven solutions grows.

The concept of sustainability in ICT covers the responsible and ethical use of technology to minimize its negative environmental, social, and economic impacts while maximizing its positive contributions to society (Zhang et al., 2022). In addition, as a more general term, *sustainable Information Technology* (IT), also known as *green IT* or *green informatics*, includes, among others

- the effort to reduce energy consumption and carbon emissions by manufacturers, data centers and end-users for the benefit of individuals and other stakeholders (Ziemba, 2019),
- the choice of sustainably sourced raw materials,
- the mitigation of e-waste, and
- the use of renewable resources (Filho et al., 2017).

These inclusions may lead to the minimization of the environmental impact by paying attention to the proper construction, use, management, and disposal of information technology components and peripherals (Amekudzi et al., 2015). There are several key aspects of sustainability in ICT that can be corresponded to the following domains:

[1] *Green computing*: Green computing involves the design, manufacturing, usage, and disposal of computers and other ICT equipment in an environmentally friendly manner. This manner includes using energy-efficient processors, optimizing Data Centers (DCs), and promoting virtualization and cloud computing to reduce the physical hardware requirements (Rahman, 2022). In addition, the use of application virtualization enables safe remote work and affects the overall architecture of a network and data transfer, as well as the internal structure of the data center, by helping optimize resource usage, leading to reduced hardware requirements and energy consumption (Katal et al., 2022).

[2] *Responsible supply chain*: Green informatics focuses on ensuring that the entire supply chain of technology products is environmentally and socially responsible. This focus includes sourcing raw materials ethically, promoting fair labor practices, and considering the life cycle of products, from design to end-of-life recycling (Taghikhah et al., 2019). Furthermore, green informatics promotes and adopts a circular economy approach that involves designing ICT products with durability, repairability, and recyclability. This approach extends the lifecycle of devices and reduces the need for constant upgrades and replacements (Ibáñez- Forés et al., 2022).

[3] *Data privacy and security*: Ensuring data privacy and security is an essential aspect of green informatics. This aspect supports and promotes the protection of the users' data from unauthorized access along with the secure communication channels and emphasizes that the data protection regulations are vital for building trust and maintaining a sustainable digital ecosystem (Ismagilova et al., 2022). Consequently, governments and international bodies play a crucial role in promoting sustainability in ICT through policies, regulations and data protection rules, which enhance how people can access information about them and place limits on what organizations can do with the users' personal data.

[4] *Green software development*: The development of sustainable software (also known as sustainable software engineering) focuses on energy efficiency and environmental sustainability in all software development stages, from the software design to the implementation, development and software maintenance, while meeting user needs and quality standards. This approach involves the writing of efficient code that optimizes resource usage, reduces energy consumption, and considers the environmental impact by minimizing the adverse effects of the applications and their hosting infrastructure on the environment (Venters et al., 2018).

[5] *Monitoring and reporting*: Organizations can measure and track their sustainability in ICT performance over time by adopting and benefiting from the use of sustainability reporting frameworks or standards, such as the Global Reporting Initiative (GRI) or the ISO 14001 (Mougenot & Doussoulin, 2023). These standards are designed to help organizations prepare and report information related to their environmental, social, and economic impact in a comparable and credible way, thereby increasing transparency on their contribution to SD (Ibáñez- Forés et al., 2022). At the same time, these standards establish a global, common language through which these organizations can communicate and assess those impacts of ICT operations and encourage continuous improvement.

[6] *Digital inclusion and environmental awareness*: Green informatics strives to bridge the digital divide and to ensure that everyone can access technology and the Internet. It involves initiatives to provide connectivity and digital literacy programs, especially in underserved and remote areas (Alhassan & Adam, 2021). Simultaneously, it aims to educate and raise awareness about responsible e-waste disposal, energy-efficient practices, and how digital activities can impact the environment and society (Higón et al., 2017).

By incorporating these principles into ICT practices, individuals, businesses, and governments can work together to create a more sustainable and environmentally friendly digital future. Green informatics is not only beneficial for the planet, but it also helps build a more inclusive and equitable society where technology serves as a force for positive change.

1.2.1 Sustainable Human-Computer Interaction

Sustainable Human-Computer Interaction (HCI) refers to the design and development of interactive systems that take into account environmental, social, and economic sustainability considerations. The concept of sustainable interaction design was presented first by Blevis (2007), who argued that sustainability should be considered a first-class criterion for technology design, as important as other more conventional design criteria such as usability or robustness. Sustainable HCI considers not only the material aspects of a system's design but also the interaction throughout the life cycle of the system. Sustainable HCI takes into account how a system might be designed to encourage longer use, transfer of ownership, and responsible disposal at the end-of-life (Ren et al., 2019).

For this reason, sustainable HCI is an interdisciplinary field that combines principles from HCI and sustainable design to create technology solutions that minimize the negative impacts on the environment and society while maximizing the positive contributions (Issa & Isaias, 2022). Sustainable HCI focuses on the relationship between humans and technology in the context of sustainability and comprises several approaches and essential principles:

- *Environmental Impact*: Sustainable HCI focuses on reducing the environmental footprint of interactive technologies. This focus includes energy consumption, resource usage, e-waste management, and the lifecycle impact of products and services. In addition, emphasizing energy-efficient design and optimizing power consumption in interactive systems is a crucial aspect of sustainable HCI.
- *User-Centered Design*: The understanding of the user's needs, behavior and preferences plays a vital role in sustainable HCI. This understanding guides the designers and the developers to create systems that encourage sustainable practices and support environmentally friendly actions. Sustainable HCI aims to influence user behavior toward more eco-friendly practices. These practices can be achieved through persuasive technologies, eco-feedback mechanisms, and the promotion of pro-environmental behaviors. At the same time, this design considers the broader social impact of technology as it aims to address issues related to digital inclusion, accessibility, privacy, and equity to ensure that the benefits of technology are distributed more equitably across society (Issa & Isaias, 2022).
- *Longevity and Durability*: The design of products and services that ensure longevity and durability promotes sustainability. The creation of ICT systems that last longer reduces the need for frequent replacements; thus, it results in the reduction of e-waste generation. Simultaneously, by encouraging and supporting sustainable business models, such as product leasing, sharing economies, and responsible recycling, the overall sustainability of interactive technologies can be significantly improved (Raghavan & Pargman, 2017).

The integration of the principles mentioned above into the design and development process of an ICT system fosters positive environmental and social outcomes while still meeting the needs and desires of the users. The goal is to shift the focus from short-term gains to long-term benefits for both the users and the planet. As technology continues to play an increasingly significant role in people's lives, the adoption of sustainability-oriented practices in HCI becomes essential for a more sustainable future.

1.3 Environmental Impacts of ICT

The digital transformation of modern society has brought about significant advancements and benefits, i.e., less paper is being used, and less traveling is needed, but this transformation is not immune to drawbacks in terms of its various environmental impacts. The relationship of ICT with the environment is a complex and multidimensional issue, as ICT can have both positive and negative effects on environmental sustainability. The ICT industry gives communities a powerful tool to protect the environment around them and the means to reduce their need for natural sources and the amount of waste they release into the environment. However, it takes significant amounts of energy and resources to develop, manufacture, and distribute ICT devices and equipment. Since these devices tend to have a short lifespan, the development of ICT has also increased the amount of e-waste released into the environment. Apparently, from the energy used to manufacture smartphones to the fact that even emails generate carbon emissions, the world's Internet addiction comes at a cost to the climate.

Various studies have categorized the environmental effect of ICT in a variety of configurations. Berkhout & Hertin (2001), for instance, classify these effects as direct, indirect, and structural-behavioral. Direct effects are exclusively negative effects that result from the processes associated with the production, use, and disposal of ICT devices. The application of ICT can have both negative and positive indirect effects, such as dematerialization and efficiency gains. Structural-behavioral effects are related to structural and lifestyle changes caused by ICT, such as the transition from a material economy to a service economy, and can be both positive and negative, including the rebound effects (i.e., increased demand stimulated by efficiency improvements).

Hilty & Aebischer (2015) note that the rebound effects within the ICT sector is significant. However, this effect has been largely missed out by studies evaluating the potential role of ICT in reducing energy consumption and GreenHouse Gas (GHG) emissions. These studies base their claims about the great potential of ICT on efficiency considerations alone (Fagas et al., 2017; Lange et al., 2020). Other forms of rebound effects are also discussed in the literature; for instance, Håkansson & Finnveden (2015) discuss the reverse rebound effects, which occurs when the increased consumption of ICT leads to a decrease in the consumption of other goods, thereby reducing the environmental impact overall.

Some of the critical environmental concerns associated with green informatics and the mitigation of the environmental footprint of the ICT industry are the following:

[1] *Energy consumption*: The ICT infrastructure, including DCs, Internet and communication networks, as well as the ICT devices' usage, require a substantial amount of electricity to operate efficiently and thus, they contribute to energy consumption. DCs, which constitute the backbone of the digital world, are energy-intensive facilities that host servers and hardware in order to store and process vast amounts of data. The need for DCs is increasing rapidly due to the rapid advancements in cloud computing, which uses many DCs and servers to service a considerable number of clients using a pay-per-use model (Jiang et al., 2020).

The DCs require significant power to provide these services, which leads to higher GHG emissions, particularly carbon dioxide (CO_2), thus contributing to global warming. The energy consumption of DCs is expected to rise from 200 Terawatt-hour (TWh) in 2016 to 2967 TWh in 2030 (Katal et al., 2022). Green cloud computing is anticipated to reduce this energy consumption and effectively process and utilize computing resources (Baldassarre et al., 2018). These improvements are necessary to ensure the sustainable future of cloud computing. Otherwise, cloud computing will significantly increase energy usage as continuously increasing front-end client devices interact with back-end data centers (Vakilinia, 2018).

[2] *E-waste recycling and management*: Electronic waste, e-scrap, and e-waste, as well as end-of-life electronics, are often used to describe used electronic devices approaching the end of their useful life, which are donated, discarded, or given for recycling. E-waste is estimated to increase from 3% to 5% annually (Ilankoon et al., 2018). It has been recognized as the fastest-growing waste confluence worldwide and contributes to 2-5% of municipal waste (Kumar et al., 2017). The International Telecommunication Union (ITU, 2022) identifies that e-waste is one of the most complex and extensive waste streams in the world.

In addition, the Global E-waste Monitor 2020 predicts a 38% increase in worldwide e-waste between 2020 and 2030 (Forti et al., 2020). The amount of e-waste produced by electronic devices - such as cell phones, printers, discarded computers, televisions, and batteries - increases yearly. This growing volume of e-waste can be related to the population's request for greater competition between producers and functionality of electronic devices, which constantly increases the rate at which these electronic devices become outdated (Debnath et al., 2016).

E-waste contains not only many hazardous toxins but valuable materials as well. This combination makes the effective material recovery and safe management of e-waste notable for its economic value and for the protection of the environment and human health (Goosey & Goosey, 2019). Recent studies reveal that the improper e-waste management has effects on both the health and the environment: more than 1,000 materials are used to make ICT products (i.e., heavy metals, PVC, chlorinated solvents, and plastics) which contain hazardous substances such as cadmium, lead, mercury, and zinc (Decharat & Kiddee, 2022; Kumar et al., 2017; Nowakowski, 2016). These materials can cause severe health problems such as thyroid, cancer, and neurological disorders if disposed of improperly (Brindhadevi et al., 2023).

Similarly, the toxic components in e-waste may permeate the soil and contaminate groundwater or enter the atmosphere as poisonous fumes if burning is applied as a disposal method (Kumar et al., 2017). Such pollution directly affects the drinking water quality and the production of crops. For example, the cadmium from one cell phone battery can contaminate $600m^3$ of water (Soetrisno & Delgado-Saborita, 2020). Previous research consistently reports that the rates of e-waste are higher in developing countries (i.e., Tanzania and Indonesia) due to the lack of policies, formal systems for recycling and appropriate legislation regarding e-waste (Wang et al., 2021). For this reason, e-waste is often burned or buried along with other rubbish in many landfills (Zeng et al., 2017).

According to one report, the improper handling of e-waste has caused a significant loss of valuable raw materials, many of which are scarce, including many precious metals such as indium (used in flat-panel TVs), neodymium (vital for magnets in motors), and cobalt (extensively used for batteries) (Holgersson et al., 2018). It should also be noted that almost no rare earth minerals are extracted in non-formal recycling. In addition, mining from disposed electronic devices produces 80% fewer CO_2 emissions per gold unit than mining it from the ground (Shyam et al., 2017). As stated by the Global E-waste Monitor 2020, only 9.3 Mmt of e-waste (17%) of the world generated 53.6 Mmt in 2019, which was recorded, is being properly collected, treated and recycled (Forti et al., 2020). The United Nations Environment Program (UNEP) also estimated in a 2021 report that 60-90% of e-waste in the world, worth nearly 19 billion USD, is illegally dumped or traded annually.

[3] *Resource extraction of raw materials*: The manufacturing of ICT devices and infrastructure components requires the resource extraction of raw materials, including rare minerals and metals. The raw materials are obtained by excavation, drilling, boring, or other methods. These mining activities can have significant an environmental impact, including habitat destruction, water pollution, and soil degradation. Researchers analyzing the national responsibility for ecological breakdown – through calculating the extent to which each nation has overshot its fair share of sustainable resource use thresholds – find that excessive global resource extraction fast tracks CO_2 emissions and increases ecological damage (Helbig et al., 2017). This resource extraction of natural materials is swiftly escalating climate change, not only in terms of CO_2 emissions, but also in land-use change, biodiversity loss, chemical pollution, and biogeochemical flows.

[4] *Emissions from electronic manufacturing*: The entire life cycle of the ICT equipment - from manufacturing to use and disposal - has a considerable impact on climate change and contributes to its carbon footprint increase. More specifically, the design, production, distribution, maintenance and disposal of ICT products and services by the ICT industry are related to the GHG emissions that result from the energy used to produce materials, operate facilities, transport goods, and provide services (Teehan & Kandlikar, 2013). Furthermore, the production of electronic components and devices involves various chemicals and processes that can release harmful emissions and pollutants into the atmosphere.

[5] *Water usage*: DCs, which are critical components of the ICT infrastructure, require the consumption of substantial amounts of water for various purposes within these facilities. The primary area where water is used is in cooling systems, which are necessary because DCs generate a significant amount of heat due to the operation of servers and other ICT equipment. Thus, cooling systems are essential to maintain a stable temperature and prevent overheating. There are various cooling methods, including air-based and liquid-based, with the latter using, in most cases, water for heat dissipation (Vakilinia, 2018).

At the same time, some DCs require precise humidity levels to prevent static discharge and other issues related to dry environments. Therefore, water may be used for humidification to maintain the desired humidity levels as well as for general facility maintenance, such as cleaning floors, equipment, and other areas. The amount of water usage in DCs can vary depending on the size of the facility, the cooling technologies employed, the geographical location, and the efficiency of the infrastructure (Katal et al., 2022). The water consumption impacts the local ecosystems and is a major concern in regions where the water is scarce.

[6] *Deforestation and habitat loss:* The expansion of ICT infrastructure (e.g., laying fiber-optic cables, building DCs) in remote or previously undisturbed areas, if not properly managed, can lead to deforestation or habitat destruction, especially in sensitive ecosystems. Moreover, the demand for resources such as minerals used in electronics or metals for infrastructure components can drive indirect land use changes in some regions (Katila et al., 2019). For example, mining activities for these resources might encroach upon natural habitats.

In order to address these severe environmental challenges, we can take advantage of ICT benefits while minimizing its negative impact on the environment and working all together toward a more sustainable future. It is worth mentioning that while ICT contributes to energy consumption, it also enables energy savings and efficiency improvements in other sectors, such as smart grids, smart buildings, and remote work. The efforts to balance the benefits of ICT with its environmental impact include:

- *Improving energy efficiency* by promoting energy-efficient technologies and practices that can reduce electricity consumption and GHG emissions. This promotion involves designing energy-efficient hardware, optimizing software applications, and adopting energy-saving practices in DCs and computing devices. In addition, renewable energy sources such as solar, wind, and hydroelectric power should be integrated to run DCs and to power ICT infrastructure in order to reduce their overall environmental impact and mitigate the carbon footprint of this sector. At the same time, the DCs operators should increasingly adopt more water-efficient cooling systems, recycle the water when possible, and optimize cooling methods to reduce the overall water usage.
- *Implementing proper recycling and disposal programs for e-waste* can help reduce its environmental impact and recover valuable materials in order to prevent hazardous substances from polluting the environment. In addition, responsible product design and extended product lifecycles are crucial to minimizing e-waste effects on the environment.
- *Encouraging manufacturers to take extended producer responsibility* for the entire life cycle of their products, including proper disposal and recycling, can incentivize more sustainable design and production practices. Furthermore, governments and organizations can develop and implement green ICT policies, such as energy efficiency standards and e-waste regulations, that promote environmentally friendly practices in the ICT industry.
- *Raising awareness* about the environmental impacts of ICT, *cultivating environmentally friendly habits* within everyday life, and *promoting responsible consumer behavior*, including young adults and children, can lead to more sustainable choices in technology usage and facilitate positive changes for everyone in order to tackle these environmental concerns.

1.4 Education for Sustainable Development (ESD)

Education has a fundamental role to play in personal and social development. It is one of the principal means available to foster a deeper and more harmonious form of human development and, thereby, to reduce poverty, exclusion, ignorance, oppression, and war. In 2005, UNESCO (United Nations Educational, Scientific and Cultural Organization) launched the "United Nations Decade of Education for Sustainable Development" (2005-2014), which aimed to promote and integrate the Education for Sustainable Development (ESD) concept globally. This initiative was followed by the UNESCO Global Action Program on ESD, which continued the efforts to incorporate SD principles into education.

The concept of ESD, or *Education for Sustainability* (EfS), supports the development of the knowledge, skills, understanding, and actions required to create a sustainable world, which ensures environmental protection and conservation, promotes social equity and encourages economic sustainability (Marouli, 2021). According to the report to UNESCO of the International Commission on Education for the Twenty-first Century (Delors, 1996), the sustainability infusion in education promotes the four types of learning as the basis for fostering SD (Figure 2).

These types are:

[1] *Learning to know,* by means of taking into consideration all the processes and practices that lead people to experience, construct, and transform knowledge for making sustainability a mode of life and being.

[2] *Learning to do,* by means of taking into consideration all the processes and practices that lead to merging knowledge with action for building a sustainable future.

[3] *Learning to live together,* by means of taking into consideration all the processes and practices that lead to a peaceful and non-discriminatory society and human co-existence with the natural world.

[4] *Learning to be,* by means of taking into consideration all the processes and practices that lead to a peaceful and non-discriminatory society and to human co-existence with the natural world.

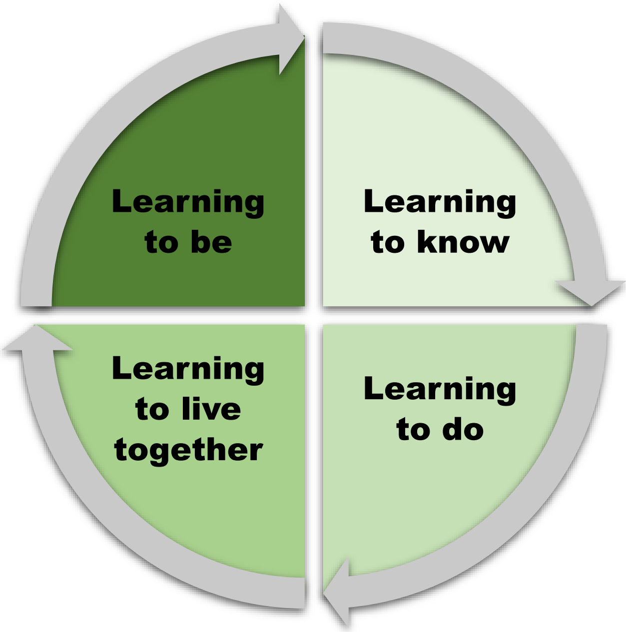


Figure 2. The four pillars of education for sustainable development

ESD proposes the inclusion of key SD issues in teaching and learning, such as poverty alleviation, citizenship, peace, ethics, responsibility in local and global contexts, democracy and governance, justice, security, human rights, health, gender equity, cultural diversity, rural and urban development, economy, production and consumption patterns, corporate responsibility, environmental protection, natural resource management and biological and landscape diversity (Aikens et al., 2016). As a consequence, ESD plays a crucial role in empowering individuals with the knowledge and skills necessary to address the complex challenges our world is facing and work toward a more sustainable and just future.

ESD can be integrated into various levels of education, from formal schooling to informal and non-formal learning settings. It is not limited to specific subjects, but it can be woven into various subjects and activities, allowing learners to connect sustainability principles with their everyday lives. It is generally accepted that characteristics which reflect the equal importance of both the learning process and the outcomes of the education process are essential for the successful implementation of ESD. Therefore, ESD requires participatory teaching and learning methods that motivate and empower learners to change their behavior and take action for sustainable development (Sammalisto & Lindhqvist, 2008).

According to UNESCO (2012), a whole-school approach to sustainability ensures that pupils "learn what they live and live what they learn", which means that students need more than just the knowledge and skills to recognize SD; they also need the capacity to develop and adopt SD principles in their own world too. Therefore, such an educational approach should enable the involved parties to recognize the interconnectedness of social, economic, and environmental dimensions of sustainability, the holistic understanding of complex global challenges, the encouragement for integrated solutions, and, the most critical thing, that sustainability must be a part of the school-wide curricula. Accordingly, the principles of ESD must be supported and valued by the entire learning community (Steinfeld & Mino, 2009).

The ESD principles include:

- *The interdisciplinary learning* that transcends traditional subject boundaries and integrates various disciplines to provide a comprehensive understanding of sustainability issues.
- *The critical thinking and problem-solving* skills, as well as the ability to analyze and solve complex sustainability challenges; in such an approach, students are encouraged to question assumptions, seek innovative solutions, and evaluate the implications of their decisions.

- *The active participation and engagement of students* by encouraging collaboration, dialogue, and partnerships among students, educators, communities, and stakeholders to create a shared vision for SD.
- *The local relevance and the global perspective* by recognizing the importance of addressing local sustainability issues while also understanding their global context; thus, the students are encouraged to consider both local and global implications of their actions.
- *The ethical considerations and the cultural sensitivity* in order to promote values such as responsibility, empathy, respect for diversity, and social justice; thus, students are encouraged to make ethical choices that consider the impacts of decisions and actions on the present and the future generations well-being.
- *The experiential learning* that involves hands-on, practical experiences that allow students to apply theoretical knowledge in real-world contexts, imagining future scenarios and making decisions in a collaborative way.
- *The lifelong learning* that promotes learning throughout life and encourages students to continually update their knowledge and skills to adapt to changing sustainability challenges.

The embracement and the adoption of the previously mentioned reflective principles and values in a school program provide a continuity perspective over time. They could lead to sustainable practices that meet the characteristics of a sustainable-oriented school. For this to be achieved, the leadership, operations, and the entire school community should be clearly involved in sustainability-related practices and support effective teaching and learning based on ESD principles (Lim et al., 2022).

1.5 The Role of ICT in ESD

ICT is defined as a diverse set of technological tools and resources used to transmit, store, create, share, or exchange information and involves skills regarding computing, software that operates devices, applications, and systems that interact with each other (Chen et al., 2015). ICT is widely used in our everyday lives, and its use is ever-growing in the education sector by revolutionizing the way students learn and teachers instruct. One prominent example of this revolution is the almost immediate process of adjusting the education delivery methods to respond to the recent COVID-19 pandemic worldwide. All the images, audio, videos, multimedia presentations, simulations, or a combination of these tools used for teaching constitute ICT in education. In this way, ICT in education means the use of information and communication to improve the delivery of educational content in every way and the possibility to access this content anytime and from anywhere, in a way tailored to the specific learner's needs.

According to the Mid-Pacific ICT Center (2011), ICT in education should consider both the digital literacy component as well as the infrastructure and supporting applied technologies component. The availability, accessibility, and use of open-source software and technologies such as 3D printing give rise to the students' participation in activities where they are the center of the learning process. Furthermore, with the sufficient development of sensors, networks, media, and artificial intelligence technologies, a modern classroom environment has the right tools to optimize teaching content presentation, facilitate learning, and obtain and promote classroom interaction development.

In addition, the high growth and ubiquity of the Internet and the rapid 5G technology deployment provide the necessary bandwidth capacity to deploy high-tech educational content anywhere and anytime (Lwoga & Sangeda, 2019). This ICT-supported environment may promote the integration of an education that encourages changes in learning, abilities, values and attitudes in order to enable a more sustainable society for all students.

Furthermore, it may advocate the cultivation of the students' environmental awareness and contribute to their ESD. Moreover, students can be taught STEM (Science, Technology, Engineering, and Mathematics) curricula content using project-based learning technologies in ways that comply with real-world sustainable practices (Marouli, 2021). Therefore, a sustainable technology-enhanced education can be a significant driver toward green informatics as it can enhance and promote the awareness, appreciation, and practical application of green informatics in everyday activities as well as in professional life (Holst, 2022).

In this context, ICT education can play a significant role in the ESD core challenges and help speed up the progress toward every single SDG (Kyle, 2020). Moreover, ICT can play a substantial role in ESD by enhancing learning, promoting awareness, facilitating collaboration among learners, and supporting these goals in various ways:

- *Access to information and resources*: ICT enables access to a vast amount of information and educational resources related to sustainability and ESD. Online platforms, digital libraries, and educational websites provide learners with up-to-date and diverse content, allowing them to explore various perspectives on SD (Machado et al., 2017). In addition, ESD can be delivered through online courses and webinars, enabling learners to access quality education regardless of their geographical location. Online platforms also offer certifications in sustainability-related topics, enhancing individuals' employability and expertise. At the same time, ICT can promote sustainable practices by reducing the need for physical resources. Digital textbooks, online assessments, and virtual classrooms minimize paper usage and energy consumption, contributing to environmental conservation.
- *Interactive learning*: ICT offers interactive and engaging learning experiences through multimedia, simulations, virtual reality, and gamification. These methods can help learners grasp complex sustainability concepts more effectively and engage them in problem-solving scenarios related to real-world sustainability challenges (Paul et al., 2020). Concurrently, ICT fosters creativity and innovation by providing tools for designing and implementing sustainable solutions. Students can use technologies like 3D printing and programming to develop prototypes for, i.e., renewable energy systems or e-waste management solutions.
- *Global awareness and connectivity*: ICT connects learners worldwide, fostering cross-cultural understanding and global awareness. Through online discussions, video conferencing, and collaborative projects, students can interact with peers worldwide and gain insights into diverse sustainability issues and solutions (González-Zamar et al., 2020).
- *Data analysis and visualization*: ICT allows students to collect, analyze, and visualize data related to environmental, social, and economic aspects of sustainability (Mishra & Mishra, 2020). These actions empower students to understand patterns, trends, and impacts, enabling informed decision-making and problem-solving. Simultaneously, ICT enables the monitoring and evaluation of sustainability initiatives and projects. Through data collection and analysis, educators and policymakers can assess the effectiveness of ESD programs and make informed decisions for continuous improvement.
- *Empowerment and participation*: ICT encourages active participation and engagement in sustainability initiatives. Social media platforms, blogs, and online communities provide spaces for individuals to share their thoughts, ideas, and projects related to SD, amplifying their voices and impact. In this way, ICT supports lifelong learning by offering flexible and self-paced learning opportunities (Gordon, 2010). Individuals can continue to expand their knowledge and skills in sustainability throughout their lives and adapt to the ever-evolving challenges.

Taking into consideration the observations mentioned above, it is apparent that the simple application and use of ICT in traditional face-to-face teaching and learning practices (i.e., straightforward presentation of images and videos) cannot contribute to the development of methods toward a school that supports sustainability. This happens because the development of the individual and the manifestation of critical dialogue, elements that could emerge through a holistic integration of ICT to support sustainability, are not approached (Lee & Louis, 2019).

Therefore, a teaching model that deals with the knowledge within the context of social reality and that depends on personal experiences is the appropriate one toward a sustainable school. This model supports teaching methods with a bidirectional interaction. In addition, the delivery of the educational content is revolutionized through the use of multiple mobile applications (apps). For this reason, the learning environment is rapidly transformed and adapted to provide smart learning opportunities for all students and meet their diverse learning needs (Kwet & Prinsloo, 2020).

At the same time, it is crucial for the teacher to adopt the above mentioned approaches of teaching and learning in the classroom in order to better engage students in sustainability. To achieve this environmentally friendly goal, it is essential that the teacher is adequately trained and familiarized with the necessary technology. Furthermore, the teacher should communicate how ICT can play a significant role in enabling students to live more sustainably and to move to a more "smart" use of their time, energy and resources, so that they can critically evaluate each aspect of them (Henderson & Tilbury, 2004).

However, it is essential to acknowledge that not all communities can access ICT resources equally. Ensuring equitable access to technology is crucial for ESD efforts to be truly inclusive and effective. Additionally, balancing the benefits of technology with the need for physical experiences in nature and for hands-on learning is essential for a holistic approach to ESD.

1.5.1 Supporting ESD with the Use of Mobile Transit Apps

According to the United Nations (UN DESA, 2018), 68% of the world's population will live in a city by 2050. That is why cities must rush to optimize population flows, provide efficient means of transport, and promote sustainable traveling behaviors. Simultaneously, there is an explosion of new mobility shared services (such as carsharing and ridesharing), and disruptive changes are being experienced in traditional services, such as in the taxi domain (such as Uber and Lyft).

The daily use of mobile electronic devices like smartphones, tablets, PCs, and handheld Global Positioning System (GPS) navigation devices may potentially influence and recruit users to support various sustainable travel actions. Through mobile transit apps, travelers can manage and transform their mobility in a more user-friendly manner. At the same time, as mobile technology can facilitate "anytime and anywhere" learning, it has the potential to support young people's education and encourage their choices toward greener travel habits (Miao et al., 2017). Moreover, relevant research shows that establishing walking or an active lifestyle in childhood can influence physical activity and eco-friendly transport decisions along the course of a lifetime (Telama et al., 2005).

An extensive literature has been dedicated to the children's well-being, which can be affected by - among other factors - independent mobility (IM) with numerous health and environmental benefits (Armstrong, 1993; Harten & Olds, 2004; Leung & Loo, 2017; Waygood & Kitamura, 2009). Mobility, in general, refers to "the ability to move easily from one place to another" (Oxford Dictionaries). More specifically, children's IM is typically defined as the freedom to travel around the neighborhood or city without adult supervision, and it often involves active travel modes (non-motorized) like walking and cycling or using the public transport modes (Buliung et al., 2017; Hillman et al., 1990). The most significant and determinant factor for the children to safely navigate the street network and their neighborhood environment alone is their age (Fyhri et al., 2011; Lam & Loo, 2014). Prior research suggests that independent travel is more common once a child reaches the age of 13 or 14 (Larsen et al., 2015).

From this perspective, the education on increasing the sensitivity of eco-friendly travel habits could clearly provide long-term benefits. Children educated to be aware of sustainability will probably become more sustainability-conscious adults. In addition, providing education to children in this direction, besides encouraging them to adopt a more sustainable behavior, also creates a domino effect: they may influence their parents and relatives and encourage other adults toward sustainable choices in their daily activities (Gandini et al., 2019). Since today's children are tomorrow's adult transport users, intermodal travel behavior must be cultivated and adopted at a very early age.

Considering the fact that the popularity of mobile devices, along with the accompanying apps among children is growing exponentially around the world (Cano & Sevillano-García, 2018), the mobile devices can create exciting and effective learning environments for learning and education in every age (Goodwin, 2020; Papadakis & Kalogiannakis, 2017). Many studies (Alfawareh & Jusoh, 2014, 2017; Froese et al., 2012; Seralidou & Douligeris, 2019; Tindell & Bohlander, 2012) have been conducted on assessing the use and effects of smartphones, especially for learning purposes and for supporting formal, informal and autonomous learner engagement. These environments can integrate motivational techniques in the direction of supporting the adoption of more sustainable intermodal transport choices and behaviors by children within their region, including walking, cycling, and public transport.

In this light, the use of mobile electronic devices could facilitate the ESD and increase interaction with the natural environment. Several studies have reported the effects of location-based learning with mobile devices: Ruchter et al. (2010) found an increased motivation to engage in environmental education if children use mobile devices, compared to the use of field guides and human guides. Kremer et al. (2013), as well as Lai et al. (2007), also highlight the motivational aspects of using mobile devices during outdoor education activities, while Uzunboylu et al. (2009) foster smartphone-moderated activities (taking and sharing pictures in real-time of local deteriorated environments) to increase awareness of environmental concerns.

Given the above, there is a need for well-designed mobile transit apps to influence young people toward a sustainable mobile traveling attitude. These apps use the most advanced, emerging, and innovative technologies to change the attitudes of the users toward the systematic use of eco-friendly alternative means of transport. In the medium to long term, these apps would try to make users adopt sustainable mobility patterns (Stibe & Larson, 2016). Therefore, these apps can play a crucial role in raising awareness, providing information, and encouraging positive behavior changes by promoting sustainability and responsible urban living. Consequently, the use of mobile apps in sustainable travel and urban behavior education has the potential to significantly impact how young people interact with and contribute to their urban environments.

Therefore, the mobile transit apps can integrate motivational techniques in the direction of supporting the adoption of more sustainable intermodal transport choices and behaviors without coercion but through persuasion (Fogg, 2002). In this way, mobile apps can raise awareness about the environmental impacts of different travel choices, encourage users to make more sustainable decisions (Dutzik et al., 2013) and support ESD, especially for young people, in a variety of ways:

- The mobile apps can deliver *educational content* on sustainable travel practices, urban planning, and environmental impacts.
- Through *interactive multimedia, videos, quizzes, and infographics*, users can learn about the benefits of sustainable transportation modes like walking, cycling, carpooling, and using public transport (Lai et al., 2007; Ruchter et al., 2010).
- The mobile apps can provide users with *information about sustainable transportation options*, such as public transit routes, bike-sharing stations, electric vehicle charging points, and carpooling opportunities.

The success of such mobile transit recommendation apps can be measured by the degree to which they manage to increase the motivation of the users to adopt an environmentally friendly mobility behavior (Baker-Eveleth & Stone, 2020; Celina et al., 2019). By combining education, convenience, real-time information, and engagement, these apps can empower young people to make environmentally friendly transportation choices and contribute to the reduction of carbon emissions, the alleviation of traffic congestion, and the fostering of a culture of environmentally conscious urban mobility. A well-designed mobile app may have the potential to become a strong influence on the young people's travel habits and attitudes and, consequently, on whether and how they adopt sustainable mobility patterns (Stibe & Larson, 2016).

1.5.2 Supporting ESD with the Integration of Sustainability Issues into the ICT Curricula

According to the Sustainable Development Solutions Network (SDSN, 2017), Higher Education Institutes (HEIs) can promote and support ESD and, consequently, the implementation of the SDGs in various ways; first, by incorporating sustainability principles into all university curricula and educational and research initiatives; second, by acting as vital local knowledge hubs for sustainability; and third, by elevating sustainability as a guiding principle in their own planning and administrative processes. In addition, HEIs can develop the appropriate knowledge, skills, values, and attitudes, which may empower and motivate students to contribute to SD actively (Wang et al., 2022). Therefore, HEIs should focus on their environmentally friendly institutional responsibility by promoting and implementing SD initiatives.

In any case, HEIs can contribute to the minimization of the negative environmental impacts of the IT industry by raising awareness among students as well as by actively encouraging appropriate sustainable technical and organizational measures (Zhang et al., 2019). Consequently, to promote the change needed in society, HEIs themselves will need to change even quicker than society as a whole through attitudes enabling the integration of sustainability, regulations, standards, and faculty goals. In order to ensure a more sustainable future, higher education will have to provide college and university graduates with the skills, background, knowledge, and mental habits that prepare them to meet the challenges of the future.

To infuse sustainability into the curricula means to integrate into the existing curricula the knowledge, competencies, perspectives, values, skills and actions needed to transform society and to sustain the environmental, social and economic integrity of the planet. UNESCO (2018) indicates that ESD has the prospective to attract more students due to its essential significance for the future. Indeed, toward the journey to sustainability, education should not restrict itself to just give students information but also to provide them with an experience that brings opportunities to work collaboratively, appreciate multiple perspectives, be reflective, think critically and creatively, and act constructively.

In connection with ICT, embedding sustainability issues into the ICT curricula is essential to prepare students for a world that requires both technical expertise and a strong understanding of environmental and social impacts. It is also vital to provide education in, among others, the sustainability aspects of the engineering professional activity, such as engineering for a sustainable society, decision analysis for sustainability, sustainable product design, materials and processes for sustainable engineering, and sustainability in project management.

As sustainability is becoming a necessary competence across different engineering disciplines, the ACM/IEEE-CS and the ACM/AIS curricula guidelines for ICT degree programs have also specified sustainability under essential as well as supplemental knowledge areas. It involves the development and use of technologies, tools, standards, methods, regulations, policies, and practices, as well as human and social or institutional behavior, so that sustainability can be achieved throughout the data and information lifecycle.

Table 2 presents selected proposed topics according to the ACM/IEEE-CS and the ACM/AIS curricula guidelines of the last decade. It should be noted that environmental sustainability was first introduced in the Computer Science Curriculum 2008 ACM / IEEE curricular guidelines as a topic into the elective course Economics of Computing. Since then, to the best of my knowledge, there have been no significant changes in the ICT curricula regarding the implementation of the proposals or guidelines related to sustainability. A possible explanation may be that although many courses in ICT curricula may contain material directly related to SD, this material may neither be clearly identified as such nor the faculty necessarily consider the relation of this material to SD (Steinfeld & Mino, 2009).

Therefore, a starting point to discover the possibilities for this engagement of the HEIs could be the examination of the current ICT curricula and map of what is already being implemented to support and contribute to the SDGs across all topics. Moreover, the HEIs could identify the potential synergies and collaborations across the different HEIs departments by participating in the SDGs. Some indicative aspects that could possibly require attention are

- the SD topics that the curricula *currently include*,
- *where* the SD could naturally fit into it, and
- where *″space″ could be found* to contain new SD material (Tilbury, 2016).

Table 2. The ACM/IEEE-CS and the ACM/AIS curricula guidelines related to sustainability

Curricula/Competency model	Curricula guidelines
Computer Science Curricula 2023 (ACM/IEEE) https://csed.acm.org/wp-content/uploads/2023/03/Version-Beta-v2.pdf	AI *Applications and Societal Impact* • Applications of AI to a broad set of problems and diverse fields, such as medicine, health, sustainability, social media, economics, education, robotics, etc. *Knowledge Unit 2* • Accountability and Responsibility in Design: Sustainability, security, privacy, trust, and ethics *Society, Ethics and Professionalism (SEP)/Sustainability* *Social, Legal, and Ethical Considerations for Game Platforms* • Sustainability: materials, power usage, supply-chain, recycling, planned obsolescence, etc.
A Competency Model for Undergraduate Programs in Information Systems IS2020 (ACM/AIS) https://dl.acm.org/citation.cfm?id=3460863	A3.3.3 *Emerging Technologies* Competency 5: Evaluate technologies from an ethical and sustainability perspective (Sustainability fundamentals) A3.5.1 IS *Ethics, Sustainability, Use and Implications for Society* Competency 5: Identify aspects of sustainability and adaptive systems and data (Sustainability of systems)
Computing Curricula 2020 CC2020 (ACM/IEEE-CS) https://dl.acm.org/citation.cfm?id=3467967	*Systems and Project Engineering* • Manage a project for an institution that requires the analysis of a system (software and hardware), including system requirements, both technical (including performance and functional requirements) and in terms of usability, suitability, and inclusiveness, taking a holistic perspective to craft specifications and evaluating reliability. *Ethics, Impacts, and Sustainability* • Apply sustainable system approaches by integrating multiple IT practices for a corporate environment in a manner that ensures personnel integrity and privacy. • Develop a policy concerning contracts usable within an enterprise or government that ensures health and safety standards in compliance with regulatory requirements and statutes for mutual benefit, irrespective of personal and cultural characteristics.
Global Competency Model for Graduate Degree Programs in Information Systems MSIS 2016 (ACM/AIS) https://doi.org/10.1145/3127597	*Competencies in the area of Impacts, Ethics and Sustainability* • Align IT with organizational sustainability policy. • Adopt sustainable approaches for IT solutions development, IT operations, IT procurement, IT resources management, and other IT practices.
Computer Science Curricula 2013 (ACM/IEEE) http://dx.doi.org/10.1145/2534860	*Human-Computer Interaction (HCI) and Software Engineering (SE) Knowledge* • Be a sustainable professional by considering environmental and cultural impacts of implementation decisions • Explore social, global, and environmental impacts of computer use and its disposal (e-waste) • Environmental impacts of design choices in specific areas such as databases, algorithms, networks, operating systems, or human-computer interaction • Guidelines for the design of sustainable standards • Research on applications of computing to environmental issues • The interdependence of the sustainability of software systems with social systems, including the skills and knowledge of its users, organizational policies and processes, and its societal context

Chapter 2 Rationale of the PhD Thesis

This chapter contains the rationale of the PhD Thesis. The overall purpose is presented, as well as the two primary studies, which constitute the PhD Thesis, are described along with the research objectives derived. Then, the complementary methodologies used in order to address the research objectives, along with the assumptions made, follow. The expected original contributions and the research outputs with the research ethics are listed next. The chapter concludes by listing the structure of the PhD Thesis.

2.1 Purpose of the Thesis

In view of what has been discussed and presented in the previous *Chapter 1*, the overall purpose of this thesis is to investigate and contribute novel and generalizable findings on the effects of embedding sustainability in ICT education in the Greek educational system, including the secondary as well as higher education in terms of the young people's broader consciousness of SD. The effects of embedding sustainability in ICT education will be investigated through two primary studies (Figure 3).

The first study, Study One, deals with the out-of-school or informal education in Greece. It aims to explore

- *the impact* of mobile transit apps in EfS among young people,
- *the potential* to foster environmental consciousness among them, and
- *the intention* to actively engage in sustainable traveling practices.

Concerning this first study, a review of some mobile apps and projects for sustainable urban public transportation is conducted. These apps have been selected based on their popularity, innovation, and committed support. From this perspective, gaps in their design and implementation have been explored and identified, and possible improvements and adjustments have been proposed. These proposals could be integrated into the existing apps in order to maximize their capability to be widely used in travelers' daily lives.

As a result, a novel, enriched theoretical and conceptual framework named *Eco Persuasive Mobile Application* (EPMA) is introduced. EPMA is based on the user's continuous feedback to support the evaluation of the user's behavioral travel change. Compared to existing frameworks that are used to assess this behavioral travel change, this active feedback is the new element of EPMA.

In this light, EPMA is used for the design of two prospective mobile transit apps:

[1] The first mobile app mockup, named *Education in Sustainable Travel urban behavior through mobile Applications* (ESTA), is presented and assessed by a group of upper secondary school pupils, the outcome of which is analyzed. The analysis takes into consideration the possibility of the daily use of ESTA in order for the young people to become more mindful of their environmental impact and to be educated about the incorporation of more sustainable practices in their daily lives.

[2] The second mobile app mockup, named Epma_App, is presented and evaluated by a group of university students. The evaluation explores the willingness of the participants to change their traveling habits toward more sustainable options and their intention to use Epma_App for this change.

The second study, Study Two, deals with the in-school or formal education in Greece and focuses on the secondary and higher levels. It aims to elicit the students' prior knowledge regarding sustainability issues, assess the effects of integrating ESD into ICT curricula, and explore their intention to deal with green informatics in Greece. Furthermore, it aims to investigate the contribution of education to the students' environmental awareness about energy conservation, attitudinal disposition, and e-waste management practices.

Study Two also aims to explore the necessity for redesigning and including sustainability issues into the ICT curricula in order to increase the students' sustainability consciousness and their environmental awareness. The study advocates the concept of sustainability integration into undergraduate ICT curricula and provides indications for developing ICT curricula that integrate sustainability issues. Furthermore, the study aims to offer insights into the challenge of the introduction of ESD in the HEIs in order to achieve the goals of the UN 2030 Agenda.

Moreover, it aims to analyze how these challenges could be addressed and records the essential principles that can guide the incorporation of sustainability into the ICT curricula.

In the following two sections, the rationale of the two studies and the corresponding deriving research objectives are presented in detail.

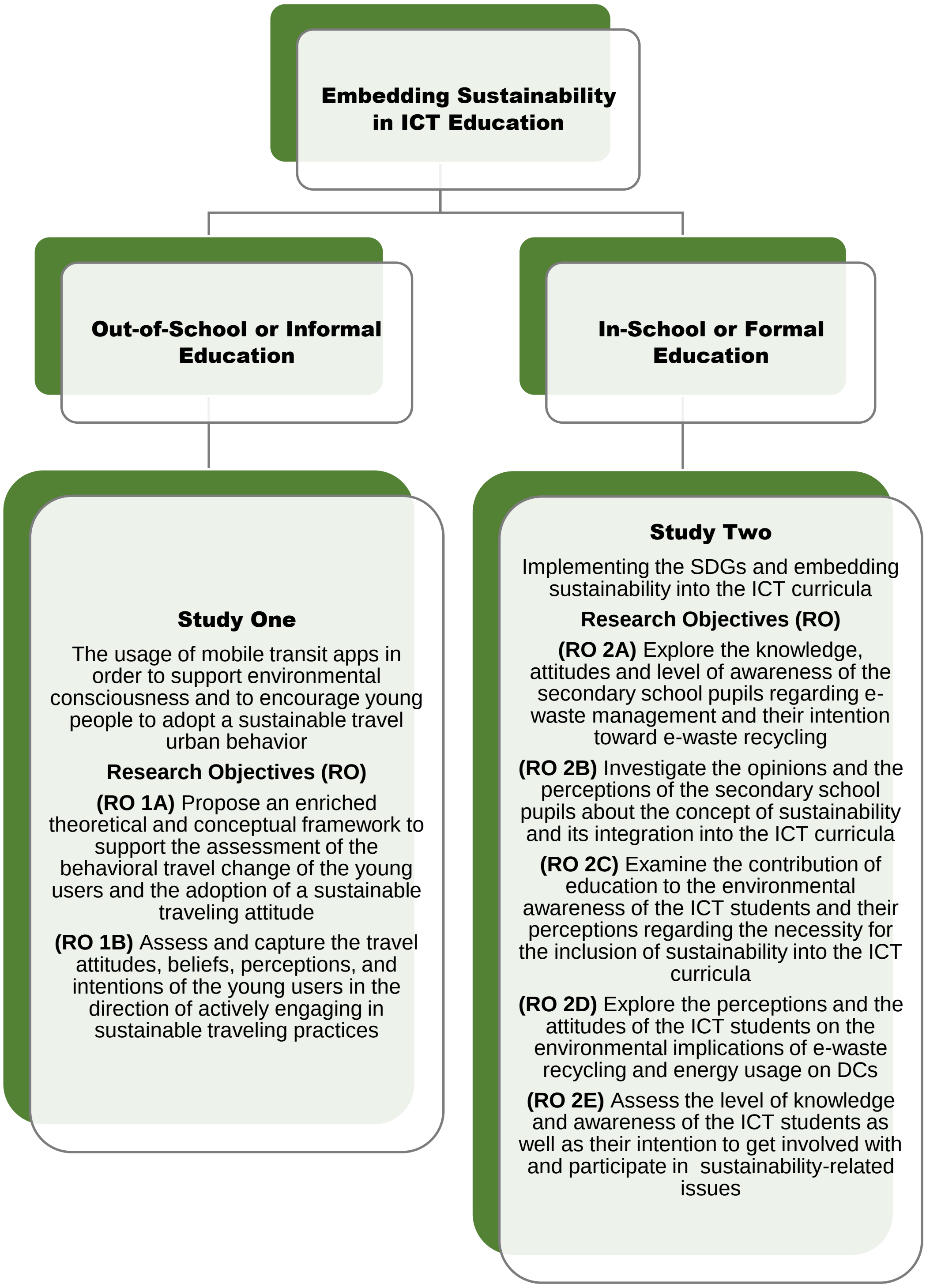


Figure 3. The dissertation outline in the form of two major studies and the corresponding research objectives

2.2. Rational and Research Objectives of Study One

As previously mentioned, ICT can promote sustainable urban mobility in various ways by changing travel demand, patterns, and urban forms. Study One only considers the ICT's potential effects on adopting a sustainable urban travel behavior of young people as they understand the subsequent environmental benefits and become conscious about sustainability issues.

Mobile electronic devices with integrated GPS receivers are increasingly popular in ESD as technology continues to advance. Mobile transit apps have emerged as a response to growing environmental concerns. These apps are designed to assist individuals in reducing their ecological footprint and in making more sustainable intermodal travel choices in their everyday lives. At their core, mobile transit apps integrate persuasive and motivational techniques in the direction of educating and empowering young users to embrace sustainable practices. By raising awareness about the impact of their actions on the environment, these apps intend to equip young people with the tools and knowledge needed to adopt greener habits.

Simultaneously, these apps are a constant reminder that even the smallest gestures can significantly impact the world around us without coercion but through persuasion and positive reinforcement. It should be noted, though, that the adoption of eco-friendly attitudes is a long-term process that depends on a variety of influencing elements: they may be perceived well by some people, but they may be ignored or rejected by others (Gabrielli et al., 2014). It has been well-documented that a traveling behavioral change may be initiated if the proposed alternatives are somehow advantageous and if the individual is genuinely willing to change (Piras et al., 2018).

In this direction, the existing literature claims that reward reinforcement is most effective when it occurs immediately after the desired behavior is performed (Fogg, 1997). Moreover, the shorter the time gap between the behavior and the presentation of the positive reinforcement, the stronger the connection. This immediate provision of incentives by the decision-makers with the cooperation of the local transport authorities and of the relevant private companies leads to the establishment of a desirable young people's eco-friendly travel behavior.

From this perspective, the most effective persuasive and motivational strategies depend on the individual user characteristics (such as the user's personality and affective stage) and on various existing attitudes, behaviors, knowledge, and goals (Masthoff & Vassileva, 2015). Recent studies combine behavioral change techniques and establish theoretical constructs from behavior theories and methodologies, aiming to develop various software applications in this research area (Bamberg, 2013; Cellina et al., 2019; Warren et al., 2018). Most of these studies propose the inclusion of behavioral change techniques in the design phase of these apps (Bamberg, 2013; Warren et al., 2018). Regarding this goal, theoretical frameworks that encompass multiple persuasive interventions by providing the means to explain the behavior change process have been proposed. (Andersson et al., 2018; Oinas-Kukkonen & Harjumaa, 2008; Perra, 2016; Reitberger et al., 2007; Zhao & Baird, 2014). These interventions, usually implemented in stages, may influence young people and lead them to sustainable mobile travel behaviors.

However, the existing literature (Anagnostopoulou et al., 2018a, 2018b; Sunio & Schmöcker, 2017) lacks a long-term process connected to the evaluation of the achieved behavioral effects and the impact of the persuasive methods applied in the change of the travel attitude. In addition, the presented evaluative studies of the mobile transit apps were conducted in relatively short time periods - most of them cover only a few months – with a relatively small number of users and within a limited global geographical spread. Besides, there is no clear evidence that these changes are long-lasting (Anagnostopoulou et al., 2017; Gabrielli et al., 2013; Piras et al., 2013;).

In order to support an assessment of the behavioral travel change of the young users and the adoption of a sustainable traveling attitude, *the first research objective of* ***Study One (RO 1A)*** *is to propose an enriched theoretical and conceptual framework* named Eco-Persuasive-Mobile-Application (EPMA). EPMA is based on the rewarded user feedback related to how this behavioral travel change affects the environment and the planning decisions for future sustainable mobility. EPMA takes into account various elements and stages from existing frameworks. Its major innovation lies in the introduction of a new element: the active feedback, which is derived from the user and is used for the assessment of the personalized persuasive strategy used.

To perform an initial assessment of EPMA regarding how it affects the environmental consciousness and the travel behavior of the young people toward the systematic use of sustainable transport modes, I built one mobile transit app mockup named *Education in Sustainable Travel urban behavior through mobile Applications* (ESTA) for use in pupils of secondary education and a second mobile transit app mockup named Epma_App for use with university students, both of which include motivational features. The purpose of creating these mobile app mockups was to embed the structure and the rationale of the EPMA framework within all the design elements of the apps in order to achieve an optimal software product design and a positive user experience. These mobile app mockups were evaluated using online questionnaires because of the restrictive measures implemented due to the COVID-19 pandemic. Considering this evaluation, *the second research objective of* ***Study One (RO 1B)*** *is to assess and capture the travel attitudes, beliefs, perceptions, and intentions of the young users in the direction of actively engaging in sustainable traveling practices.*

2.3 Rational and Research Objectives of Study Two

The ESD and the sustainable use of ICT products are considered crucial for young people to develop knowledge, skills, values, and ecological consciousness. Moreover, these elements are necessary for them to act as adults in ways that contribute to more sustainable living patterns (Chowdhury & Koya, 2017). Additionally, a consistent and combined use of digital technologies brings significant benefits to young people since they live immersed in a world where they are heavily involved in the use of smartphones and social networks.

From this perspective, it is even more critical to make young users conscious of the available options for their end-of-life electronic ICT devices and focus on each young user's crucial part in making circularity a certainty for these devices. Moreover, to promote ESD by means of e-waste recycling, environmental awareness for young people must be established as "the new generation" contributes considerably to the growth of electronic equipment consumption. For this reason, it becomes indispensable for this new generation to understand the importance of purchasing environmentally friendly green products and of participating in sustainable and responsible e-waste management (Ercan & Bilen, 2014).

Concerning secondary education, a number of studies until now have dealt with the results of e-waste recycling in the educational context. Most of the studies show positive results regarding the level of knowledge and the attitude change of the students (Dagiliūtė et al., 2019; Ercan & Bilen, 2014; Namusonga & Carter, 2020; So et al., 2019). However, some studies emphasize that although e-waste recycling increases the understanding of the importance of the environment in children, they do not report significant results in attitude change or action (Çakirlar et al., 2018; De Jager, 2015).

Furthermore, some results reveal that students involved in sustainability education follow more ecological rules but sustain a small percentage of their conservation attitudes in the future (Sammalisto & Lindhqvist, 2008). Therefore, the success of a sustainability project is considered very important. In this context, *the first research objective of* ***Study Two (RO 2A)*** *is via a two-stage sustainability/e-waste recycling project to explore the knowledge, attitudes, and level of awareness of the secondary school pupils in Greece regarding e-waste management and to investigate their intention for e-waste recycling.*

In parallel, it is crucial to introduce "sustainable" ICT curricula into secondary education. These curricula may include courses that (a) even though they are focused on a subject other than sustainability, they incorporate a module or a unit on sustainability or face a sustainability challenge, (b) include one or more sustainability-focused activities, and (c) integrate sustainability issues throughout the ICT course. Based on all the previously mentioned, *the second research objective of* ***Study Two (RO 2B)*** *is to investigate the opinions and the perceptions of the secondary school pupils in Greece about the concept of sustainability and its integration into the ICT curricula.*

In higher education, HEIs are called to embrace SD practices and yield a beneficial impact on the economic, social, and environmental activities of the community since they are not exempt from critical environmental concerns associated with sustainability (Chankseliani & McCowan, 2021). The HEIs can play a significant role in the education of the next leaders by contributing considerably to the transformation toward a sustainable society via (a) creating knowledge and (b) transferring this knowledge to society and preparing students for their future role in this society (Mohamed Hashim et al., 2022). Hence, the HEIs can play a critical role in achieving the SDGs, while they could also greatly benefit from engaging with them.

Gordon (2010) and Ceulemans et al. (2015) emphasize the importance and necessity of integrating the concept of sustainability in the curricula of all disciplines, including engineering and ICT. According to their findings, the inclusion of SD helps students to obtain an understanding on how their actions and decisions affect the environment and society. Nevertheless, there is no explicit agreement on the definition or the list of desired skills, competencies, or learning outcomes in ICT education for SD (Lim et al., 2022). In addition, there is little guidance on which courses and subjects should be included and how in this education.

However, although the urgent need for embedding sustainability issues in ICT curricula is evident according to the results from a survey of students in higher education around the world (SOS International, 2021), previous studies provide empirical evidence that sustainability is not yet taught as much as believed in the ICT education (Chaudhary & Dey, 2021; Mishra & Mishra, 2020). Nevertheless, to maximize the effects of the different ICT education initiatives for ESD, it is considered critical to understand the current perceptions of the ICT students regarding ESD and sustainability and their expectations about the integration of this subject into the ICT curricula and their own future contribution as professionals in their fields. (Machado et al., 2017).

For this reason, whether the ICT tools and ICT curricula that integrate sustainability subjects can contribute to ESD needs to be investigated. In this context, *the third research objective of* ***Study Two (RO 2C)*** *is to examine the contribution of education to the environmental awareness of the students at a Greek university and their perceptions regarding the necessity for the inclusion of sustainability into the ICT curricula.*

Simultaneously, interdisciplinary approaches in which several disciplines (e.g., environment, biology, medicine, geography, engineering, agronomics, architecture, nutrition, history, economics and business) work in an integrated way to these emerging environmental concerns related to green informatics (Annan-Diab & Molinari, 2017; Duarte et al., 2020) also denote the importance of the role of ESD in awareness. In addition, they underline the importance of shaping good practices among university ICT students, especially in e-waste and energy waste, since they serve as the primary generators of e-waste, and there has been a limited to no integration of these issues in university curricula. To this effect, research on the pro-environmental behavior, i.e., on the behavior in which individuals take protective actions toward the environment, either performed in public (e.g., participation in environmental activities) or private domains (e.g., recycling) (Krajhanzl, 2010) is becoming increasingly crucial in solving environmental issues and reaching SDGs.

The literature asserts that the effectiveness of e-waste management is contingent upon the presence of students' awareness and accessibility to recycling facilities (Islam, 2021). There are several studies that examine the knowledge, attitude, and perceptions of the students regarding e-waste management and their familiarity with key environmental legislations, policies, and standards (Edumadze et al. (2013; Yushkova & Feng, 2017; Zhang et al., 2019). Nevertheless, there is a general lack of students awareness regarding the proper disposal of e-waste, and existing rules are inadequate in promoting the e-waste recycling. The predominant method of e-waste disposal, known as informal disposal systems, is characterized by a lack of consideration for environmental impact. Moreover, students have limited knowledge of the locations where e-waste is disposed of.

In addition, there is a gap in the literature regarding the effect of integrating environmental education issues, such as e-waste recycling practices, into the ICT university curricula on the sustainable behavior of the students (Ramzan et al., 2019; Yadav & Pathak, 2016). Furthermore, a recent systematic literature review also emphasized the absence of thorough studies on ICT students' understanding of e-waste and its disposal procedures in developing nations, particularly in South Asia (Gilal et al., 2022). This gap in the existing body of research suggests a necessity to investigate the level of awareness among ICT students regarding e-waste and their disposal methods. Such an exploration would yield detailed and specific findings that are relevant to particular groups, so contributing to the development of effective policies.

At the same time, students frequently lack awareness regarding the energy use in DCs and the possible cost reductions that can be achieved with the utilization and control of renewable energy usage (Nowotny et al., 2018; Ntona et al., 2015). Hence, it is imperative to ascertain efficacious approaches for students engagement that facilitate the embracement of sustainable behaviors and the reinforcement of these patterns. There is a dearth of studies regarding the knowledge of the students and their level of awareness of the energy usage of DCs in HEIs. Furthermore, there is a widespread recognition that the dedication of younger generations has the potential to inspire adults to decrease energy use and shift to renewable energy through the promotion of awareness and the pursuit of long-term outcomes (Rodgers, 2021).

In order to fill this literature gap, *the fourth research objective of* ***Study Two (RO 2D)*** *is to explore the perceptions and the attitudes of ICT students on the environmental implications of e-waste recycling and energy usage on DCs. The fifth research objective* ***(RO 2E)*** *is to assess the level of knowledge and awareness of the ICT students as well as their intention to get involved with and participate in these sustainability-related issues.* For this reason, this PhD Thesis advocates that the e-waste recycling practices of ICT students might be sustainable if they are conscious of their interaction with the environment and aware of environmental policy issues related to their studies.

2.4 Methodologies and Tools Used to Address the Research Objectives

During the process of conducting the PhD Thesis, several methodologies and tools combining quantitative and qualitative approaches in an interdisciplinary context were used in order to address the research objectives. Table 3 presents these methodologies and tools, the reasons why they were selected to support this Thesis, as well as the corresponding research objectives to which these methodologies and tools have been applied.

Table 3. Methodologies and tools used to address the research objectives of the PhD Thesis and their justification

Methodology or tool to address the research objectives	**Purpose**
Literature review	Development of the background for the research, the problem identification, and the development of the proposed frameworks and the assessment questionnaires (RO 1A, RO 1B, RO 2A, RO 2B, RO 2C, RO 2D, and RO 2E)
Prototyping tool for mobile apps (Justinmind)	Design and creation of simulation screens for testing and iteration of a mobile transit app in order to get a sense of what is working and what needs improvement (RO 1B)
User-centered design system	Thorough exploration of the needs and desires of the users, as well as the intended uses and expectations of the transit mobile app being developed (RO 1B)
Surveys performed with assessment questionnaires and assessment rubrics to evaluate mobile transit app reports (MS Word, Google Forms)	Collection, determination, and validation of data on students' perceptions, travel attitudes, and level of satisfaction using mobile transit apps and on students' ICT sustainability competencies developed during educational interventions (RO 1B, RO 2A, RO 2B, RO 2C, RO 2D, and RO 2E)
Use cases for a mobile transit app	Demonstration of the potential positive contribution of a mobile transit app for supporting the sustainable mobile traveling attitude of a student (RO 1B)
Case studies (using brainstorming, project-based learning, personalization of learning, collaborative learning, interdisciplinary instruction, personalized assessment, and active learning techniques)	Educational interventions in the university and in the high school to assess the development of sustainability competencies in ICT education in learners (RO 2A, RO 2B, RO 2C, RO 2D, and RO 2E)
Quantitative analysis of data and visualization of results (tables and figures) from surveys and other assessment tools using appropriate software (IBM SPSS, MS Excel)	Assessment of the validity and of the reliability of the assessment measures developed and the effectiveness of educational interventions in the environmental awareness of ICT students and the integration of sustainability issues into the ICT curricula (RO 1B, RO 2A, RO 2B, RO 2C, RO 2D, and RO 2E)

2.5 PhD Thesis Assumptions

For the implementation of this PhD Thesis, some assumptions had to be made in order to begin the research and development process:

[1] Mobile technology can create exciting and effective learning environments for learning and education at every age and has the potential to support ESD and encourage young people to adopt choices toward greener habits (RO 1A and RO 1B).

[2] The alignment of skills and expected learning outcomes to SD can be assessed by evaluating the extent to which they cover sustainability issues and attributes in the educational community (RO 2A and RO 2B).

[3] The SDGs can provide a practical normative framework for schools and HEIs to decide in a participatory way the sustainability competencies that they should develop in order to achieve their vision of SD (RO 2C, RO 2D, and RO 2E)

[4] The learners can develop sustainability competencies if the appropriate pedagogies and assessments aligned to SD vision are provided and are in place (RO 2A, RO 2D, and RO 2E).

[5] The e-waste recycling practices of ICT students can be sustainable if they are conscious of the feedback from their interaction with the environment and aware of environmental policy issues related to their studies (RO 2A, RO 2D, and RO 2E).

[6] The results collected through the assessment of sustainability integration into ICT curricula can aid decision-making in the reorientation of these curricula, the teaching methodology, and the pedagogy development (RO 2B and RO 2C).

2.6 Expected Original Contributions and Research Outputs

This PhD Thesis aims to contribute theoretical support of what should be the role of ICT in ESD and to provide explanatory research answers for the potential of ESD in terms of empowering learners with sustainability competencies in relation to ICT. In addition, it provides empirical evidence on the effectiveness of the educational interventions regarding ICT sustainability issues in schools and HEIs. It also recommends that integrating sustainability into different pedagogical approaches must be a key priority in education for future research initiatives.

Furthermore, this PhD Thesis advocates that equipping young people with knowledge, understanding, and skills related to ICT sustainability competencies leads to an improved understanding of unresolved environmental problems and can potentially provide the change needed and create a real impact in the journey of the next generations to a sustainable future.

More specifically, the following are the original contributions of this PhD Thesis:

- An innovative, enriched theoretical and conceptual framework named EPMA for the development of a persuasive prototype for supporting and evolving the individual's behavioral traveling attitude through mobile phone use for sustainable urban mobility purposes.
- A mobile app mockup named Epma_App. Epma_App, which embeds the functionality of EPMA and includes a set of features specifically designed to support the users/students in each stage of their travel behavior change.
- A prospective travel mobile app mockup named ESTA, which integrates a novel combination of motivational features in order to educate young people/pupils and raise their awareness to become more mindful of their environmental impact, as well as to adopt a sustainable travel urban behavior progressively.
- An innovative conceptual model for integrating ESD in a smart classroom learning environment, which implies that the integration of the sustainability educational part needs a holistic approach related to the classroom (educational program, teaching methods, and infrastructure).
- Recommendations that will assist schools to adopt a sustainable school approach, which emphasizes the redesign and the reorientation of ICT curricula, the pedagogy and assessment methods transformations, and the policymaking in enabling the integration of ESD into educational programs.

- The mapping and the delimitation of the global research trend regarding the challenges faced by HEIs in their effort to support the transformations required to achieve the SDGs and, more specifically, the integration of sustainability issues into the ICT curricula.
- An experimental validation of the effect of ESD on the involvement and engagement of upper secondary school pupils and ICT students in sustainability for the support of the main idea of this Thesis: the integration of sustainability into ICT curricula in secondary education and HEIs in Greece.

Appendix A presents in detail the produced research outputs of this PhD Thesis:

- One published book chapter.
- Five published papers in reputable peer-reviewed journals indexed by the Web of Science master journal list by Clarivate.
- Five published papers in peer-reviewed proceedings of international conferences.

Furthermore, one more produced output is the development, the presentation and the evaluation of four independent "green informatics" modules for the Computer Networks undergraduate course at the Department of Informatics of the University of Piraeus in Greece during two lectures, namely

- module 1, entitled *Green Informatics Introduction*,
- module 2, entitled *Energy Saving*,
- module 3, entitled *E-waste*, and
- module 4, entitled *Energy Consumption in Cloud Computing Data Centers*.

2.7 Research Ethics

As part of this PhD thesis, the surveys data from undergraduate students at the University of Piraeus and from upper secondary school pupils were collected and analyzed to support the research objectives. According to guidance provided by the Hellenic Ministry of Education, Religious Affairs and Sports and the Department of Informatics of the University of Piraeus, the appropriate steps were taken to ensure compliance with the ethical and the experimental considerations of this research. As this research involves the participation of human subjects and handling their data, every effort has been made to ensure compliance with the ethical standards and procedures, including data handling under the General Data Protection Regulation (GDPR) of every educational institution involved.

The pupils were given participant information sheets and informed consent forms to complete before entering the study. In order to take part in the survey, each underaged pupil's parent had to sign a parental consent form. The university participants were informed that they could withdraw at any point in the study without this having an adverse effect on their relationship with the university and the researchers. The participants were recruited through the formal teaching procedures in the Department of Informatics of the University of Piraeus and through my official work as an upper secondary ICT and Math teacher in a school in Greece. The data collected were anonymous, and participant confidentiality was maintained throughout the duration of the research. Data were held in accordance with the strategy and the ethics and good practice code of the University of Piraeus (www.unipi.gr) and were used for publications and conference presentations.

2.8 Structure of the Thesis

Each chapter includes an introduction that contains a literature overview of the concepts analyzed, the methodology that was followed, the results of the findings, along with a discussion in relation to the research objectives as well as the limitations identified and ways to overcome them.

Chapters 3, 4, 5 and *6* provide a thorough and detailed description of Study One, which deals with the out-of-school or informal education in Greece related to the education, the engagement and the support of young people in sustainable travel urban behavior through the use of a mobile transit app which embeds motivational features. More specifically:

Chapter 3 provides to Study One the advantage of efficiently recognizing the potential capabilities offered by mobile transit apps and selecting the most significant and preferred aspects for the development of an ESD-focused mobile transit app. For this reason, this approach reviews several mobile transit apps and projects for sustainable urban mobility, which have been selected based on their popularity, innovation, and committed support. The review has been implemented from the perspective of two dimensions: type of service and provision of incentives for changing travel behavior. At the same time, gaps in the design have been identified, and improvements and adjustments have likely been proposed to maximize the capability to integrate mobile apps and widely use them in the traveler's daily life.

Chapter 4 describes the five stages of an innovative theoretical framework named Eco-Persuasive-Mobile-Application (EPMA) for the development of a persuasive prototype for supporting the assessment of the behavioral travel change of the young users and the adoption of a sustainable traveling attitude. This framework can be implemented in well-designed persuasive mobile transit apps for sustainable urban mobility purposes in order to contribute to ESD. EPMA emphasizes the importance of engaging and committing users to improve their travel habits through continuous motivation and evaluation of both how their traveling habits affect the environment and how they contribute to better future mobility planning decisions. At the same time, EPMA takes into consideration various elements from existing frameworks and introduces a critical stage, that of the users' rewarded assessment/feedback, based on the daily evaluation of the app's effectiveness to persuade the user to move in an eco-friendlier way.

Chapter 5 describes the user-centered design process that a mobile app's design is based on. This app is used for secondary education purposes, aiming to educate young people to become more mindful of their environmental impact. To this effect and taking into consideration the proposed EPMA framework in *Chapter 4*, existing persuasive strategies are adopted, implemented, integrated, and presented in six simulated screens of a prospective mobile app named ESTA, which was designed for this purpose. Secondary education pupils then assess these screens, the outcome of which is analyzed and presented next. Moreover, the potential of ESTA is demonstrated via two use cases: the "Daily Commuting" case deals with the pupils who want to move within their area of residence/neighborhood following their daily routine of activities, while the "Weekend Entertainment" deals with the pupils who want to move using the public transport modes and is being encouraged toward greener weekend travel habits.

Chapter 6 presents the implementation of seven simulation screens in a second mobile transit app mockup named Epma_App, which also embeds the functionality of the EPMA framework. Epma_App is used for higher education purposes. Afterwards, students' results of the Epma_App assessment are provided in detail. The assessment has as a primary goal to capture the attitudes and the perceptions of the students related to whether they are willing to change their traveling habits and use a transit app in their daily routine for this purpose. The potential positive contribution of Epma_App for supporting the sustainable mobile traveling attitude of the students is demonstrated via two use cases: the "Exploration" case is addressed toward a student who may use the public transport modes or hire a taxi instead of taking the subway for sightseeing, while the "Movement" case is addressed toward a student who either intends to go to work or move within the area of residence.

Chapters 7, 8 and *9* provide a thorough and detailed description of Study Two, which deals with the in-school or formal education in Greece related to the education and the engagement of the students in sustainable practices by integrating SD education into the ICT curricula. More specifically:

Chapter 7 presents a conceptual model for integrating ESD in a smart classroom learning environment. This environment may support the education that enables a more sustainable society for all the students and actively promotes the cultivation of the students' environmental awareness. The model, which has the students and the teachers at its center, consists of four core components, namely the infrastructure, the sustainability content, the evaluation, feedback, and the motivation. Furthermore, the proposed model implies that the integration of the sustainability educational part needs a holistic approach related to the classroom (educational program, teaching methods and the infrastructure) instead of adding supplementary topics or themes on sustainability into an existing curriculum or educational projects that a smart classroom may offer.

Chapter 8 deals with the introduction of ESD in upper secondary education and the engagement of the pupils in sustainability-based learning in order to become environmentally conscious young people. It presents the results based on the pupils-generated data collected from two studies that were conducted in an ICT course in Greece, taking into consideration the proposed conceptual model in *Chapter 7*. The first study is related to green informatics and the integration of sustainability into the ICT curricula, while the second is related to e-waste management and recycling. The studies highlight the need for redesigning secondary education curricula in order to increase sustainability and for raising environmental awareness among young adults through e-waste recycling to achieve environmentally-related skills, behavior, and attitudes consistent with SD and the protection of the planet.

Chapter 9 presents the challenges of the introduction of ESD in HEIs, analyzes how these challenges could be addressed, and records the essential principles that can guide the incorporation of SD education in higher education. At the same time, it advocates the concept of sustainability integration into undergraduate ICT curricula and provides indications for developing ICT curricula that integrate sustainability issues. Moreover, *Chapter 9* examines the contribution of education to the environmental awareness of the ICT students at a Greek university. At the same time, it captures their perceptions regarding the necessity for the inclusion of sustainability, energy conservation, attitudinal disposition, and e-waste management practices into the ICT curricula. The results are based on the processing of two questionnaires (pre-test and post-test data) distributed during two lectures regarding sustainability at a two-week interval.

Chapter 10 is dedicated to a critical analysis and discussion of the previous chapters in relation to the overall purpose and the research objectives of the Thesis. An attempt is made to synthesize the findings and make concrete recommendations regarding the challenges faced by secondary and higher education in order to support the transformations required to achieve the SDGs. Moreover, in *Chapter 10,* ways are suggested that can prove meaningful for educators and learners as well as for policymakers in their efforts to integrate sustainability issues into the ICT curricula. The weaknesses and limitations of the studies, as well as perspectives for future research, are also presented.

Part B

Study One – ESD in Out-of-School or Informal Education

Chapter 3 – Mobile Apps and Projects for Sustainable Urban Public Transportations

This chapter explores the potential capabilities and identifies key aspects of the mobile transit apps for ESD-focused support and implementation. The features of the mobile transit apps are listed. The strategy for a selective review of mobile transit apps and projects based on popularity, innovation, and committed support is analyzed. The presentation of the primary services provided by these selected mobile apps and projects, the identified gaps in design, and improvements proposed for widespread application follow next. The chapter concludes by listing suggestions and future directions.

3.1 Introduction - Features of the Mobile Transit Apps

A large number of tools and methods - including guidelines, software, manuals, mobile apps, games and simulators - have been developed, and a plethora of research and development projects have been undertaken in order to facilitate and simplify the new mobility services. These services include vehicle sharing, advanced transport services, and payment methods through integrated platforms – the so-called *Mobility as a Service* (MaaS) approach. The main focus of these tools and methods is the process of managing the vast amount of transport/mobility data derived from the daily smartphone use for transportation purposes within the development and evolution of urban mobility (Söderberg et al., 2018).

Smartphones offer the opportunity for developing apps to incorporate services from various areas, such as roadside assistance and real-time information for passengers, notification of delays, traffic jams, route changes, protection of "vulnerable" drivers (two-wheeled or pedestrians) and single ticket or personalized cards for all public transport. A mobile transit app should provide a high-quality user experience while facilitating the information-searching process and convincing potential travelers-users of the appropriateness of the proposed services (Bothos & Mentzas, 2013).

Furthermore, it should aim to maximize the user's motivation in fostering the adoption of an environmentally friendly mobility behavior (Perra, 2016), thus supporting the education of young people in sustainable-related travel practices. The development of such a mobile transit app requires that designers and transport stakeholders take into consideration the following features and components:

- *Fare information:* The users of the mobile transit apps should be able to calculate the cost of their trip and access information about ticket pricing, passes, and discounts. In addition, mobile ticketing enables users to purchase and store digital tickets or transit cards on their smartphones for easy payment.
- *Habits in transportation behavior:* The developers of the mobile transit apps should adequately consider the role of habits for understanding human behavior, e.g., the primary transport user's mode, the most frequently used routes, stops, and destinations for quick access must be included.
- *Persuasive strategies:* Mobile transit apps should also include persuasive strategies aiming to induce the systematic use of sustainable transport modes (Anagnostopoulou et al., 2018b). Common persuasive strategies used for this purpose are goal setting, provision of incentives or rewards, self-monitoring, sharing information, and gaming. Special attention should be paid to situations where computer-mediated persuasion takes place without the user being aware of it. This persuasion may happen when people who create, distribute, or adopt the technology are the ones who have the intention to affect the user's attitudes or behavior through computers, e.g., discussion

forums, emails, instant messages, blogs, or social networks (Oinas-Kukkonen & Harjumaa, 2008).

- *Real-time information:* In smart city contexts, these mobile transit apps should be integrated with the urban infrastructure and a variety of data sources and should provide real-time updates on public transportation schedules, availability of shared mobility options (e.g., bike-sharing, ride-sharing), traffic congestion, and air quality (Chowdhury & Ceder, 2016). This information empowers users to make informed decisions that contributes to reduced traffic congestion and air pollution. Moreover, mobile apps should offer real-time trip planning and navigation assistance for various sustainable transportation modes. They should suggest optimal routes, estimate travel times, and even calculate the carbon footprint of different travel options, helping users choose the most eco-friendly route.
- *Route planning:* Mobile transit apps should offer route planning for various transportation modes, highlighting the most eco-friendly options. They should consider factors like distance, time, cost, and environmental impact, guiding users to choose sustainable travel routes. At the same time, mobile transit apps should analyze users' travel patterns and preferences to provide personalized recommendations for sustainable transportation options (Vlassenroot et al., 2015). These recommendations should be tailored to individual needs and lifestyles.
- *Gamification:* Mobile transit apps should make the learning process more engaging and motivating by gamifying sustainable travel behaviors by providing information, entertainment, and interactive games for contributing to the reduction of the "waiting and travel time" perception of users (Gupta et al., 2022). Furthermore, users could earn rewards, badges, or points for using sustainable transportation modes or public transport, walking, or cycling, fostering a sense of achievement and competition among users (Gebresselassie & Sanchez, 2018). In this way, these gamification elements can motivate users to adopt greener travel behaviors.
- *Carbon footprint tracking:* Mobile transit apps should allow users to track their carbon footprint based on their transportation choices. By visualizing the environmental impact of their actions, users may be more inclined to adopt sustainable behaviors and reduce their carbon emissions (Sunio & Schmöcker, 2017). These apps should provide insights into how the users' travel choices contribute to their overall carbon footprint and offer options to offset emissions through various means.
- *Community engagement and social sharing:* Mobile transit apps should facilitate community engagement by enabling users to share their sustainable travel experiences, tips, and success stories related to eco-friendly transportation options (Andersson et al., 2018). This engagement fosters a sense of belonging to a more significant movement, encourages peer-to-peer learning, and creates a sense of community among users who are interested in sustainable travel.
- *Incentives and Discounts:* Many mobile transit apps should collaborate with businesses, local governments, and organizations to provide incentives like discounts, vouchers, access to exclusive events, reduced fares for public transport users or special offers for cyclists and walkers. These incentives further encourage sustainable choices for the users who choose sustainable transportation options or participate in community events (Kamargianni et al., 2015).
- *Data Collection and Analysis:* Mobile transit apps should collect data on users' travel patterns, preferences, and behavior changes (Piras et al., 2018). Analyzing this data can help urban planners and policymakers make informed decisions about infrastructure improvements and policy changes.
- *Interactive Challenges:* Mobile transit apps should create interactive challenges and campaigns that encourage users to adopt sustainable travel behaviors for a specific period. For example, a "Car-Free Week" challenge could enable users to use alternative transportation modes for a week for free (Arnott et al., 2014).
- *Feedback and Suggestions:* Users should receive relevant feedback about the progress toward adopting more sustainable practices and personalized suggestions/messages and rewards by collecting green credits/points, which will be used for discounts based on their travel behavior. This information helps users

understand how their actions contribute to positive environmental outcomes over time and identifies areas for improvement.

The mobile transit apps that incorporate some of or all the features mentioned above can be used as a part of educational programs focused on sustainability and environmental awareness. Educators can emphasize the potential benefits of using public transportation in order to reduce the carbon footprint. Furthermore, another potential benefit of the transit apps' daily use is the continuous improvement of transportation efficiency and the increased user safety (Siuhi & Mwakalonge, 2016). Efficiency can be achieved by taking into account the needs and the priorities of the users in parallel to the real-time traffic and road conditions, thus reducing travel time (Pender et al., 2014), cost and vehicle emissions and increasing the health benefits. Safety can be accomplished by providing drivers with helpful information about road conditions, including collision warnings and road sign alarms (Vahdat-Nejad et al., 2016).

In order to manage this modern transport ecosystem, the region covered by the app must be equipped with the appropriate roadside and network infrastructure along with the availability of various transport modes. This envisioned final integrated system would allow users to travel comfortably without owning a car (or minimally using a private car), and it should entice them to quit a car-dependent daily trip (Li & Voege, 2017).

3.2 The Strategy for a Selective Review of Mobile Transit Apps and Projects

At present, there is a remarkable number of free multimodal mobile apps and projects on the market or under development all over the world. Their main objective is the efficient and seamless integration of all the transport modes (motorized and non-motorized, public transport, and flexible services such as transport on-demand) and mobility sharing schemes (car sharing, motorbike sharing and carpooling). This Thesis reviews 15 of them. The selection of these specific apps and projects has been based on the following factors, which the selected apps satisfy to varying degrees:

- *Popularity.* The keywords that were used in the search across the Apple App Store (apple.com/app-store/), the Google Play Store (play.google.com/store), and the Microsoft Store (microsoft.com/en-us/store/apps/windows) were: highest rated apps, popular apps, the most used and the most downloaded apps.
- *Innovation.* Apps and projects that either have a particular feature (reward system for promoting eco-mobility and transit behavior change) or address a modern transportation challenge (MaaS), or both.
- *Their support* from major funding research organizations, such as the European Union's Horizon 2020 research and innovation program.

This review takes into account the perspective of two dimensions; *the type of service* (A) and *the provision of incentives* (B), which are presented analytically in the following:

A. Type of the most commonly used or popular service offered by the app, including the Mobility as a Service (MaaS) scheme:

- *User profile and preferences* - via filling forms - and saving favorite locations or routes for active recommendations and suggestions according to the user's needs (Vlassenroot et al., 2015).
- *Modes of transport* including public, private, and shared with the location of stations (bus, metro, etc.) (Kamargianni et al., 2016); timetable information, itineraries, and schedule; available parking places and bike-sharing stations (Aguilera & Boutueil, 2019).
- *Route advice and live step-by-step directions* for providing guidance about the best route from one place to another, including fixed or real-time information about traffic, service status, arrival or departure time, and stops that are left. The routes can be selected based on various criteria, such as the shortest route. Intermodal journey planners that combine all the transport options to find the fastest route along with travel times and potential alternative choices (Chowdhury & Ceder, 2016).
- *Traffic congestion alerts, accident reports, and notifications* about the delays or disruptions of a line. Moreover, feedback possibility by reporting traffic incidents, road

hazards, and transport mode conditions (driver behavior, cleanliness), thus providing the capability of rating the app and sending feedback (Siuhi & Mwakalonge, 2016).

- *Surrounding points of interest* by allowing the user to explore a location or a potential destination and show them filtered through categories. Points on the map can be included in route requests (Vahdat-Nejad et al., 2016).
- *Ticket price information* for public transport, taxis, tolls, and car parking (Kamargianni et al., 2016).

B. Provision of incentives by the decision makers, with the cooperation of the local transport authorities and private companies, for changing travel behavior to promote an eco-friendlier transit attitude and healthier way of living, consisting of:

- *Fitness information* about the number of calories a user will consume by walking or cycling (Kamargianni et al., 2015).
- *Energy efficiency calculations* by providing information related to the energy consumption of the various journey options in order to show "greener" transport decisions (Anagnostopoulou et al., 2018a).
- *Points collection* based on how the traveler chooses to travel/move, giving more points for eco-friendly and more efficient methods and offering rewards like gift cards to favorite stores and restaurants or planning-trees programs (Gebresselassie & Sanchez, 2018).

Taking into consideration all the possibilities as mentioned above and the capabilities that an app could offer, we can point out that mobile apps may change the urban public transportation into two main fields: the immediate travel-related information provided on the move and the new mobility services based on the sharing of vehicles. This change will result in a "fully-featured" trip with a technology and mobility combination that starts with the trip planning, continues with the implementation in different stages, and ends with the passengers' arrival at the expected destination.

3.3 The Mobile Transit Apps and Projects

The mobile apps and projects under review are alphabetically presented in Tables 4 and 5. All the information included has been derived from the respective official app store pages and/or the apps' and projects' official websites. Based on this general overview, one may realize the considerable potential of these apps in the transportation area and the significant support that they could provide to individual travelers for moving in a more efficient, eco-friendly and sustainable lifestyle. The remarkable number of services offered (i.e., saved user profile and preferences, route advice with live step-by-step directions, accurate time estimation about the travel's mode arrival or departure time, traffic congestion alerts, etc.) lead to a better understanding of how these apps could dynamically facilitate many inexpensive and eco-friendly transport options. They also provide an alternative to private car usage and single-occupancy vehicle trips.

At the same time, passengers take advantage of integrating shared mobility into regional multimodal transportation planning as well as into the growing trend of micro-mobility. This trend refers to short-distance transport - usually less than 5 miles – using electric scooters and docked and dockless shared bikes. Therefore, these modes have already been included in the majority of the apps for improving congestion, complementing public transportation, and reducing individuals' carbon footprints.

Table 4 shows that the apps that operate for free in a vast number of cities and different languages have more installations than others. This global coverage assists the extensive range of the app and increases the possibility of expanding and enriching it with new features and services according to the users' priorities and needs. For this reason, online feedback, based on the evaluation derived from the users' daily perception via questionnaires, may contribute to this goal and should be included as a service in every app. At the same time, this feedback could help the app developers verify the functionality of the app's features by the users and make the necessary interventions.

The small number of an app's installation base may indicate that it either covers a few areas or that it is in a beta use for scientific and research purposes (project) with limited functionality. Many projects aim to deliver advanced state-of-the-art solutions, and thus, they begin with high expectations about the potential of the outcome and the continuous provision of valuable information and transit services. In the end, though, platforms usually fail to be embedded by public or private transport operators, and they stop being operational. This is a point that researchers and projects designers should carefully consider and be prepared to address it in the very early stages of design and planning.

Table 4. General overview of mobile transit apps and projects

Name	Platform / Operating System	Status (O)perational Or (C)losed / Year	Cities	Website / Installations	Cost
Citymapper	PC + MA* / Android & iOS	O / (2011-)	86+	citymapper.com / 10,000,000+	Free
Google Maps	PC + MA* / Android & iOS	O / (2008-)	220+	google.com /maps / 10,000,000,000+	Free
HERE WeGo	MA* / Android & iOS	O /(2012-)	110+	wego.here.com / 10,000,000+	Free
IMOVE	P** - EU Horizon 2020	C / (2017-2020)	5	imove-project.eu	-
incenTrip	P** - MA* / Android & iOS	O / (2018-)	2	incentrip.org / 1000+	Free
MaaS4EU	P** - EU Horizon 2020	C / (2017-2020)	17	maas4eu.eu	-
GoEzy	MA* / Android & iOS	O / (2015-)	5	https://www.metropia.com /goezy-app / 100+	Free
MOMENTUM	P** - EU Horizon 2020	O / (2019-2022)	13	h2020-momentum.eu	-
Moovit	PC + MA* / Android & iOS	O / (2012-)	107+	moovit.com / 50,000,000+	Free
MyCorridor	P** - EU Horizon 2020 – MA* / Android & iOS	C / (2017-2020)	20	mycorridor.eu / 50+	Free
SETA	P** - EU Horizon 2020 – MA* / Android & iOS	C / (2016-2019)	3	setamobility.weebly.com	Free
Sygic	MA* / Android & iOS	O / (2004-)	63+	sygic.com/50,000,000+	With charge
Transit	MA* / Android & iOS	O / (2012-)	300+	transitapp.com / 10,000,000+	Free
TripGo	PC + MA* / Android & iOS	O / (2012-)	200+	skedgo.com/tripgo / 100,000+	Free
Whim	MA* / Android & iOS	O / (2016-)	7	whimapp.com / 100,000+	With charge

* Mobile App
** Project

Table 5 shows that all the apps and projects are addressed to all the user types, while the majority of them cover many different public transport modes (conventional and new schemes). Concurrently, there are services common in all the apps that encourage the use of several modes (multimodal) and different modes (intermodal) within a single trip. However, in a significant number of apps, there is a certain lack of notifications about available parking places. These notifications are necessary to obtain more sustainable cities in the future, as traffic congestion and searching for parking spots may increase environmental pollution. This pollution happens due to the increase in fuel consumption, which, in turn, results in an increase in CO_2 emissions and harmful gases (Al-Turjmana & Malekloob, 2019).

At the same time, the provisions, i.e., the fitness information or the rewards, for motivating passengers to permanently quit their individual mode of transport (car) in favor of public means, are not offered as services as well. This transition from a self-directed stage to a habitual stage is fundamental for the viability, usability, and popularity of the app. To achieve this transition, common persuasive strategies and techniques (e.g., goal setting, personalized notification about CO_2 emissions consumption, self-monitoring, sharing information, cause-and-effect simulation, suggestions, and feedback (Gabrielli et al., 2014) should be applied to complete the change process and to reduce the risk of relapse into the old travel habits.

Table 5. Type of service and provision of incentives for changing travel behavior

Name	Type of service									Provision of incentives for changing travel behavior		
	User profile and preferences	Modes	Available parking places	Route advice / Journey planner	Congestion and accidents	Point of interests	Feedback	Ticket price information	MaaS	Fitness information	CO_2 consumption	Rewards
Citymapper	•	Public, Car-Bike Sharing, E-scooters	Bike	•	•	-	•	•	•	•	-	-
Google Maps	•	Public, Taxi, Car-Bike Sharing, E-scooters	•	•	•	•	•	Uber Lyft	-	-	-	-
HERE WeGo	•	Public, Taxi	-	•	•	-	-	•	-	-	-	-
IMOVE	•	Public, Taxi, Car-Bike-Scooter Sharing	-	•	•	-	-	•	•	-	-	-
incenTrip	•	Public, Car-Bike Sharing	-	•	•	-	-	-	-	-	-	•
MaaS4EU	•	Public, Car, Bike	-	•	•	-	-	•	•	-	-	-
GoEzy	•	Public, Carpooling, Uber, Lyft	-	•	•	-	•	Uber Lyft	-	-	-	-
MOMENTUM	•	Public, E-Bike, E-Scooter	Bike, Scooter	•	•	-	-	•	•	-	-	-
Moovit	•	Public, Bike Sharing, Uber, Scooter	Bike, Scooter	•	•	•	•	•	•	-	-	-
MyCorridor	•	Public, Car Sharing	-	•	•	-	•	•	•	-	-	•
SETA	•	Bus, Bike	Bike	•	•	-	•	-	-	•	-	•
Sygic	•	Car, Walking	•	•	•	•	•	-	-	-	•	-
Transit	•	Public, Uber, Bike-Scooter Sharing	Bike, Scooter	•	•	-	-	•	-	-	-	-
TripGo	•	Public, Taxi, Car-Bike Sharing	-	•	•	-	-	-	-	-	•	-
Whim	•	Public, Taxi, Car-Bike Rental/Sharing	•	•	-	-	-	•	•	-	-	-

We also observe a gap in the integration of payment services that a MaaS scheme could provide in order to deliver affordable and flexible mobility options – including "pay as you use" and subscription services combining various transport services. An all-in-one solution for the access and payment for all the types of transport modes would potentially facilitate and expedite their use during a trip; especially among the latest users of smartphones, such as the elderly travelers (Li & Voege, 2017). To achieve this goal, a mobility data platform has to be created with the ability to structure, integrate, and collaborate heterogeneous and multi-stakeholder environments into a centralized and dynamic repository. This repository should cross-reference real-time transport data from different public and private sectors to assist the city's decision-making in order to achieve operational efficiency and fully integrated mobility services.

It should also be pointed out that our research did not manage to reveal assistive features for persons with disabilities (permanent or temporary) - such as inclusive information about wheelchair accessibility or voice navigation for blind users (Fernández-Llorca et al., 2017; Gebresselassie & Sanchez, 2018). This denotes that the accessibility of smartphone apps by persons with special needs must be a consideration for the developers. At the same time, an app could be used as a personal travel assistant with direct communication via voice reminders or alerts about ongoing trips, aiming to schedule routes between home, work, and events based on the user's calendar. Therefore, during the ecosystem/app design, the app's developers should take into consideration all the different types of users as well as their individual needs.

Finally, special attention should be given to the capability of the mobile app to overcome unexpected problems (e.g., limited Internet access), to be resource-conversing by preserving its battery life while in use (e.g., GPS on), and to protect the users' privacy.

3.4 Suggestions and Future Directions

Chapter 3 denoted the significant potential effect of smartphone usage on mobility. It presented the primary services provided by a list of selected mobile apps and projects, and it highlighted possible improvements and adjustments. In this way, it helps Study One to identify at a glance the possibilities that these mobile transit apps could offer and to choose the most essential and favorite features in order to integrate them during the development of a mobile transit app for ESD purposes.

In general, the usage of these apps could help passengers manage mobility through access to real-time information, and it could broaden the range of their activities' potential, while on the move. It is also noticed that these apps serve and support the use of new mobility-shared services (car-sharing, ride-sharing) while existing ones (such as the ones that serve taxis) may or already have been updated or modified (transport network companies). The future updates of the apps should facilitate the transition to shared automated mobility (modes must include a shared automated vehicle option).

In addition, the majority of these apps promote a participatory culture to disseminate information and to contribute useful content among the users by using crowdsourcing data (Welch & Widita, 2019). Therefore, another point that researchers, developers, and planners should pay more attention to is the real-time exchange of valuable information service between users - i.e., seat availability on a crowded bus, train, or metro - aiming to increase the public transportation use and comfort. Besides, the future research should emphasize the assessment and examination, on a global level, of whether the primary goal of these apps (i.e., to facilitate travelers on the door-to-door mobility by giving them absolute control over their transits and reducing the inconveniences associated with the public transportation) has been accomplished.

Moreover, it is observed that there are similarities and overlaps of some of the offered services (personalization, real-time route information and journey planner, traffic congestion) between these apps. However, some features may require additional attention and should entice policymakers to prioritize different apps interventions for the inclusion of:

- **[1]** *An integrated e-ticket payment* by combining all the available options and by using a single app to access and pay for all the transport modes.
- **[2]** *A feedback* factor with online user reports for evaluation purposes and user satisfaction about the accuracy of the provided travel data.
- **[3]** *A real-time notification option* about parking availability, pay-by-phone options, alerts on remaining parking time and reminders about where the user parked her vehicle.
- **[4]** *Surrounding points of interest* with personalized suggestions.
- **[5]** *Persuasive features* by providing information about fitness, CO_2 emissions consumption, and rewards, i.e., free/cheaper parking for people who carpool to work, in order for the user to change her daily travel habits.

The inclusion of the features mentioned above and services in the apps may increase their functionality and, therefore, their popularity (more installations), their appeal (abandon an app and switch to another), and their appropriate use (eliminate the car usage). This inclusion leads to an *ALL-IN-ONE* consolidated app that will embrace all the features mentioned above (type of services and provision of incentives), an integrated e-ticket in order to encourage the switch to greener modes (walking, cycling, public transport) and a human-like interface to enhance the interaction between the app and the user.

For the purpose of Study One, the features of the suggested "ALL-IN-ONE" app are used and embedded for educational sustainability-related purposes in the two mobile transit apps, which are presented and evaluated by pupils and students in *Chapters 5* and *6*, respectively.

Chapter 4 A Theoretical Conceptual Persuasive Framework for Supporting and Evolving Sustainable Mobile Traveling Attitude

This chapter presents the persuasive strategies used for a behavioral travel change. Then, a theoretical and conceptual framework that embeds some of these strategies for the development of a persuasive prototype to be used by young users to adopt sustainable travel habits is introduced. The detailed description of this framework, by means of its stages, is given next. The chapter concludes by listing limitations and future suggestions of the proposed framework.

4.1 Introduction - Persuasive Strategies for Behavioral Travel Change

Several persuasive strategies that focus on sustainability have been proposed to change the traveling attitudes of the users (Boukerche & De Grande, 2018; Schrammel et al., 2015; Sunio & Schmöcker, 2017), and have been assessed to various degrees (Anagnostopoulou et al., 2017; Oinas-Kukkonen & Harjumaa, 2008). These strategies aim to raise the awareness of the individuals about their traveling choices and behavior patterns and about the consequences of their activities (Stibe & Oinas-Kukkonen, 2014). Table 6 outlines the main persuasive strategies listed in the literature.

Table 6. Persuasive strategies for behavioral travel change

Cause-and-effect simulation, by providing graphical representations about the impact of mode choices on the environment (Meurer et al., 2016)
Challenges and goals setting, which are essential for the user, realistic, and with positive visual feedback (Munson and Consolvo, 2012; Gabrielli et al., 2014; Anagnostopoulou et al., 2018a)
Cooperation, when the users need to cooperate to achieve or adopt a target behavior (Schrammel et al., 2015)
Gamification, for contributing to the reduction of the "waiting and travel time" perception of users (Boukerche & De Grande, 2018)
Influence on the emotion (pride, hope, fear, guilt), via messages, images, symbols, sounds, and voice-based artificial intelligence assistants (Oinas-Kukkonen & Harjumaa, 2008)
Liking, with the system being visually attractive for its users (Sunio & Schmöcker, 2017)
Personalization, with the information provided about route planners tailored to the user attitude and past preferences (Anagnostopoulou et al., 2017; Sunio & Schmöcker, 2017)
Recognition, via virtual (badges) or monetary (green credits or points) rewards, to provide a sense of accomplishment in the users and to motivate them to participate actively and continuously (Sunio & Schmöcker, 2017)
Reduction, which makes a complex task simpler, usually by eliminating some of the steps of a sequence required to achieve a specific goal or filtering the trips to provide fewer alternative travel choices (Wunsch et al., 2015; Anagnostopoulou et al., 2018a)
Self-monitoring and reminders, by tracking user behavior and providing a review of goals achieved (Munson & Consolvo, 2012; Anagnostopoulou et al., 2017)
Similarity, when the system is designed to look familiar to users and imitate them in some meaningful way (Sunio & Schmöcker, 2017)
Social reinforcement and normative influence, through network comparison and online competitions among community users or friends (Gabrielli et al., 2014; Meurer et al., 2016)
Suggestion, by urging the user to follow more eco-friendly transportation options displayed in a more prominent position on the screen (Guerini et al., 2017; Anagnostopoulou et al., 2018a)
Tunneling, with a step-by-step guide (environmentally friendly options, are included by default) through the route searching where the users do not require a decision on specific transport modes (Bothos et al., 2014; Stibe & Oinas-Kukkonen, 2014)
Virtual rehearsal, for improving self-efficacy by providing means for practicing newly learned behaviors (Stibe & Oinas-Kukkonen, 2014)

In order to achieve this eco-friendlier transition, several of these strategies have been followed and adopted during the study based upon, among others, challenges and goal setting

(Anagnostopoulou et al., 2018a; Zhao & Baird, 2014), self-monitoring (Anagnostopoulou et al., 2017; Munson & Consolvo, 2012;), social network comparison (Gabrielli et al., 2014, Meurer et al., 2016) and gamification and rewards (Boukerche & De Grande, 2018). However, a lack of personalization, motivation (Bothos et al., 2014), resistance to change (Anagnostopoulou et al., 2017) and compliance (Lee et al., 2019) have been considered significant barriers to this traveling behavior change. To overcome these obstacles, the provision of extrinsic motivation and the intrinsic willingness of the individual to change, when used together, may maximize the potential positive changes in human traveling behavior (Fogg, 2002).

From this perspective, the success of each persuasive strategy and approach used to promote sustainable mobility depends on the changes evoked in the users' experience and routine and on the differences in their susceptibility to persuasive methods (Stibe & Larson, 2016). The development of a mobile transit app in the direction of motivating people to change their travel behavior should implement some or all of these strategies. In addition, it requires detailed insights into the factors or processes underlying this change.

The desired behavioral change is achieved by bridging the gap of the appropriate implementation of the behavioral change techniques combined with established theoretical constructs from behavior theories such as the Theory of Planned Behavior (TPB) (Ajzen, 1991; Hardeman et al., 2002), and the Transtheoretical Therapy Model (TTM) (Prochaska & DiClemente, 1982). According to TPB, behavior is based on intention, which in turn is based on three determinants: the attitude toward the behavior, the subjective norm, and the perceived behavioral control. TTM postulates that a behavioral change is accomplished through a series of stages rather than by a single or sudden event.

Another such theory is the Integrated Behavioral Model (IBM) (Montaño & Kasprzyk, 2008). IBM combines constructs represented in the theory of reasoned action (Ajzen & Fishbein, 1980) and in the theory of planned behavior (Ajzen, 1991) and is designed to provide an understanding of the human behavior. IBM claims that the personal attitudes, beliefs, and perceived norms can explain the intention of the individual toward a healthy behavior. In this way, IBM highlights that behavioral intention is one of the strongest predictors of the likelihood that an individual may subsequently embrace a healthy behavior. Additionally, other elements that may influence this transition are the knowledge and the skills one possesses to perform this behavior, the environmental constraints that may prevent such an engagement, and the familiarization with the present behavior.

To this effect, the design of mobile transit app components should consider the fundamental motivational aspects. These aspects involve innate psychological needs, such as autonomy, relatedness, and competence, as well as learned social needs, such as leadership, achievement, followership, intimacy, and affiliation (Keldrs et al., 2012; Weiser et al., 2015). Furthermore, the determinants of behavior and the ways to promote a healthier behavior change or interest can be very complicated (Arnott et al., 2014). Therefore, several theoretical models have been developed to connect the psychosocial and the environmental constructs of this meaningful behavior change.

In the literature, one may find several theoretical frameworks as a basis for systematic intervention development. Fogg (2002) proposed a helpful framework for understanding persuasive technologies and thinking about behavior change factors. In this model, behavior is a product of three elements: motivation, ability, and triggers. This framework has been applied to promote environmental sustainability through persuasive technology (DiSalvo et al., 2010). Oinas-Kukkonen & Harjumaa (2008) presented a conceptual framework for designing and evaluating persuasive systems. This framework focuses on sustainability by assuming that ICT could be a useful tool to influence travel behavior. Such a theoretical holistic perspective offers new possibilities and new challenges during the design and the development of a behavioral change support system (Klein et al., 2014; Sunio & Schmöcker, 2017).

Some frameworks conceptualize travel behavioral change as a transition through the time-ordered sequence of four stages. Bamberg (2013), for example, proposed the self-regulated behavior change stage model. This model has the pre-decision, the preaction, the action, and the post-action stages. Andersson et al. (2018) introduced a theoretical framework with the stages of adopting, shaping, changing, and keeping sustainable travel behaviors with the use of smartphone apps. People can participate in setting or activating goals, in defining their own strategies to reach these goals, and, finally, in revising their goals and strategies based on their needs.

4.2 Description of the Proposed Framework

The development of a successful mobile transit app to motivate and educate young people to change their travel behavior should implement some or all of the persuasive strategies shown in Table 6. In addition, this development requires detailed insights into the factors or processes underlying this change and evidence that these changes are long-lasting. Furthermore, each persuasive strategy may significantly contribute to the continuous enhancement and effectiveness of a transit mobile app's "green" primary purpose and educational nature.

Therefore, the designers should take into consideration the importance of appropriately choosing and implementing influence techniques to prevent unintended interactions (Kaptein & Duplinsky, 2013) and carefully select the most suitable extrinsic rewards applied for every stage to achieve the primary mobile app's goal. It is essential to provide a pleasant stimulus as soon as possible after the desired behavior is performed, thus making it more likely that the desirable travel behavior will reoccur (Skinner, 1953).

In order to support the evaluation of the achieved behavioral effects and the impact of the persuasive methods applied in the change of the travel attitude, a theoretical and conceptual active participant framework is proposed. This framework is named Eco-Persuasive-Mobile-Application (EPMA) and is based on the user feedback to assess their behavioral travel change. This newly introduced element of active feedback fills a gap in the literature so far: the long-term evaluation of the behavioral effects and the impact of the persuasive methods used to change travel attitude. EPMA aims to use this feedback to support the users toward sustainable urban mobility continuously and support in conducting evaluation research with a long duration and with a high number of active participants simultaneously.

EPMA consists of five stages that may occasionally overlap (Figure 4). Each stage has as its primary goal the continuous improvement of the mobile app users' traveling behavior, especially for urban purposes and the identification of the most promising ways to keep up this behavior through appropriate persuasive techniques. The final goal is the adoption by the users of a lifetime sustainable transportation habit in order to contribute to the reduction of the carbon footprint and the adoption of a more eco-friendly and healthy way of living.

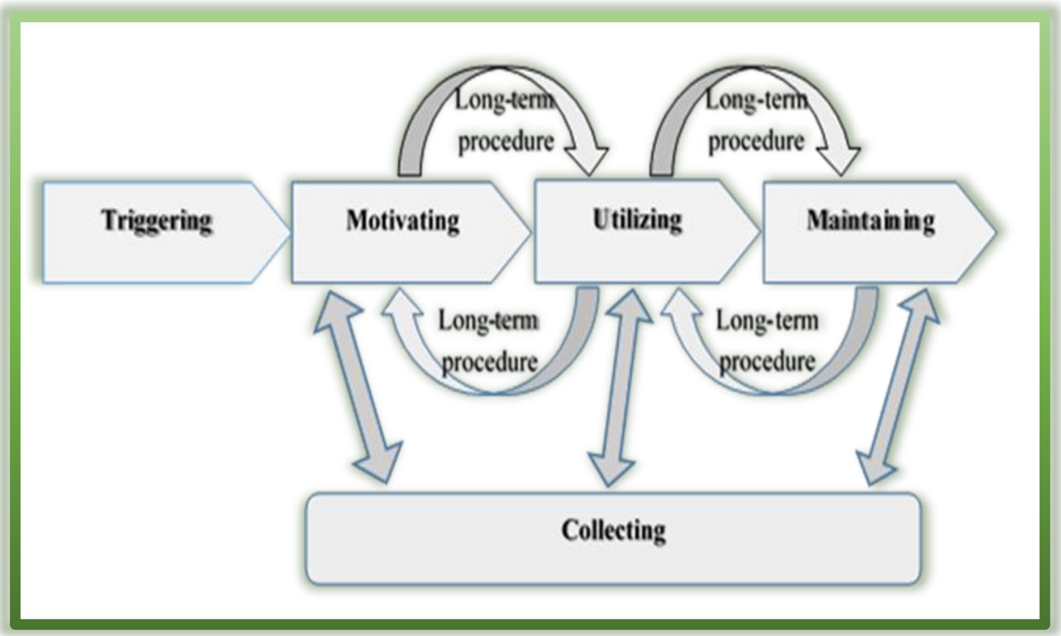


Figure 4. Overview of the theoretical and conceptual persuasive EPMA framework

Four of these stages have been adopted from existing frameworks and practices, and the fifth one, namely the *Collecting* stage, is newly introduced in EPMA. This stage has as a primary goal the improvement of the traveling behavior of the mobile app users. The addition of this stage will make the users choose more sustainable and eco-friendly practices, especially for urban purposes. The *Collecting* stage also focuses on identifying the most promising ways to maintain this behavior via appropriate persuasive techniques. In order to reach these goals, personal and travel data provided by the mobile app users must be collected. These data are related to the travel services offered as well as the ease of use and the effectiveness of the app. They can be collected via an assessment-feedback combination mechanism, which can include a variety of rewards.

This positive reinforcement increases the likelihood that the behavior will continue or increase in the future (Skinner, 1953; Bandura, 1977). Moreover, the existing literature has highlighted that positive reinforcement via the provision of rewards is most effective when it happens immediately after the desired behavior is performed. The shorter the time gap between the behavior and the presented positive reinforcement, the stronger the connection will be (Fogg, 1997). This immediate reward by the decision-makers, with the cooperation of the local transport authorities and private companies, is expected to lead to the establishment of a desirable eco-friendly travel behavior of the user and a continuous up-to-date assessment of the travel services provided.

The detailed description of this framework, by means of its stages, is given in the next section.

4.3 The Stages of the Proposed Framework

The five stages of EPMA and the processes of the travel behavioral change are described next. This description provides the potential target groups that it is addressing, as well as the methods that the persuasive strategies could be successfully implemented, thus allowing a potentially operational framework.

[1] *Triggering:* Triggering is the process in which the users are informed about the app and are engaged with its content. At this stage, people may use a smartphone, but they do not feel the need to change their travel behavior. This can be due to the individual struggling with the adoption of new technologies (a common phenomenon especially among older people) (Meurer et al., 2016), due to the insufficiency of the appropriated infrastructure or, more generally, due to the individual's persistent refusal to change (devoted drivers who prefer to drive a car than any other means of transportation).

Triggering can be achieved through a user-centered information campaign. This campaign may involve actions such as sending "green" emails during the day with valuable personalized notifications. The attached information may be daily weather forecasts about the transport mode that could be used (bicycle); entertaining elements; short videos; virtual tours using different modes (multimodal) within a single trip, and messages in attractive dialogue boxes that are varied to avoid feeling annoyingly repetitious or make them feel guilty about their travel preferences so far. The users should also be aware that the transit app is smoothly accessible and easy to use, with high-quality traveling information (Baker-Eveleth and Stone, 2020). The users should also be aware that they can have a personal account and adapt the user interface to their preferences.

[2] *Motivating:* Motivating is the process in which the app should influence the users to think of their travel habits and consider how their personal mobility could be more sustainable. At this stage, people use smartphones, and they are open to changes in their travel behavior. This behavioral change can be achieved if the proposed alternative travel plan offered by the app is advantageous and if the individual is willing to change.

Motivating can be promoted with the means of the daily encouragement of the user via an avatar (character, pet, or cartoon chosen by the user) or via an authority - such as a doctor or a professor (ask her to answer) (Fogg, 1997) - in an attractive and appealing user interface. This avatar should be in a "physically" active mode (e.g., a cyclist or a pedestrian) while setting realistic challenges or goals.

Furthermore, a comparison of the present and a desirable future situation could positively motivate the user to demonstrate an intended behavior. A "reciprocity" approach (Fogg, 2002) between the app and the user may be implemented as a reward to the second (e.g., fastest suggested route, the most convenient itinerary proposed, congestion avoidance, or information about free seat availability in a mode). Finally, trial periods with free tickets or rides could also be offered in cooperation with the transport authorities and decision-makers.

[3] *Utilizing:* Utilizing is the process in which the app guides the users toward accomplishing their goals and thus making the necessary changes to reach these goals. At this stage, people accept their behavioral travel change and recognize that this change may also benefit other people. *Utilizing* which can be realized by providing the appropriate information to the users on why and how different routes have been selected in the initial set of recommendations aims to gain trustfulness. Furthermore, the app should identify and notify the users of their daily traveling habits or plans based on their traveling history, status confirmation, and information provided by sensors or requests. Simultaneously, the users may earn points or rewards, visualized with images or an exploratory slogan about the ambitious goal accomplished, and be sincerely praised for the excellent work that they have done.

[4] *Maintaining:* Maintaining is the process in which the users may need continuous motivation to ensure that they will adopt the new travel behavior and not relapse into their old travel habits. When people integrate daily transit habits that are based more on public transportation and physical activity into their daily routines, they can repeat eco-friendly actions without paying too much attention. This normative influence, which may lead to a sustained behavioral change, can be achieved by sharing relevant information within the same app or social media. The real-time exchange of valuable information service between users - i.e., seat availability on a crowded bus, train, or metro - aims to increase public transportation use and comfort.

Moreover, participating in competitions may gradually affect users' attitudes through, for example, a visualized podium for places 1, 2, and 3, followed by a list of the other ranks. Finally, cooperating to achieve a specific common goal and the social comparison within a group could potentially lead the user to a long-term procedure of self-enhancement and self-improvement (Wunsch et al., 2015).

[5] *Collecting:* Collecting is the process of tracking the travel behavior and the progress of the users, alongside achieving their engagement in a self-determined and collaborative approach to behavioral change. These actions aim to ensure a proper consideration of privacy, security, and ethical aspects (Hu et al., 2019). This crucial stage offers feedback based on the assessment derived from the users' perception via quantitative and qualitative research questionnaires. It is critical to focus on the systematic assessment of the travel services provided and the actual impact of the persuasive methods applied in the change of the travel attitude.

This assessment is achieved by carefully designing the appropriate embedded short questionnaires (targeting the improvement of the app based on the satisfaction and the perceptions of the users). There are two approaches to online feedback forms

- *the active one* (e.g., triggering a feedback form when the users reach a specific goal or when they leave the page), and
- *the passive one* (e.g., a feedback button on the side of the app).

To initiate this feedback, the users should be provided immediately with bonus features - such as games, free mobile data or phone calls, and limited subscriptions to a favorite media service provider (e.g., Netflix).

The three stages of *Motivating*, *Utilizing*, and *Maintaining* constitute a long-lasting and back-and-forth procedure. The implementation of the *Collecting* travel data stage alongside the previously mentioned stages intends to shorten the travel changes procedure and consequently to maximize the environmental effect of the app on the user through the provision of incentives. Furthermore, the ubiquitous feedback on the satisfaction of the user via a user-friendly interface could be used to check and improve the reliability and popularity of the app.

At the same time, the users' feedback could help the app developers verify the functionality of these features and proceed to potential enhancements. Besides, the provision of effective problem-solving methods according to the facts and personal opinions of the users also helps prevent a possible misperception about using a specific public transportation means by the user. Therefore, the desirable features of the mobile transit app, based on the previously mentioned users' feedback, should be enabled and combined in future app updates to establish a sustainable daily use of the app.

Table 7 presents the persuasive strategies provided in Table 6 that could be utilized in each of the five stages of EPMA. Each strategy may significantly contribute to the continuous enhancement and effectiveness of the "green" purpose of a mobile transit app. We observe that there is an overlap among many of these strategies within these stages. Therefore, the app designers should consider the importance of appropriately choosing and implementing influence strategies to prevent unintended interactions. Moreover, they should carefully select the most suitable extrinsic rewards applied in every stage to achieve the primary goal of the mobile transit app.

Table 7. Persuasive strategies that could be used in each stage of the EPMA framework

Persuasive Strategies	Stages of EPMA				
	Triggering	Motivating	Utilizing	Maintaining	Collecting
Cause-and-effect simulation	•	•	•	•	
Challenges and goals setting	•	•	•	•	
Cooperation			•	•	•
Gamification	•	•	•	•	•
Influence on the emotion	•	•	•	•	•
Liking	•	•	•	•	•
Personalization	•	•	•	•	•
Recognition			•	•	•
Reduction		•	•	•	
Self-monitoring and reminders			•	•	
Similarity	•	•	•	•	
Social network			•	•	•
Suggestion	•	•	•	•	
Tunnelling		•	•	•	
Virtual rehearsal	•				

Having described the five stages of EPMA, the next step is to examine whether these principles can be incorporated into a mobile transit app and how the young users would react to such an app. Given the fact that a real-world, extensive evaluation for testing the app's usability and functionality would require a considerable budget and a long time frame, I opted to simulate the principles mentioned above with the means of simulation screens of a mobile app mockup, as outlined in the following *Chapters 5* and *6*.

4.4 Limitations of the Proposed Framework and Future Suggestions

The main limitation of the EPMA framework is its theoretical nature and the fact that it has not been empirically tested widely; thus, it has not been thoroughly validated. Nonetheless, in *Chapters 5* and *6*, I provide some evidence of its adaptation and application in two mobile transit apps, specially designed and developed for the ESD purposes in upper secondary and higher education, respectively.

In addition, as the proposed *Collecting* stage of EPMA contains the collection and analysis of personal data and sensitive information, security, privacy, and safety aspects must be considered by design and by default, as well as the GDPR principles should be carefully considered. More precisely, all aspects of data transmission, processing, and storage must comply with the international legislation for data protection regulation. One of the most crucial requirements of the GDPR is to acquire the consent of the user before collecting or processing her personal information.

Besides, the user must have

- the right *to access* what information is shared with the app and ask how exactly it is used,

- the right *to be informed* and *be requested* for consent each time the app gathers any data and how exactly this data will be used, and
- the right *to stop* the processing of their information at any time during the app use.

Yet, the fact that this data collection requires a strong user commitment and engagement should be further examined and worked on, mainly when it addresses the young people. The requested feedback should not repeatedly disturb and interrupt the traveler and should be adaptive to her personality.

Moreover, the development of a mobile transit app implementing the EPMA framework should recognize and be cautious about the appropriate time for persuasive interventions and the relevant information that should be collected. In any case, the ethical dimensions of applying behavior change strategies should be taken into consideration to ensure the moral acceptability of such interventions (De Medeiros et al., 2018). Therefore, more conclusive studies should be developed toward the direction of increasing the impact and the effect of the system on the users' travel habits and the acceptance of these interventions when applying persuasive techniques. One such study is described in the following *Chapters 5* and *6.*

Chapter 5 ESD in Secondary Education: Educating Young People in Sustainable Travel Urban Behavior Through Mobile Apps

This chapter presents the design and the assessment of six simulation screens of a mobile transit app mockup based on EPMA. This app aims to educate young people about the environmental impact of their transportation. The app's potential is demonstrated through two use cases: "Daily Commuting" for daily activities and "Weekend Entertainment" for greener weekend travel habits. Then, the user-centered design process, including Stage One and Stage Two, is described, and the methodology for assessment of the app’s screens by secondary school pupils is analyzed. The chapter concludes by listing the results and the limitations of the research.

5.1 Introduction

The fundamental changes required for a sustainable future must start with young people, including, among others, their travel behavior, attitude, and lifestyle change. At the same time, the contextual factors and the institutional support provide an environment that can enable and emerge individual contributions. This is particularly so among the younger people whose transformative action related to traveling practices is often prompted when they attach importance to certain concepts, i.e., sustainability and a lifestyle that corresponds to their sense of identity. Today's children are tomorrow's adult transport users, and intermodal travel behavior must be cultivated and adopted very early.

Nowadays, there exist several measures to increase young people's healthy behaviors like walking and cycling: physical measures (i.e., safer routes with footpaths on most streets and low traffic speeds, school crossing patrols with an adult stopping the traffic for enabling children to cross the road safely, improvement in the schools' infrastructure including providing secure cycle parking and lockers), school trips, campaigns and information, i.e., sets of guidance (Mackett, 2013).

The promotion of healthy daily routine activities, such as active commuting to school, is seen as a strategy for tackling obesity and other chronic diseases and as an opportunity to increase physical activity and fitness. The existing literature implies that young people who cycle less or walk less are more likely to become overweight and unhealthy (The CONNECT project, 2010). Another study suggests that the young people's well-being can be affected by many factors, including, amongst others, perceived road safety, active travel and Independent Mobility (IM) (Leung & Loo, 2017). A systematic review of the association of IM with physical activity, sedentary behavior, and weight status identified a consistent positive association between IM and physical activity (Schoeppe et al., 2013).

For the promotion of IM, new mobile technologies should be incorporated, as various studies have reported an increased parental feeling of safety when children take a mobile phone when roaming in the neighborhood independently (Bennetts et al., 2018). Through a mobile phone, the parents can quickly contact their children at any time or directly observe them through GPS tracking. Although mobile phone use is positively associated with sedentary behavior (Barkley et al., 2015), mobile phone ownership has no negative effect on IM (Marzi & Reimers, 2018).

At the same time, a few projects, educational games, and mobile apps have been developed in the field of education, aiming to facilitate the IM and help young people to be aware of moving safely on the roads, to use alternative transport modes, as well as to learn about the advantages of using sustainable transport (Table 8). So far, the young people's education concerning traveling and mobility from their parents, is still too often only related to learning traffic rules or road safety training, i.e., how to cross the road. For this reason, there is a need to develop mobile educational apps using motivational techniques adapted to young people for establishing a sustainable travel behavior. A detailed description of the development of such a mobile app mockup, which is based on EPMA, is given in the next section.

Table 8. Tools for educating young people in sustainable travel urban behavior

Tools	Short Description	Web Page
ACTIVE – HEALTHY to Kindergarten and School (Project)	A program for active and healthy mobility management for Vienna's kindergartens and schools: educating children on how to behave in the transport system, improving their travel safety, and strengthening their skills in autonomously using different modes of transport	http://young-mobility.at/en/active-healthy/
Active Mobility – Healthy Travelling 2019-2022 (Project)	A project that encourages Active Mobility, including walking, cycling and use of public transport, resulting in environmental, economic and social benefits	https://aktive-mobilitaet.at/
B-TRACK-B Family cycling for energy efficiency in urban leisure travel (Project)	"Bike the track/ track the bike" promotes the use of bicycles by families with children aged 9-15 for their leisure (urban) trips in 7 European cities. The action intends to engage indicatively 100 families per site in an innovative track-the-bike "lottery" to motivate them to shift from car to bike use	https://btrackb.eu/
CONNECT (Project)	CONNECT encourages children and their parents, as well as young people, to use more sustainable transport modes when traveling to and from school	https://www.connect-science.net/
Do The Right Mix (Project)	This project provides useful material, including effective and funny cartoon videos, to explain how to move in an eco-friendly way using all the different means of transport available	http://dotherightmix.eu/
Youth For Public Transport (Y4PT) (Project)	Y4PT aims to promote the active participation of young people on transport and mobility issues at all levels and settings by promoting the integrated use of public transport with other means of transportation to achieve a greater well-being and a better quality of life for all people around the world	http://www.y4pt.org/
Beat the Street (Educational Game)	Beat the Street is an educational game that turns towns into giant games. The participants can earn points, win prizes and discover more about their area by walking, running and cycling	https://www.beatthestreet.me/
Kids Go Green (Educational Game)	Kids Go Green is an educational game that involves the school, the children and their families in an adventure around the world and promotes a more sustainable mobility	https://kidsgogreen.eu/en/
Traffic Snake Game Network (TSG NETWORK) (Educational Game)	TSG established an effective EU-wide and long-term support network to replicate, transfer and expand the uptake of the Traffic Snake Game as a successful tool for changing the travel behavior of primary school children (age 6-12) and of their parents	https://trimis.ec.europa.eu/project/traffic-snake-game-network
SETA app (Mobile application)	Seta for school tracks the movements of students and helps the school get free perks. Seta is a project funded by the European Union	http://setamobility.weebly.com/seta-app.html

5.2 Designing A Mobile Transit App Using Motivational Features

The first implementation of the EPMA, along with the mix of several motivational strategies and their integration into a mobile transit app, has as a primary goal the motivation and the education of the secondary school pupils to daily use and finally permanently adopt sustainable transport choices. This aspect aims to progressively build a more just and sustainable world through strengthening ESD and contributing to the achievement of the 17 SDGs.

To this effect, EPMA and existing persuasive strategies are adopted, implemented, and integrated into six simulated screens of a prospective mobile app mockup named *Education in Sustainable Travel urban behavior through mobile Applications* (ESTA), designed for this purpose through a User-Centered Design (UCD) process. This process incorporates the needs and feelings of users to guide each phase of product design and development (Cellina et al., 2019; Kahraman, 2010). UCD also heavily emphasizes iteration — ideas are tested and redesigned to achieve usable, satisfying, and emotionally impactful products.

As the product for Study One is a mobile transit app mockup, the adoption of UCD ensures that every single process that goes into the app design and development must consider the user first – their needs, objectives, and feedback. Once this robust comprehension of the user is created, the designers can use what they know to build an app that users will love and accept (Sadeghian et al., 2022). In addition, the UCD approach helps to ensure that the app isn't just another generic solution that will inevitably get discarded when something better comes along. It provides an explicit value, user-friendliness, and a positive user experience. The primary key of UCD is that feedback is collected continuously and iterated on the design accordingly. This procedure helps the app be future-proof and ensures that it stays relevant.

The main types of persuasive strategies that have been investigated more extensively and have been used in Study One are:

- *Challenges and goals setting*, which are essential for young people, realistic, with positive visual feedback about their performance (Gabrielli et al., 2014; Munson & Consolvo, 2012), i.e., "green" e-mails, mainly sent during the day or occasionally in the evening (last motivational thought of the day) with a variety of information that may be daily weather forecasts about the transport mode that could be used (bicycle); entertaining elements; short videos; virtual tours using several modes (intermodal) and different modes (multimodal) within a single trip.
- *Self-monitoring and reminders*, which are used for the daily tracking of young people's travel behavior and for providing a review of the achieved goals (Anagnostopoulou et al., 2018a; Munson & Consolvo, 2012) along with a traveling history.
- *Social reinforcement and normative influence*, through sharing information, network comparison, cooperation to achieve a specific common goal, and online competitions among community schools and schoolmates (Gabrielli et al., 2014; Meurer et al., 2016).
- *Gaming*, which contributes to the reduction of the "waiting and travel time" perception of young people. In addition, gaming stimulates young people playfully and amusingly to walk, cycle, and use public transport more intensely (Boukerche & De Grande, 2018) by earning points or rewards and learning more about sustainability.
- *Recognition*, via virtual (badges or podiums for places 1, 2, and 3 or monetary (green credits or points which will be used for discounts under some conditions) rewards, to provide a sense of accomplishment and to motivate the young people to participate actively and continuously (Cellina et al., 2023; Sunio & Schmöcker, 2017)
- *Cooperation*, which is used when the classmates need to cooperate to succeed or adopt a particular target behavior, i.e., walking every day to or from school (Schrammel et al., 2015).
- *Influence on the emotion*, (pride, hope, guilt) via messages, images, symbols, sounds and voice-based avatars (Oinas-Kukkonen & Harjumaa, 2008).
- *Cause-and-effect simulation*, by providing graphical representations and awareness-raising images about the impact of mode choices on the environment (Bothos et al., 2014).

The expected result of implementing a combination of these persuasive strategies during the mobile app's daily use becomes even more profound when each strategy is implemented separately. Existing studies have shown that combining multiple strategies leads to temporally increased compliance. However, the relevant long-term results have consistently demonstrated a relatively negligible effect (Prochaska & DiClemente, 1982). The mix of the above-mentioned motivational strategies and their integration in a mobile transit app has as a primary goal the young people's motivation to use daily and, finally, to adopt sustainable transport choices.

Within the framework of the ESTA design, the UCD methodology has been followed in order to fully explore the needs and desires of the pupils, as well as the intended uses and expectations about the mobile app (Kahraman, 2010; Kırdar & Ardıç, 2020). The significant advantage of this approach emerges from the pupils' involvement during the design, taking into consideration their habits, travel attitudes and requirements (Stage One) and the implementation and evaluation (Stage Two) of the prospective mobile app. This participation, therefore, may lead to the development of a product that is more effective, efficient and suitable for its intended purpose in the environment in which it will be used. Moreover, this involvement provides a sense of ownership for the final product (it is *my* application) that often results in a higher user satisfaction and in a smoother integration of the mobile app into the pupils' daily routine.

5.3 The User-Centered Design Process - Stage One

In Stage One, the user habits, travel attitudes and user requirements were investigated with the means of an online questionnaire survey. The questionnaire was created using the Google Forms service, and it was called *Questionnaire for the use of smartphones and mobile transit applications* (Appendix B). The questions used were open-ended and close-ended (multiple-choice, matrix, and rating scale). The first section of the questionnaire included questions related to the users' demographics information. The second section included questions related to the users' daily travel habits, and the third section included questions related to the use of the smartphone and its applications and the intention to obtain a more sustainable travel behavior via a mobile app. The 46 pupils (24 boys and 22 girls) who accepted to take part in the study were mostly first- and second-year pupils (age range 15-18) of a public senior high school (Lyceum) in the area of Attica, Greece. The survey was performed in the spring of 2020.

The pupils surveyed conduct an average of M=4.17 (±1.27) routes per day, while the most common is four routes per day (N=18, 39.1%). This result can be easily explained by the fact that on a regular basis, all pupils travel to and from school (5–10 and 10–15 minutes are the most common durations), and most of them to foreign language classes or tutorial centers (less than 5 minutes is the most common duration). Other trips include going to sports or outdoor play and visiting friends with a 10-15 min most common duration, and arts (mostly music and painting) or interest—hobbies (e.g., chess) with a 5–10 min common duration. More than six (6) trips per day are fairly uncommon. The primary transport mode is walking or cycling (N=37, 80.4%), with metro or tram (N=7, 15.2%) and bus (N=2, 4.3%) coming next. All of the pupils are smartphone or tablet owners.

Table 9 shows the apps that the pupils use the most; social networking, messaging and entertainment are in the top three, while traveling and maps are at the end of the list as the majority of the pupils move within their familiar neighborhood or their school's transport is dominated by the use of automotive transport, whether by private vehicle, public transportation, or school bus.

Table 9. Mobile apps that the pupils use the most

Categories of Mobile Apps	Relative Frequency (f %)	Frequency (N)
Social networking	82.6	38
Messaging	71.7	33
Entertainment (music, dance, etc.)	58.7	27
Searching tools	43.5	20
Gaming	37.0	17
Sport, health and fitness	34.8	16
News	21.7	10
Weather forecasting	19.6	9
Traveling and maps	15.2	7

Table 10 presents the features that the pupils like to have in a mobile transit app in order to use it on a daily basis. We observe that earning points or rewards (i.e., recognition) set up a powerful incentive for the everyday use of the app alongside with playing eco-games (i.e., gaming). Moreover, sharing or posting travel information and their itineraries with other users (i.e., social reinforcement, normative influence and cooperation) seems to be an essential part of the overall teenage socializing. Being part of a peer group is significant during adolescence, offering to its members the opportunity to develop various social skills like empathy, sharing and leadership. For this reason, reporting positive experiences and green travel choices is more likely to influence other pupils and users to foster the same behavior (Barker, 2009).

Table 10. Features that the pupils like to have in a mobile transit app in order to use it daily

Mobile Transit App Features	Relative Frequency (f %)	Frequency (N)
Set a journey planner	69.6	32
Collect points or get rewards, i.e., free public transportation tickets	65.2	30
Set reminders—get notifications about a scheduled trip	45.7	21
Play eco-games	43.5	20
Share or post real-time information about traffic, disruptive events and transport choices	43.5	20
Share or post your itineraries with other users	41.3	19
Learn more on the topic of sustainability with relevant information, i.e., calories burned, carbon footprint calculation	32.6	15
Suggest travel options to other users	21.7	10
Give feedback on travel options provided	17.4	8

The privacy and the personal data protection upon the use of a mobile app concerned considerably (N=30, 65.2%) or sufficiently (N=10, 21.7%) the pupils, with the main problems mentioned being:

[1] The mobile app must collect only those data that are strictly necessary to perform the lawful functionalities as identified and planned (N=37, 80.4%).

[2] The user must be able to choose which data they want to share with others or with third-party services (N=34, 74.0%).

[3] The app must be hack-proof (N=28, 60.9%).

[4] The personal data needs to be protected when stored through effective encryption (N=24, 52.2%).

The majority of the pupils (N=33, 71.7% answered «yes» and N=10, 21.7% answered «maybe») are interested in or are prepared to change their behavior just for the sake of the environment. Figure 5 shows their intention to use a mobile app in order to obtain a more sustainable travel behavior. This answer reflects the mobile app's potential positive contribution to educating pupils to become more mindful of their environmental impact and choose more "green" travel options. Furthermore, it underlines the prospect to develop a mobile app adapted to the expectations and the needs of young people in this area.

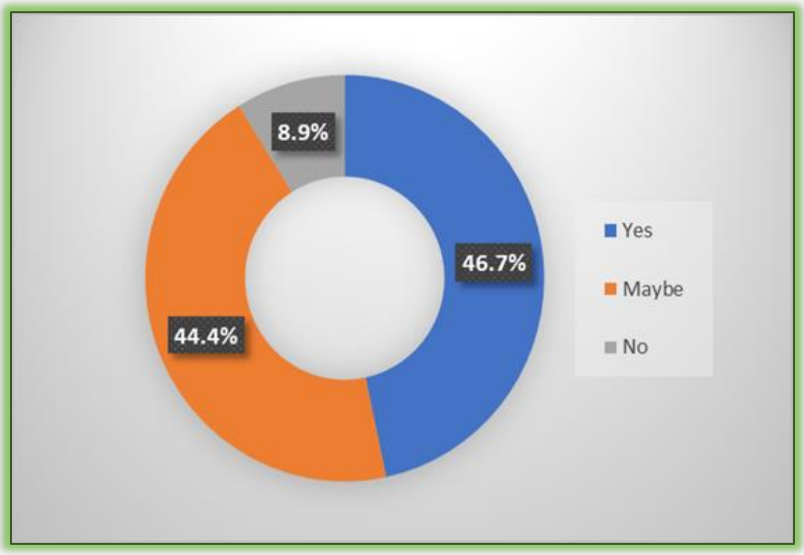


Figure 5. Intention of the pupils to use a mobile app in order to obtain a more sustainable travel behavior

5.4 The User-Centered Design Process - Stage Two

In Stage Two, the six simulations screen of the ESTA was implemented using the Justinmind Prototyper 8.7.4 tool (https://www.justinmind.com/) in order to collect data connected to the subjective perceptions, the intention to use and the level of satisfaction among pupils. This app was mainly based on the pupils' responses (Table 10), and it integrated the previously mentioned motivational features. The primary purpose of the ESTA was to support the pupils' ESD and raise their awareness in order to become more mindful of their environmental impact, as well as to adopt a sustainable travel urban behavior progressively.

5.4.1 The Simulation Screens of the ESTA

From the *Welcome Screen* (Figure 6a), the pupil can be attracted by a promotional message about the rewards she could earn for herself and her school by using ESTA. By clicking on the *Get Started* button, the pupil can create an account using a name and a password, and optionally, her school or the pupil can sign in to her account. From the *Home Screen* (Figure 6b), the pupil can set her travel preferences and eco goals, make a trip plan request and review her past trips. In addition, the pupil can see the total number of points collected. By clicking on the *Check rewards!* button, the pupil can overview the corresponding rewards (e.g., free talk time or mobile data, special discounts on public transport tickets, free tablets or gadgets for her school, free rides with municipal bicycle).

Figure 6. The ESTA (a) *Welcome Screen* integrates social reinforcement and recognition; (b) *Home Screen* integrates options for personalization, challenges and goal setting, recognition, and cause-and-effect simulation

In the *My Preferences Screen* (Figure 7a), the pupil can review the modes of transport (public, private, and shared) with the location of stations and maps, set her travel preferences, choose whether she wants to get notifications about upcoming trips, give feedback on travel suggestions, learn more relevant information on the topic of sustainability, calories burned, carbon footprint calculation, search schoolmates and, finally, play online games or take online quizzes for earning more points.

In the *My EcoGoals Screen* (Figure 7b), the pupil can set new eco goals in a particular time period using the slider bar. The pupil can also review the points or rewards they have collected. These rewards are placed on a visualized podium among other users.

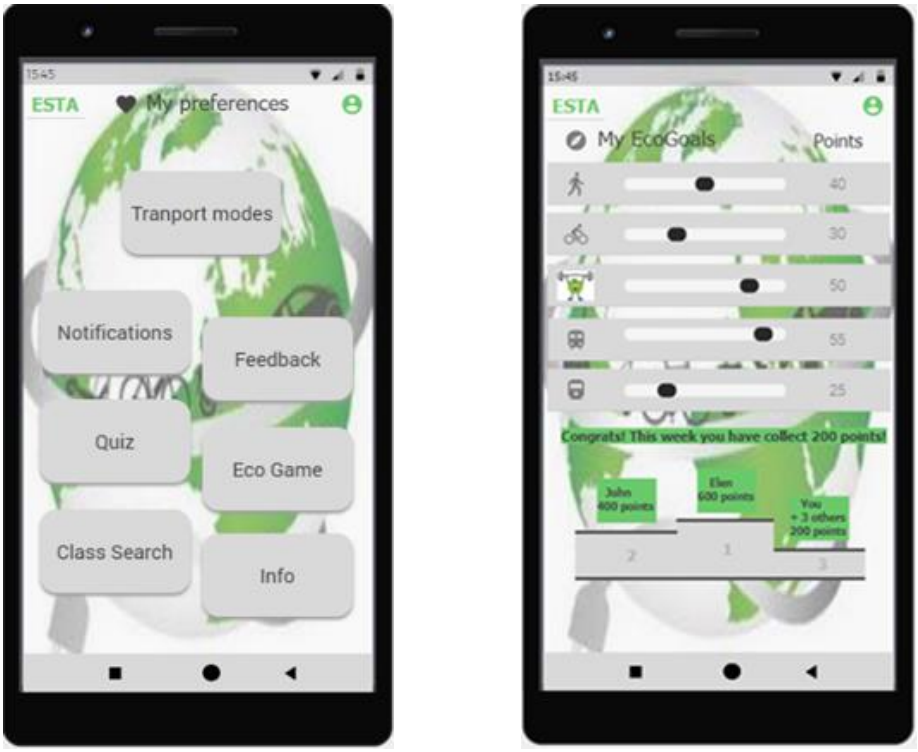


Figure 7. The ESTA (a) *My Preferences Screen* integrates options for gaming, social reinforcement, and normative influence and cooperation; (b) *My EcoGoals Screen* integrates social network, recognition, influence on the emotion and self-monitoring and reminders

The *Plan a Trip Screen* (Figure 8a) provides sustainable route recommendations and live step-by-step directions for choosing the best route from one place to another according to the pupil's criteria and preferences and the possibility to socialize by sharing mobility-relevant messages with friends and spreading the app among her schoolmates.

My Past Trips Screen (Figure 8b) allows the pupil to save previous trips history and to review the real past trips using graphical representations showing how much she used the different modes of transport over a time-period, with information about calories burned, carbon footprint mitigation, and trees saved. She is also praised for the excellent work that she has done. Furthermore, by clicking on the *grey circles*, the pupil can learn about eco-mobility options and the consequences of sustainable transport choices regarding fitness and personal health. In this way, the pupil can monitor her travel behavior and her progress toward improving her transport habits over time.

Figure 8. The ESTA (a) *Plan a Trip Screen* integrates social reinforcement, normative influence, and cooperation; (b) *My Past Trips Screen* integrates self-monitoring and reminders of weekly reflection, suggestion recognition, goal setting, influence on the emotion, and cause-and-effect simulation

5.5 Use Cases

The potential of the ESTA was demonstrated to the pupils via two use cases. For this purpose, two different actors and the scenarios corresponding to these actors have been created. The subject of these scenarios was to complete a story about the ideal daily pupil's experience, thus providing us with information on how the actor interacts with the system. The first use case, "Daily Commuting", is addressed toward pupils who want to move within their area of residence or neighborhood following their daily routine and activities. The second one, named "Weekend Entertainment", is addressed toward pupils who want to move using the public transport modes and are being encouraged toward greener weekend travel habits. In the following description, the initials into parentheses refer to the EPMA stages that may be involved in the use of the app, namely *Triggering* (T), *Motivating* (MO*), Utilizing* (U*), Maintaining (*MA*)* and *Collecting* (C)*.* In contrast, the information into brackets refers to the *Home Screen* menu options of the ESTA.

5.5.1 The Daily Commuting Use Case

On her way to school on foot (it usually takes 10 minutes), Maria receives a notification from her smartphone suggesting a new route (U, MA), which takes three minutes of extra time, to walk a little more to improve her physical activity {My Past Trips}. At the same time, she can see that 10 of her classmates have chosen the same route with an overall satisfaction level of 9 to 10 (T, U), and now, they can all participate in a quiz to earn "green" points for their school {Plan a Trip}. During the school break, Maria can play an eco-game and set more eco goals for the rest of the week, as she wants to be the hero of her class and get free metro tickets (MO, U). After the end of the lessons, she receives a confirmation notification about the bus itinerary for going to her chess class {My Preferences}. If she chooses bicycling as an alternative route, she could take the first podium {My Eco Goals}. While waiting for the bus, she is sociable and interacts with friends, trying to save one more tree at the community game "Save A Tree!" {My Eco Goals}. Before going to sleep, Maria adds a reminder for the next day's school trip (U, MA); the app will notify her when to leave in the morning and will also inform her about the weather conditions so that she can do some extra exercise in case of a sunny day {My Past Trips}.

5.5.2. The Weekend Entertainment Use Case

On a Saturday morning, John is informed about his weekly progress with a graphical representation and a review of points he has earned {My Eco Goals} in parallel with a suggestion for more eco-friendly ways to spend them, i.e., special discounts for an e-bicycle sale (T, MO). Furthermore, as it is the weekend, he can try walking with his classmates for about an hour and listening to a podcast about saving the Amazonian Forest (U, MA). Then, John shares this event with his classmates {Plan a Trip} and participates in an online competition to win a tablet for his school {My Preferences}. In the afternoon, he searches for destinations to go out (non-touristic spots {Plan a Trip}, a view of suggestions and favorite places from friends and family, expert tips, as well as consumer reviews), itineraries, and suggestions of the desirable means of transportation (U, MA, C). When John is about to leave the cafeteria, he receives a notification to confirm his current location, the permission to save the route and the total distance he did (C) in order to have the calories burned and the carbon dioxide he saved calculated {My Past Trips}. Before going to sleep, John can watch a short video with virtual tours using different modes (multimodal) within his neighborhood {My Past Trips}.

5.6 Methodology for the Assessment of the ESTA Simulations Screens

5.6.1 Instruments and Data Collection

In order to assess the ESTA, a second online questionnaire survey was conducted on six simulation screens (Figures 6, 7 and 8) along with the two use scenarios. The questionnaire was created using the Google Forms service, and it was called *Evaluation questionnaire of the six simulation screens of a mobile transit application named ESTA* (Appendix C). The questions used were open-ended and close-ended (multiple-choice and rating scale), and they were divided into four distinct sections.

The first section of the questionnaire included questions related to the pupils' demographics information. The second section of the questionnaire included questions related to the functional aspects of the interface's interaction for the assessment of the previously mentioned simulation screens using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The third section of the questionnaire included questions related to the acceptance, the usability and the intention of using ESTA on a daily basis, and its goal was to identify potential usability issues. The last section included the two use cases as an essential part of the UCD process. The provided feedback allowed us to explore additional ways to enhance the pupils' interactions and to broaden our goals for the daily use of the app, i.e., the possibility of real-time exchange information service between the pupils, such as seat availability on a crowded metro.

5.6.2 Evaluation of the Validity of the Questionnaire

The variable for the acceptance comprises three items (α=0.79) and represents the "general agreement that something is satisfactory or right" (Cambridge Dictionary, 2020). The variable for the usability comprises four items (α=0.81) and represents "the extent to which specified users can use a product to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context" (ISO 9241-11, 2018). The variable for the intention of using ESTA comprises two items (α=0.76) and represents the willingness to download and use ESTA.

The Cronbach's alpha α coefficients exhibited a range of 0.76 to 0.81, indicating the level of internal consistency reliability (Fornell & Larcker, 1981). The selected measurement items have been derived from relevant literature sources (as shown in Table 11) and have been suitably modified to align with the current research study. The pupils denoted their level of agreement with the statements using a five-point Likert scale from strongly disagree (1) to strongly agree (5).

5.7 Findings and Discussion

Figure 9 shows the overall satisfaction rating scale—from 1 (strongly disagree) to 5 (strongly agree)—concerning the user-friendly app design and the position of on-screen messages on ESTA's screens.

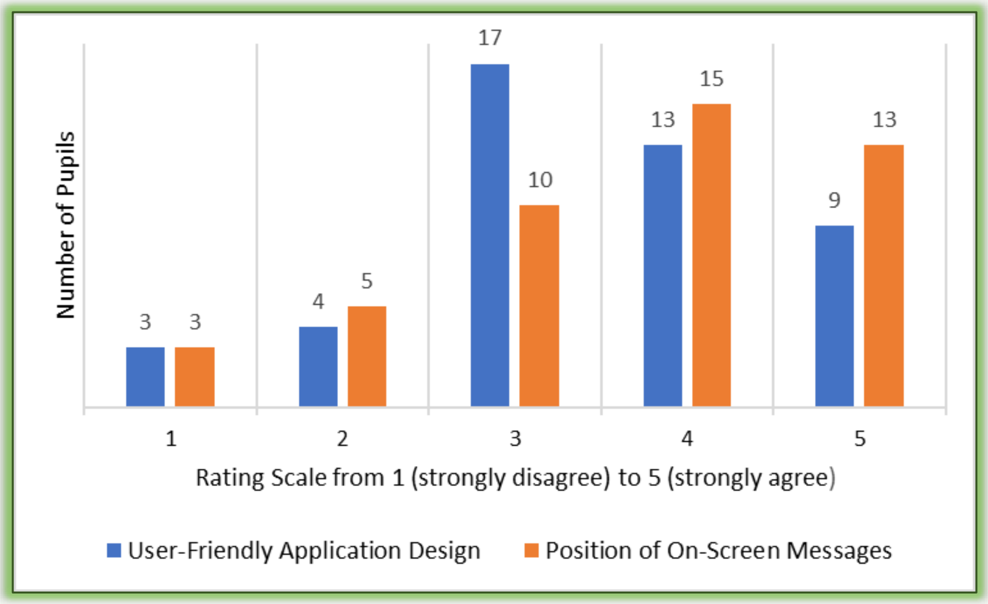


Figure 9. The ESTA simulation screens overall satisfaction rating scale concerning the user interface design and the position of on-screen messages.

According to their suggestions, the pupils would like to see the following features in an upcoming update

- an initial drop-down menu instead of an options list,
- more bright colors, with the blue one having the most preferences,
- a "vivid" background with different environmental awareness pictures in every screen,
- people or animals in the current background's vehicles,
- more clever inspirational slogans,
- a bright new original font with bold letters,
- a mascot-cartoon on the go as a virtual assistant,
- cooperation with celebrities or influencers who would motivate the pupils through video notifications and maybe even challenge users among themselves,
- replacement of some text with icons for improving interface usability,
- maximum one or two actions in every screen, and
- enforcement of a user-level app security policies, including an ensure secure network access, an isolate app information, a robust authentication mechanism and data confidentiality.

Table 11 shows the overall evaluation on accepting, using, and intention to use the ESTA app. It presents the median and the InterQuartile Range (IQR) for all the measurement items. The findings indicated positive perceptions of acceptance, usability and intention to use regarding the measurement items, since the majority of the medians are four and above, and more than half of the IQRs are one. The relatively small IQRs is an indication of consensus. This result indicates that the pupils expect the ESTA implementation in order to test it, and they are willing to use ESTA now and in the future.

Table 11. Overall evaluation of the ESTA

Variables	Measurement items	Quartiles (1 = strongly disagree to 5 = strongly agree)				Reference
		Q1 (Lower)	Q2 (Median)	Q3 (Upper)	IQR (Q3-Q1)	
Acceptance	The content that appeared in ESTA is appropriate for a pupil	3	4	4	1	
	The use of the ESTA is relevant to the pupils' needs for the adoption of sustainable travel behavior	4	4	5	1	
	ESTA works the way I would want it to work	3	4	4	1	Park, 2009
Usability	I found ESTA easy to use	4	4	5	1	Paul et al., 2012
	The language used in ESTA is easily understood	4	5	5	1	
	ESTA has functionality that is easy to understand	4	4	5	1	Venkatesh et al., 2003
	I can use ESTA without written instructions	3	4	5	2	
Intention to use	I am expecting the final ESTA implementation in order to test it	3	4	4	1	
	I think that I would use ESTA frequently	2	3	4	2	Weng et al., 2018

In addition, based on the responses of Table 11 and the feedback provided, the pupils expressed the need for a mobile app with a personalized interface in order to

- be motivated for more eco-friendly transportation and physical activity like walking or cycling daily,
- help the environment,
- have better quality in their daily journeys, more healthily and sustainably,
- obtain a long-term environmental consciousness,
- have access to real-time route information and journey planner,
- gain ecological knowledge and awareness,
- have more options on how to move,
- promote a "greener" transport attitude; get rewards, i.e., free mobile data or talk time, and
- save time on their transits.

The majority of the pupils (N=28, 60.9% answered «yes» and N=13, 28.3% answered «maybe») would recommend ESTA to a friend, and 69.6% (N=32) of them are looking forward to its implementation in order to use it as is, among other answers, «it encourages the pupils to move in a way that benefits both the environment and themselves», «it is a smart idea», «it is very easy to use», «it gives me a chance to win prizes» and «it is in Greek». Moreover, the pupils preferred the usage of high-contrast colors in the user interface. The contrast provided against the background enhances the pupil's visibility while in the action, which is very important for them. In addition, the pupils are attracted to many bright colors (e.g., green, blue) and are willing to easily detect the call-to-action buttons or any other important content.

Besides, not all pupils are triggered by environmental concerns. Some pupils may not be very interested in or eager to establish a sustainable travel behavior just for the sake of the environment. Changing the pupils' transport habits toward greener options or maintaining their existing eco orientation ones, may be achieved by providing them with suggestions that fulfil their transport needs and expectations (e.g., walking, cycling) or their criteria for making transport choices (e.g., journey time). When people incorporate transportation habits that rely more on the use of public transportation and physical walking into their daily routines, they can repeatedly take some actions without paying too much attention.

The pupils also pointed out that it is better to use an avatar as a triggering agent for supporting the eco-friendly attitude. Motivating pupils to use ESTA can be promoted by a daily encouragement via an avatar (character, pet, or cartoon) in an attractive and easy-to-handle user interface. This avatar may potentially be in a "physically" active mode (e.g., cycling, dancing or walking) and facilitate the pupils in setting realistic challenges or goals.

Simultaneously, the pupils asked for real rewards instead of virtual ones. In order to create an effective, rewarding system and for this system to be integrated into the mobile app remains a challenge. This study pointed out that the pupils requested the deployment of a rewarding system which is not just "virtual" (e.g., points or badges) but instead provides specific advantages of urban mobility offers in real life (e.g., discounts on public transport tickets, free vouchers for shopping, free mobile data or phone calls). The benefit attached to this aspect was also considered necessary for the engagement of the pupils in the eco-game within the mobile app, aiming to inform them about the environment and win at the same time.

The pupils also highlighted that mobility travel data should be shared or posted only when it is safe. Nevertheless, they are usually willing to share or post other relevant real-time information about traffic, disruptive events and transport choices. This kind of sharing or posting, though, should also include an option for the use of anonymity (N=14, 30.4%) or for the limited data sharing within a pupil's network of family and close friends (N=10, 21.7%) or both (N=22, 47.8%). Regarding the educational eco-game development, the pupils suggested to create educational games related to the environment for playing with their classmates. They also expressed a preference for games that do not need to be downloaded and installed on the smartphone but can be accessed directly from ESTA.

Finally, the pupils should have confidence and feel comfortable using ESTA. They expressed the willingness for the app to be accessible in a smooth and easy-to-use manner with high-quality traveling information. They also like to be mindful that they can have a personal account and can adapt the user interface of ESTA to their preferences.

The primary outcomes of the ESTA's screens evaluation and the pupils' comments show that the idea of a mobile transit app that works effectively and rewards the users for their environmentally friendly behavior appears to be welcome and very promising. Furthermore, starting education from the early years for the adoption of ecological consciousness and awareness should be an issue that our society ought to consider very seriously. Besides, the personal data protection and use only for the mobile apps primary purpose, along with the option of anonymity and limitation of data sharing within an own pupil network, must be a mandatory functional feature.

5.8 Limitations

The primary limitation to the generalization of the results mentioned above is the relatively small sample; therefore, the results must be interpreted cautiously. The future steps are devoted to the development of a beta version of the ESTA, taking into account the findings mentioned above. This beta version should then be assessed in a larger population of pupils to identify potential or foreseeable consequences resulting from the app’s misuse. Special attention should be paid to situations where computer-mediated persuasion takes place without the user being aware of it. This persuasion may occur when people who create, distribute, or adopt the technology are the ones who have the intention to affect the user’s attitudes or behavior through computers, e.g., discussion forums, e-mail, instant messages, blogs, or social networks.

Furthermore, the design and the development of the ESTA will first consider how the system responds according to the applied persuasive strategies, e.g., immediate feedback provision after the desired travelling change occurs. It will also consider how the system responds to normal or unexpected situations, e.g., limited Internet access or first-mile/last-mile challenges. Finally, the system should be automatically updated to content changes according to last-minute changing mobility patterns, or to potential bugs in order to avoid unsustainable behaviors, e.g., problematic smartphone use.

Chapter 6 ESD in Higher Education: Engaging and Supporting Students in Sustainable Traveling Practices through Mobile Transit Apps

This chapter presents the design and the assessment of seven simulation screens of a mobile transit app mockup based on EPMA. This prospective app aims to engage and support university students in sustainable traveling practices. The "Exploration" and the "Movement" use case demonstrate the potential of the app. Then, the design process and the research methodology for the assessment of the app's screens by the students are analyzed. The chapter concludes by listing the results and the limitations of the research.

6.1 Introduction

At present, the ubiquity of smartphones denotes that people and, especially young people, always have their devices with them. At the same time, young people, often referred to as digital natives, are more comfortable and adept at using technology. The use of mobile apps by young people is pervasive and diverse, encompassing a wide range of apps that cater to various aspects of their lives. This use is dynamic and continually evolving as new technologies and trends emerge. Young people often seek apps that align with their interests, preferences, and lifestyles, contributing to the constant innovation and development of these mobile apps. In light of this, the mobile transit apps align with young people's digital lifestyles, making it natural for them to adopt and use such apps for commuting (Baker-Eveleth & Stone, 2020). In addition, these apps leverage the capabilities of smartphones, such as GPS, to provide accurate location-based services and real-time updates.

The second application of the EPMA framework presented in *Chapter 4* provides an excellent input for the design and the development of such a mobile transit app that the young users and travelers may use. For the purposes of Study One regarding ESD in higher education, university students implemented and assessed a mobile app mockup named Epma_App. Epma_App is designed with the standards to run in the future as a continuously running background service that uses the sensing capabilities of iPhones and Android devices (e.g., GPS, accelerometer) in order to detect, record, and quantify the movements of users.

This app follows a client-server architecture, offering a service infrastructure that provides a set of core mobility together with social networking services guarded by a security layer. Correspondingly, the mobile client comprises components for graphical user interfacing, mobile sensing, and secure communication with the server. The Epma_App server consists of core services (i.e., mobility monitoring, essential social network services, and rewards) and programming interfaces (i.e., transit data log, feedback, journey planner, and questionnaires).

6.2 The Simulation Screens of the Epma_App

During the initial phase of the Epma_App design, seven simulation screens were developed (Figures 10, 11 and 12) using the Justinmind Prototyper 8.7.4 (https://www.justinmind.com/) tool. The involved design elements include, among others, the content layout, the color scheme, the typography, the spacing, the navigation visuals and the images. In addition, Epma_App includes a set of features specifically designed to support the users in each stage of their travel behavior change according to the EPMA framework.

Table 12 presents these features and components on each screen. The connections to the EPMA stages and the change processes are also shown. The common element in these screens is the positive reinforcement every time a traveling attitude change occurs and the collection of the desirable travel data. The data collection must follow *a privacy policy* (example in Appendix D). This policy describes the actions and procedures for collecting, using, and disclosing user information when they use Epma_App and informs about privacy rights and how the law protects the user.

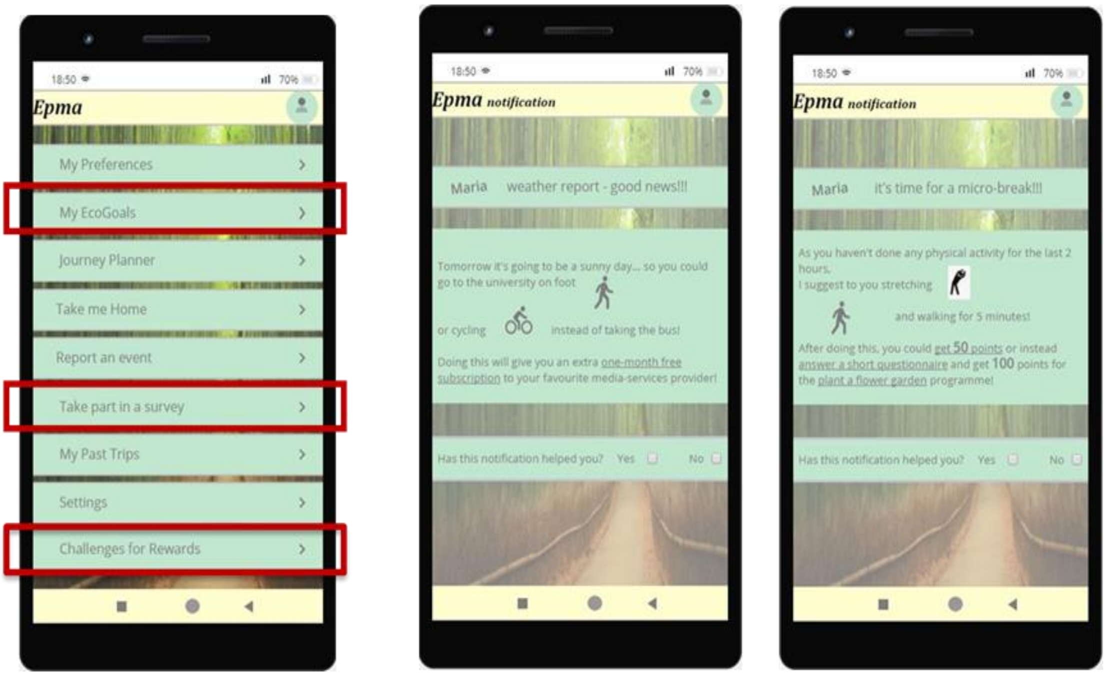


Figure 10. The Epma_App (a) *Home Screen* includes options for personalization, challenges and goal setting and rewarded online feedback; (b) *Notification Screens* integrate personalization, motivation (rewards) and assessment (confirmation of the user)

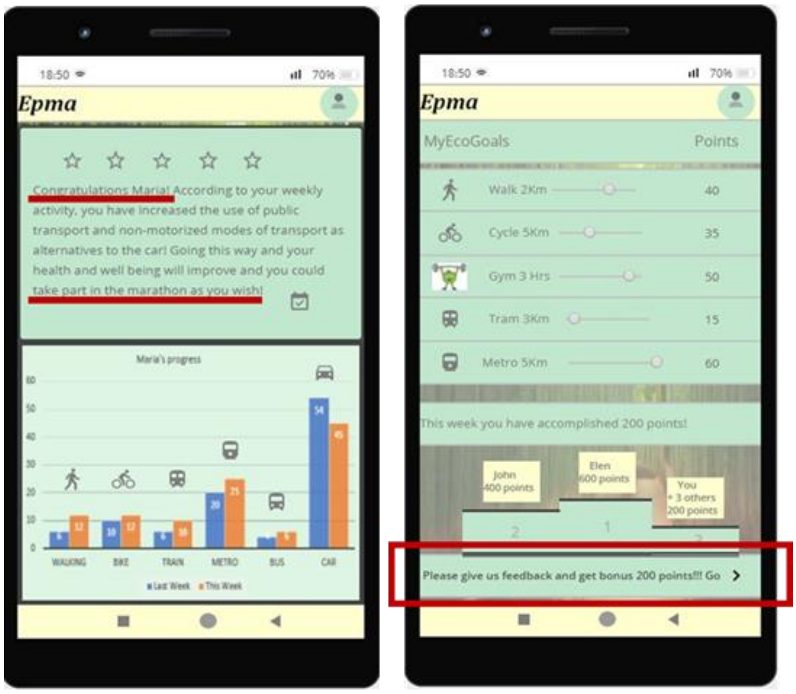


Figure 11. The Epma_App (a) *Progress Screen* integrates weekly reflection, suggestion, recognition, and goal setting; (b) *My EcoGoals Screen* integrates recognition via praise, effort and prizes, social network and recognition

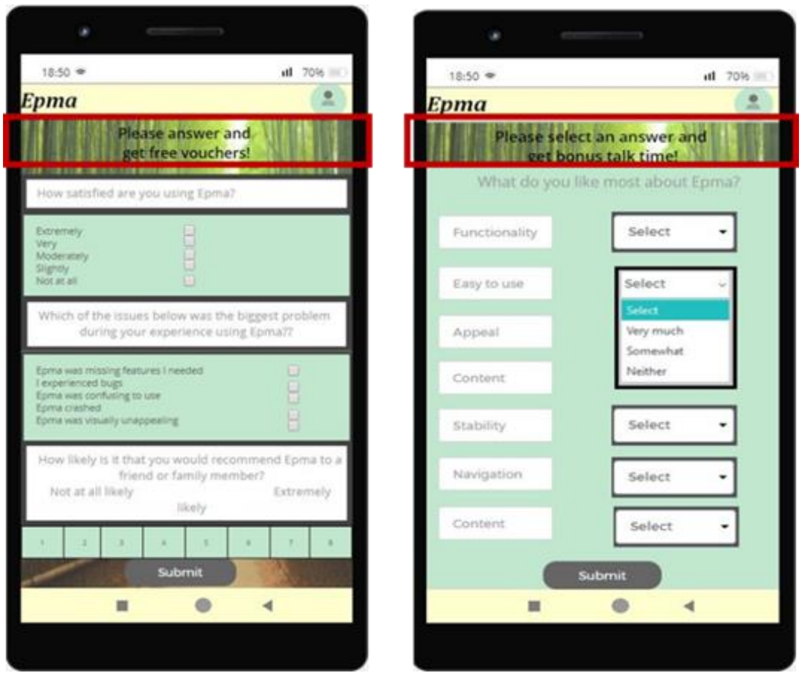


Figure 12. The Epma_App *Collecting Data Screens* for the actual evaluation of the Epma_App according to the daily use with immediate bonus

Table 12. Features and components of the Epma_App, according to the stages of the EPMA framework

Stage of the EPMA framework	Simulation Screen of the Epma_App	Features – Components of the Epma_App
Triggering	*Home* Figure 10(a)	"My Preferences" - User profile, preferences and statistics (personalization) "Journey Planner" - Route advice and live step-by-step directions for guiding the best route from one place to another according to the criteria of the user "Take me Home" - Save favourite locations or routes for active recommendations and suggestions according to the needs of the user "My Past Trips" - Save previous trips' history "Settings" - Set the modes of transport (public, private, and shared) with the location of stations, language, currency converter, notifications, maps, privacy issues
Motivating	*Notification* Figure 10(b)	Personalized messages with alternative activities adapted to the preferences and the daily routine - schedule of the user to improve the travel habits through rewards and confirmation
Utilizing	*Progress* Figure 11 (a)	Personalized positive feedback - notification encouraging the use of the non-motorized mode of transport (recognition) Suggestion - Goal setting Weekly visual report – reflection on the progress of all the transport modes used this and last week
Maintaining	*My EcoGoals* Figure 11 (b)	"My EcoGoals" - Summarizes the progress for ongoing different activity categories and shows the collected points Use of the progress bars for goal-setting Notification system to stimulate action maintenance Social comparison with other users and achievement of common goals Badges - Podium Extra points may be earned with the user feedback (reward)
Collecting	*Collecting Data* Figure 12	"Take part in a survey" - Short questionnaires with immediate bonus features are provided to encourage the user to give feedback Satisfaction checkbox

6.3 Use Cases

The potential positive contribution of Epma_App for supporting the sustainable mobile traveling attitude of the students is demonstrated via two use cases. Each of them is based on the proposed actions in Section 4.3 related to the stages of EPMA. The first use case is addressed toward a student who may use the public transport modes or hire a taxi instead of taking the subway for sightseeing. The second one is addressed toward a student who either intends to go to university or move within their area of residence. In the following description, the initials into parentheses refer to the EPMA stages that may be involved in the use of the app, namely *Triggering* (T), *Motivating (*MO*), Utilizing* (U), *Maintaining (*MA), and *Collecting* (C). In contrast, the information into brackets refers to the *Home Screen* menu options of the Epma_App.

6.3.1 The Use Case Exploration

After arriving at a specific location, a student may want to check (T, C) some points of interest and various nearby places for different kinds of services (washroom, restroom, cafe, hotel, or local attraction) based on her preferences {My Preferences, Journey Planner}. The system enables the student to set (T, MO) when and how they can be notified with pushing notifications based on specific parameters (e.g., points of interest that are located around her or a specified period for going somewhere) {My Preferences}. Meanwhile, the student could search (U, MA) for destinations and itineraries, choose the desirable means of transportation, or even book a taxi or a hail ride online {Journey Planner, Take me Home}. The student may also receive offers for free tickets or rides, set up schedules, and store customized e-tickets and QR codes, even if there is no connection to the Internet {Challenges for Rewards}.

The student could also have (T, MO) a language translator when they travel to a variety of countries and might not be familiar with the regional language for immediate feedback (T) {Settings}. At the same time, the student could find (U, MA, C) booking services and best deals for tickets according to the proper and expected use of the app with rewarding services and set up notifications for price changes {My EcoGoals, Challenges for Rewards}. Non-touristic spots and places to visit, a view of suggestions and favorites from friends and family, expert tips, as well as consumer reviews could also be provided (MO, C) to the user with personalized messages based on their preferences and travel background {My Preferences, My EcoGoals, Take part in a survey}. The extra features of time and currency converters (T, C) could help international travelers to feel more comfortable and safer {Settings}.

6.3.2 The Use Case Movement

A student can create a personal account at the online platform of the transport service provider and test the app (T, U) for a short period with some benefits, e.g., free tickets or rides {My Preferences, Challenges for Rewards}; they could provide the system with all the necessary information for offering (MO) to her localized suggestions and deals or offers, based on her location and preferences {My Preferences, Journey Planner, Take me Home}. This information may include personal data, daily travel starting points and destinations with desirable alternative routes, favorite transport means, and an upper-cost limit.

Furthermore, the student can compare and even choose to combine (MO, U, MA) any transport mode they wish to use, i.e., train, bus, or share a car, and earn personalized incentives like gift cards to their favorite stores and restaurants {My Preferences, Journey Planner, Challenges for Rewards}. They could also add a reminder (U, MA) to their trip, and the app will notify them when to leave {Settings}. Epma_App may predict (T, MO) the next destination of the student according to their past trips, their history of travel behaviors and preferences and automatically plans trips and proactively suggest {Challenges for Rewards} best possible travel times, alternatives routes, and modes of transportation between home, work, and events based on her calendar with rewarded feedback (C) {Take part in a survey}.

The system could program and deploy tailored {My Preferences} information campaigns (T) to achieve the desired outcomes, such as utilizing public transportation or avoiding peak congestion periods with critical alerts and service disruptions regarding the favorite lines of the citizen (U, MA). These campaigns could give the student a chance to win some prizes (MO), e.g., reward points or a free subscription, via energy feedback (C) {Challenges for Rewards, Take part in a survey}. Furthermore, the student could make mobile payments for transit and bike rentals (U, MA) with extra discounts or free tickets (MO) if she is giving feedback information (C) {Take part in a survey}.

6.4 Methodology for the Assessment of the Simulation Screens of the Epma_App

The assessment of the simulation screens of Epma_App has as a primary goal to capture the attitudes and the perceptions of the students related to whether they are willing to change their traveling habits and adopt the use of a transit app in their daily routine. The term attitudes refers to the tendencies and the predisposition of the individual to respond to particular events. Thus, it contains the element of subjectivity and the evaluation of the basic parameters of the condition under research. On the other hand, the perceptions of an individual are connected to the beliefs that are relevant to an object or a situation but strongly include the element of subjectivity (Baker-Eveleth & Stone, 2020).

Furthermore, the assessment aimed to reveal the students' level of satisfaction with a prospective app that embeds the functionality of the EPMA framework and supports ESD. Moreover, the assessment aimed to explore the students' familiarity with such apps and their readiness and intention to use an app by regularly providing feedback. These findings are expected to support our future phase of the Epma_App design, which will be the development and the testing of the app.

6.4.1 Instruments and Data Collection

The assessment was performed using an electronic questionnaire survey that included the two previously described use cases. This online questionnaire was created using the Google Forms service, and it was called *Evaluation questionnaire of the seven simulation screens of a mobile transit application named Epma_App* (Appendix E). The questions used were close-ended (multiple-choice, matrix, and rating scale) and open-ended, and they were divided into three distinct sections.

The first section included questions related to the demographics information of the student, the daily travel attitudes, the systematic use of the smartphone, and the intention to gain a more sustainable travel behavior via a mobile transit app. The second section included the simulation screens (Figures 10, 11, and 12) and questions related to the rating of these screens using a 5-point scale (1 = strongly disagree to 5 = strongly agree). The last section included questions related to identifying potential usability and interface interaction issues (Table 16), the acceptance and intention to use Epma_App (Table 17 and Table 18), and finally, the suggestions of the students for the improvement of the Epma_App.

The distribution of the questionnaire was made by sending the electronic address of the questionnaire (https://forms.gle/xfAq3jFXe8u4 beUy6/) via email because of the restrictive measures implemented due to the COVID-19 pandemic, in a public university in the capital city of Greece. The completion period was September - November 2020.

6.4.2 Evaluation of the Validity of the Questionnaire

The evaluation of the validity of the content as far as the acceptance and the intention to use Epma_App, has been performed using the Technology Acceptance Model (TAM) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). TAM clarifies and analyses the factors that influence the use of information technology and assesses the acceptance of technology by its perceived ease of use and its perceived usefulness. UTAUT expands TAM by incorporating multiple elements that can best explain the adoption process of the appropriate communication technology. These elements include the performance expectancy, the effort expectancy, the social influence, and facilitating conditions that influence behavioral intention to use these communication technologies. Several alterations have been conducted to adequately confront our research to evaluate the simulation screens in mobile transit apps, as described next.

The questions for the acceptance and intention to use Epma_App are composed of 18 items grouped into four variables: effort expectancy (α=0.79), performance expectancy (α=0.78), motivation (α=0.82), and intention to use Epma_App (α=0.86). The Cronbach's alpha α

indicator values ranged from 0.78 to 0.86, determining internal consistency reliability (Fornell & Larcker, 1981). The effort expectancy represents the degree of ease in the use of Epma_App. The performance expectancy represents the degree of the belief of a participant about the benefits of using Epma_App. The motivation represents the pleasure derived from using Epma_App and may underline the final decision to use it. The intention represents the potential adoption of Epma_App upon the development and loading of a beta version in the mobile stores (Venkatesh et al., 2003; 2012; Wang & Wang, 2010). The measured items are based on the pertinent bibliography (references in Table 17) and adapted appropriately for the presented research. The participants denoted their level of agreement with the statements using a five-point Likert scale from strongly disagree (1) to strongly agree (5). In addition, this last section of the questionnaire included seven open-ended questions about the positive and negative features of Epma_App and the suggestions, thoughts, and remarks of the participants for its future implementation.

6.5 Findings and Discussion

6.5.1 Students Demographics Information

The answers received were 113: 72 men (63.7%) and 41 women (36.3%). The participants are overall young, with an age range of 18-24 for the 62.8% (N=71) of them, 25-34 for the 27.4% (N=31), 35-44 for the 8.8% (N=10) and 45-54 for the 0.9% (N=1). Most of the participants are highly educated, with 59.3% (N=67) reporting that they have completed a college-university diploma or degree, 30.1% (N=34) a postgraduate-PhD degree, and 10.6% (N=12) a high school diploma. The current employment status was a student for 58.4% (N=66), full-time employed for 26.5% (N=30), part-time employed for 8% (N=9), self-employed for 2.7% (N=3) and unemployed for 4.4% (N=5).

6.5.2 Travel Habits and Use of the Smartphone

The participants surveyed conduct an average of M=3.19 (±1.49) routes per day, while the four (4) routes per day are the most common (N= 42, 37.2%), and the two (2) routes per day come next (N=39, 34.5%). Only two (1.8%) participants conduct more than six daily trips, which is relatively unusual. Every day, most of the participants (N=60, 53.1%) spent more than 30 minutes travelling to and from work-education, while 44.2% (N=50) spent less than 10 minutes for pick up - drop off. The most common travel duration for leisure, entertainment, or shopping is 10-15 minutes.

Figure 13 illustrates the breakdown of the primary transport mode by gender and by activity. We observe that men drive cars more frequently than women (1.4 times more), making them more prominent car drivers. On the other hand, the women use 1.9 times more than the men the means of metro or tram and rarely a scouter or motorbike. The car or taxi is the most popular primary transport mode for leisure, shopping, and pick up-drop off (the last activity has the highest percentage, 50.4%, N=57). The metrics for multimodal trips (use of transport modes combination) indicate that the 20.4% (N=23) of the participants make only one (1), the 30.1% (N=34) of them make two (2), and the 13.3% (N=15) make three (3) while the 28.3% (N=32) of them do not use any combination.

Figure 13. Primary transport mode used by gender and activity

Table 13 shows that environmental protection is one of the top three primary reasons to reduce car use as the primary transport mode. All the participants own a smartphone or a tablet. The most popular apps they use include messaging (N=81, 71.7%), followed by social networking (N=77, 68.1%), searching tools (N=67, 59.3%), and travelling and maps (N=27, 23.9%). We also observe that the participants used the least weather forecasting and health apps (N=5, 4.4% and N=3, 2.7%, respectively).

Table 13. Primary reasons to reduce car usage as the main transport mode

Reasons	Relative Frequency (f %)	Frequency (N)
An extensive public transport system	56.6	64
Environmental protection	37.2	42
Avoidance of traffic congestion	35.4	40
A limited car parking area	31.0	35
Low cost of public transport modes - Saving money	29.2	33
Real-time transport information on the smartphone	23.9	27
Wish for physical activity	23.9	27
Saving time	20.4	23
A well-organized bike-car-scooter sharing system in the city center	8.8	10
Avoidance of tolls	4.4	5
Social reasons	0.9	1

6.5.3 Intention Toward Sustainable Travel Behavior

The majority of the participants (N=88, 77.9% answered «yes» and N=20, 17.7% answered «maybe») are interested or prepared to change their behavior just for the sake of the environment. In addition, they would be willing (N= 80, 70.8% answered «yes» and N=27, 23.9% answered «maybe») to use a mobile transit app to obtain a more sustainable travel behavior. Table 14 shows the features of the app that participants like to have in order to use it daily.

Table 14. Features that participants like to have in a mobile transit app in order to use it daily

Features	Relative Frequency (f %)	Frequency (N)
Set an accurate journey planner	86.7	98
Integrated e-ticket payment by combining all the available options, including all the transport modes	68.1	77
Share/post-real-time information about traffic, disruptive events and transport choices	65.5	74
Ticket price information for public transport, taxis, tolls, and car parking	65.5	74
Real-time notifications about parking (availability, pay-by-phone options, alerts on remaining parking time, and reminders about where the user parked her vehicle)	63.7	72
Compare trip costs for all alternative routes and show daily travel costs	63.7	72
Set reminders or get notifications about a scheduled trip	35.4	40
Collect points or get rewards (e.g., free public transportation tickets, free/cheaper parking for people who carpool to work)	35.4	40
Learn more about environmental sustainability with relevant information, carbon footprint calculation, etc.	31.0	35
Give feedback on travel options provided	24.8	28
Suggest travel options to other users	24.8	28
Share with other users relevant information about mobility and updates on the traffic situation	15.9	18
Play eco-Games	8.8	10

Figure 14 illustrates the rewards that the participants wish to get or win whenever they choose more "green" travel options. Only 2.7% (N=3) believe that rewarding is not as important as the effectiveness and the usefulness of the app.

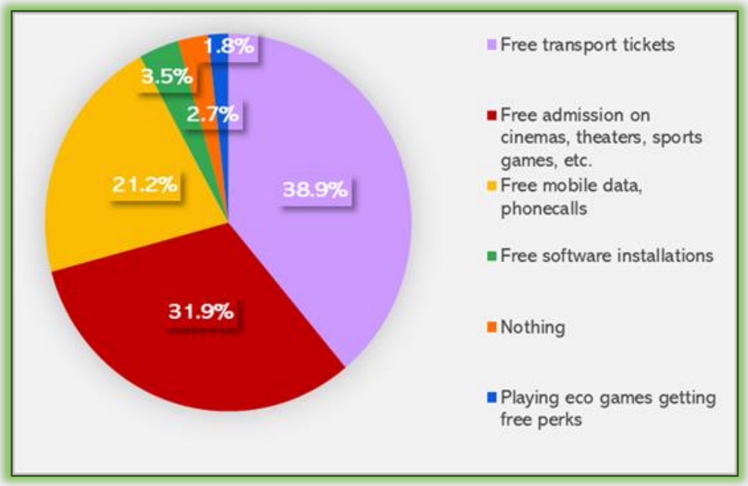


Figure 14. Desired rewards for the use of "green" travel options

Table 15 shows that most participants are concerned about privacy and personal data protection related to the data collection while using the app. It is undeniable that mobile devices increasingly collect and process more information about their users and have the power to access, transfer, and store data, often without the user knowing. Subsequently, the processing of personal data through such tools poses significant risks to the security and the privacy of the users. Such risks stem mainly from the variety of data and sensors held in mobile devices, the use of different types of identifiers and the extended possibility of tracking of the users, the complex mobile app ecosystem, and limitations of app developers as well as the extended use of third-party software and services.

Table 15. Privacy and personal data protection concerns related to the data collection during the Epma_App use

Concerns	Relative Frequency (f %)	Frequency (N)
The mobile transit application must collect only the data that are strictly necessary to perform the lawful functionalities as identified and planned	78.8	89
The user must be able to choose which data to share with other users or with third-party services	71.7	81
The application must be hack proof	61.1	69
The personal data must be protected when stored through effective encryption	51.3	58
The application should ask for access to the camera, the contacts, or the photos of the user	2.7	3
The application must delete all the data generated after signing out	2.7	3

6.5.4 Assessment of the Epma_App Screens and Suggestions

Table 16 shows the overall satisfaction from the simulation screens related to the user interface design and the layout of the on-screen messages. We observe that the medians are 3 and above, implying that most participants have positive perceptions of these screens and a high satisfaction. In addition, the relatively small IQRs is an indication of consensus.

According to the views and suggestions of the participants, the screens of the Epma_App should integrate the following features in an upcoming implementation or update:

- *Assistive features for persons with disabilities* (permanent or temporary) - such as inclusive information about wheelchair accessibility or voice navigation for blind users.
- *Extra details on the daily physical condition* of the user according to the transport modes used with improvement tips.
- *Animated buttons*, *switches, toggles and other interactive elements* which inform the user (e.g., weather forecast) or suggest an activity (yoga lessons) in split seconds, activating all the potential of fast visual perception.
- *A reminder* selected by the user, e.g., a bar at the top of the screen showing her current transit choices.

In addition, Epma_App should enable the best mobile app security practices:

- All data requests, the account information, and the user-related data must be securely removed when a sign-out is triggered.
- All app data should be encrypted with secure encryption.
- The app cannot store sensitive data on the file system.
- The app should prevent any data from being locally transferred, i.e., copying it or sending it to an unauthorized external source.

Table 16. Overall satisfaction rating scale related to the user interface design and the layout of on-screen messages of the Epma_App

Screens	Measurement items	Quartiles (1 = strongly disagree to 5 = strongly agree)			
		Q1 (Lower)	Q2 (Median)	Q3 (Upper)	IQR (Q3-Q1)
Home Screen	User interface design	2	3	3	1
	Layout of on-screen messages	3	3	4	1
Progress Screen	User interface design	3	4	4	1
	Layout of on-screen messages	3	4	4	1
Challenges Screen	User interface design	3	4	4	1
	Layout of on-screen messages	3	4	5	2
Collecting Data Screens	User interface design	2	3	4	2
	Layout of on-screen messages	3	4	4	1
Notification Screens	User interface design	2	3	4	2
	Layout of on-screen messages	3	4	4	1

Furthermore, the participants pointed out the need for a less cluttered interface without too many options. The default page should have only a few navigational buttons at the top, and the rest of the screen should be filled with attractive pictures. Besides some other suggestions related to the interface are:

- Use of *signifiers or familiar symbols* which bypass the need for explanations, creating a more intuitive and easy-to-use site.
- Use of *blue color*– the most popular color on the Internet – and red color, which make the interface more visually calming and stimulating, respectively.
- Apply an approximate *symmetry*, which usually involves one large element next to a collection of multiple smaller elements.
- Maintain *consistency* of user interface elements across the different screens.
- Use of high-quality and artistic *photos* of real people rather than objects
- Use of *full-screen background images* with safe, clean environmental visualizations and use and maintenance of bold and catchy typography (typefaces, font sizes, spacing, etc.).

Finally, regarding the triggering and motivation for using Epma_App, the participants suggested that the users should be immediately greeted with an explosive, fun-filled, dynamic video of the content in use upon loading the app. They also suggested the inclusion of a cooperation with celebrities or influencers who would motivate the user through video notifications and maybe even challenge users among themselves. Moreover, they proposed the inclusion of specially designed characters in order to storytelling the "green purpose", set the environmental awareness atmosphere, send the eco message or present the benefits of using the app.

6.5.5 Perceptions of and Intention to Use Epma_App

Table 17 shows the overall assessment of the Epma_App by presenting the median and the IQRs for all the items that correlate the acceptance determinants with the intention to use Epma_App. The findings indicated positive perceptions of effort expectancy, performance expectancy, motivation, and intention to use regarding the measurement items, since the majority of the medians are 4 and above, and more than half of the IQRs are 1. Thus, participants are willing to use Epma_App now and in the future and to recommend their friends to use it.

Table 17. Overall assessment of the Epma_App

Variables	Measurement items	Quartiles (1 = strongly disagree to 5 = strongly agree)				Reference
		Q1 (Lower)	Q2 (Median)	Q3 (Upper)	IQR (Q3-Q1)	
Effort expectancy	I found Epma_App easy to use	4	4	5	1	Paul et al., 2012
	Epma_App was not unnecessarily complex	4	5	5	1	
	I can use EPMA without written instructions	4	4	5	1	Venkatesh et al., 2003
	Epma_App works the way I would want it to work	3	4	5	2	
	The language used in EPMA is easily understood	4	4	5	1	
	The prompts for input/post are effective in making you want to contribute	2	3	4	2	
Performance expectancy	The different screens of the Epma_App are cohesive in look and feel	3	4	4	1	
	Epma_App has clearly marked way-finding buttons (exit, back, next page, etc.)	3	4	5	2	
	Epma_App has functionality that is easy to understand	3	4	5	2	Park, 2009
	Epma_App does everything I would expect it to do	3	4	4	1	
	The use of Epma_App is relevant to the user needs for the adoption of sustainable travel behavior	4	4	5	1	
	Using Epma_App was an enjoyable experience	3	4	4	1	Park, 2009
Motivation	I am motivated to use Epma_App in order to discover more healthy and sustainable options in my daily journeys	2	3	4	2	Chang et al., 2006
	I am motivated to use Epma_App in order to get rewards	4	4	5	1	
	I am motivated to use Epma_App in order to be informed of environmental actions in the city	3	4	5	2	
Intention to use	I think that I would use Epma_App frequently	2	3	4	2	Weng et al., 2018
	I would recommend Epma_App to a friend	4	5	5	1	
	I am expecting the final Epma_App implementation in order to test it	3	4	4	1	

Table 18 presents the means, standard deviations, and bivariate correlations for the latent variables of gender, performance expectancy, effort expectancy, and motivation, which were identified as factors influencing the intention to use Epma_App. These findings reveal that the acceptance variables were positively correlated with each other and negatively with gender. The intention to use correlated positively with all variables except gender, which does not affect the potential use of Epma_App. The level of performance expectancy (M=3.83), effort expectancy (M=3.83), and motivation (M=3.7) associated with the intention to use Epma_App, as noted by the participants, were moderate.

Table 18. Zero-order correlations, means, and standard deviations of gender and latent variables for the intention to use Epma_App

	Gender 1-woman 2-man	Effort	Performance	Motivation	Intention to use
Gender	1				
Effort	-0.17	1			
Performance	-0.20	0.39**	1		
Motivation	-0.26	0.54*	0.32**	1	
Intention to use	-0.23	0.45*	0.31*	0.67*	1
Mean	1.64	3.83	3.83	3.7	3.45
Standard Deviation	0.4	1.07	0.95	0.98	1.01

*p<0.05; **p<0.01

The degree of the correlation between performance expectancy and intention to use Epma_App (r=0.31, p<0.01) indicates that there is a strong positive relationship between these two variables. This relationship agrees with many literature findings that suggest that performance expectancy significantly and positively influences one's behavioral intention to accept and use a system (Chau et al., 2004; Venkatesh et al., 2003). The strong positive relationship between effort expectancy and intention to use Epma_App (r=0.45, p<0.05) implies that if participants perceive that the mobile transit app is easy to use and understandable, it will improve their intention to use it. This perception is in line with the literature, which explains that effort expectancy is a highly significant factor in influencing the intention to use a mobile app (Venkatesh et al., 2003).

In turn, the results indicate a strong positive relationship between motivation and intention to use Epma_App (r=0.67, p<0.05), which demonstrates the strong effect of triggering on the trial and the possible continuance use of the app when participants want to discover more healthy and sustainable travel options and get rewards.

According to their responses, the participants have the intention to use Epma_App in order to be motivated for the systematic use of eco-friendly alternative means of transport, improve their physical fitness and obtain ease in daily commuting with more options and carbon footprint mitigation. Moreover, they are eager to use Epma_App to get information about environmental actions in the city, to reduce the adverse health impacts of climate change, and to raise awareness of global change at a local level. Furthermore, they are also willing to use Epma_App to gain a long-term ecological empathy and environmental sensitivity, to discover more healthy and sustainable options in their daily journeys, to get rewards, i.e., free mobile data, talk time, free shows tickets, coupons for Netflix and finally, to succeed more efficient and time saver transits.

6.6 Limitations

Some limitations to this research need to be acknowledged. The assessment of the Epma_App was based on simulation screens instead of a beta version, and the analysis was based on a sample size of 113 participants, most of them in a university community. Thus, the participants of this study may not represent an average sample of the users of mobile transit apps.

In addition, as this proposal contains the collection and analysis of personal data and sensitive information, security, privacy, and safety aspects must be considered by design and by default. More precisely, all data transmission, processing, and storage aspects must comply with the international legislation for GDPR. One of the most crucial requirements of the GDPR is to acquire the consent of the user before collecting or processing their personal information. Besides, the user must have the right to access what information is shared with the app and ask how exactly it is used; the right to be informed and be requested for consent each time the app gathers any data and how exactly this data will be used; the right to stop the processing of their information at any time of the app use.

We should further examine and work on the fact that this data collection requires a strong user commitment and engagement. Furthermore, the app should recognize and be cautious about the appropriate time for persuasive interventions and the relevant information that should be collected. The requested feedback should not repeatedly disturb and interrupt the traveler and should be adaptive to their personality.

Study Two ESD in In-School or Formal Education

Chapter 7 ESD in Class: Integrating ESD in a Smart Classroom Learning Environment

This chapter deals with an essential element of the in-school or formal education: the classroom and how it can support ESD. It introduces a conceptual model for integrating education that enables and actively promotes the cultivation of the students' environmental awareness in a smart classroom learning environment. The components of the model, which has the students and the teachers in its center, are then listed and described analytically. The chapter concludes by listing the limitations of the model and the future suggestions for the implementation in a school that could realize high learning experiences, high-quality content, and high teaching efficiency, focusing on sustainability.

7.1 Introduction

Over the past several decades, there has been a relatively swift evolution of technological milestones in education, particularly within the classrooms, proving that this revolution will likely become even more vital in the future. Although computers began to be used in schools in the 1970s and 1980s, computer labs weren't very common until the 1990s as they started to progress quickly into the 21st century.

Before the COVID-19 pandemic, many educational organizations were already looking to implement more technology in the classroom, securing a "one-to-one policy" in which every student would be supplied their own electronic device, whether a tablet, personal computer, etc. With the flourishing amount of technology in today's world, many teachers have adapted ways to teach students by utilizing the technology in classroom environments. Indeed, the technology has made educators rethink the way that they teach their lessons and promote learning for their students while this technology is constantly changing and evolving.

As the COVID-19 pandemic began sweeping the world in early 2020, schools began scrambling to figure out ways to keep students engaged with classroom curricula from the comfort of their homes. Because remote learning was the only way to support schools and students during the lockdown, the rapid development of tools such as video chat and creative online assignments pushed education to online environments (Angelaki et al., 2020d). For this reason, the COVID-19 pandemic accelerated the adoption of a class structure likely to be shaped by a complex interplay of factors, including technological innovations, economic conditions, and societal values. At the same time, the pandemic brought into focus a trend that had been developing for years, especially in higher education, but with almost no urgency - a greater capability to teach and learn from anywhere because access to the educational content does not require proximity but rather a connectivity.

Technology has been gradually making its way into the classroom, with the desire in recent years that digital books and digital assignments could replace worksheets and textbooks while also giving students a plethora of information literally at their fingertips. Integrating ESD into this modern technology-enhanced classroom is essential for preparing students to be responsible and informed global citizens who can contribute to a more sustainable future. ESD is a crucial component of modern education that aims to equip students with the knowledge, skills, values, and attitudes needed to address the complex challenges of sustainability and create a more sustainable future. The rapid advances in technology and the need to develop more efficient and creative classes that support both in-class and remote activities evolved the term *Smart Classroom* over time, and nowadays, this term reflects the technological advancements incorporated in educational spaces (Kwet & Prinsloo, 2020).

Smart classrooms and ESD are two interconnected concepts that can significantly shape a more sustainable and environmentally conscious future. In general, smart classrooms can serve as a powerful platform for advancing ESD. They provide the tools and resources needed to educate and engage students in understanding and addressing the complex challenges facing our planet while also modeling sustainable practices within educational institutions. This combination can play a crucial role in shaping environmentally conscious and responsible citizens who are prepared to contribute to a more sustainable future. It addresses environmental concerns and social and economic dimensions, preparing students to be responsible global citizens capable of navigating the challenges and opportunities of an ever-changing world.

7.2 The Concept of a Smart Classroom

The smart or intelligent classroom as a concept was introduced several years ago. In the existing literature, one may identify several definitions and good practices for implementing the smart classroom concept. A smart classroom utilizes various software and hardware tools to achieve its educational goals. It can be seen as a technology-enhanced classroom that fosters teaching and learning opportunities by integrating learning with technological tools (Kwet & Prinsloo, 2020). Thus, it should not be connected with the conventional classroom, which is equipped with certain education technologies, such as projectors and overheads, as it was in the early days. It can be viewed as a transformative strategy to transition from traditional working methods to a meaningful, engaging and connected digital way of working (Al-Sharhan, 2016).

The smart classroom concept has evolved from a broader concept: the distance education paradigm that utilized the Internet as a medium to transform a conventional classroom into an intelligent space equipped with several hardware and software components (Shi et al., 2020). It could also be seen as an intelligent classroom that enables teachers to use a real classroom-type teaching approach to teach distant students (Pishva & Nishantha, 2008).

The first generation of smart classrooms, during the years 2001-2007, was primarily focused on the synchronous delivery of educational content to the students in the actual physical classroom using the face-to-face teaching mode or in remote locations using the online teaching mode (Uskov et al., 2015). The second generation of smart classrooms, from 2008 until now, has mainly been based on the active use of ICT by the students and the automatic communications between them and the smart classroom environment. Within a smart classroom, the students do not simply browse information passively. Instead, they can create, attach, connect, and distribute educational content from one location to another and from one group to the next (Simon et al., 2003).

In this way, a smart classroom is an educative space equipped with technology in different senses, from the incorporation of digital devices and learning software to the inclusion of sensor networks. This technology may help to provide more convenient teaching and learning conditions for educators and students through the processes of tracking the classroom, gathering data and offering insights to aid the decision-making for better and faster learning (Cebrián et al., 2020). Many smart classroom researchers realize that with the help of ICT, inquiry, collaborative, group, mobile and ubiquitous learning are established (Gligorić et al., 2012; Lin et al., 2010). Moreover, several pedagogical cases stress the adaptive abilities of the smart classroom for the support of the individual and interactive learning simultaneously (Li et al., 2015).

Table 19 presents the components that constitute a smart classroom in terms of hardware (devices and technological equipment), software (apps and emerging technologies), environmental conditions of the classroom, implementation of activities during the teaching process and, finally, the types of learning or pedagogy that may be used (Al-Hunaiyyan et al., 2017; Cebrián et al., 2020; Isaksson et al., 2017; Kim et al., 2018; Liu et al., 2017; MacLeod et al., 2018; Saini & Goel, 2019). A smart classroom is mainly associated with the teaching of learning content related to science.

Besides, Table 19 shows that a smart classroom employs action-oriented, innovative pedagogy, such as cooperative inquiry and collaboration amongst the students, as well as experimentation, project-based learning, and learning by doing. These methods allow such flexibility and adaptability of the learning space; thus, methodologies that address sustainability challenges can easily be adopted. Some established pedagogies related to sustainability and transformative education include community service-learning, critical emancipatory pedagogy, environmental education, participatory action research, pedagogy for eco-justice and community, and traditional ecological knowledge (Sipos et al., 2008).

Table 19. Components of a smart classroom

Hardware - Equipment	Software – App	Environmental conditions	Activities	Types of learning or pedagogy
Audio-video elements - 3D projectors - 3D printers	Learning management systems	Architecture (promotion of green materials)	Communication between the local and remote students	Collaborative learning
Internet and Bluetooth-enabled devices	Security system for log-in and log-out of a registered student	Functional design (reduce energy consumption)	Collection of data from sensors and export reports related to the students' performance, participation and interest	Participatory learning
PCs with touch screens	Software systems to support students with special needs	Control lighting (natural or artificial) -Acoustic (outside and inside)	Voting regarding an issue in a student group with local and remote students synchronously	Learning by doing
Interactive whiteboards, digital pens	Apps for drawing on smart whiteboards and navigating	Classroom temperature - Humidity	Adjusting by voice commands or automatically the classroom environment, e.g., lights, temperature	Flipped classroom pedagogy
Wearable devices (smartwatches)	Advanced software for multimedia, control and processing	Air quality (oxygen levels, carbon dioxide concentration, smell)	Learning and discussing educational content using multimedia and communications tools and devices	Storytelling-based learning - Games-based learning
Wireless sensor and recognition systems	Recognition software and motion or gesture stabilizing software	Recycled material use - Spatial arrangement	Learning and discussing educational content using multimedia and communications tools and devices	Systemic thinking and analysis with the use of real-world case studies

Moreover, a smart classroom could enable students to develop knowledge and awareness and take action to transform society into a more sustainable one. These expected results could be accomplished by including sustainable development issues, such as climate change and biodiversity, into teaching and learning. It will be easier to stimulate the students' environmental knowledge motivation in a smart classroom environment, promote the students' active sustainable behavior, and achieve good learning performance (Liu et al., 2011). Students would, thus, be encouraged to be responsible persons who resolve challenges, respect cultural diversity and contribute to creating a more sustainable world.

Furthermore, a smart classroom may promote learning through experience, communication and sharing amongst the students and help them to adapt to the environmental conditions (e.g., furniture made from recycled materials, high performance of natural lighting, reuse items and the use of the resources efficiently) in order to contribute to their local community sustainability goals (Brundiers et al., 2010).

Therefore, in terms of integrating the principles and practices of sustainable development into all aspects of education and learning, a smart classroom may lead to the reorientation of the curriculum. Thus, educational communities need to identify and select the appropriate knowledge, issues, perspectives, skills, and values addressed to sustainable development in each of the three components of sustainability, namely the environment, society, and economy and integrate them into the curriculum (Jormanainen et al., 2018).

In addition, it is generally accepted that specific characteristics related to educational content and pedagogy are essential for the successful implementation of ESD (UNESCO, 2020). This implementation should reflect the equal importance of both the learning process and the outcomes of the education process. The digital facilities of a smart classroom may support this fundamental behavioral shift to sustainable development and stimulate the students' learning motivation. Furthermore, they could provide opportunities for the students to engage in individualized and social learning activities and practices, such as

- the *promotion* of critical thinking, problem-solving and action, which develop self-confidence in addressing the challenges on the way to sustainable development,
- the *utilization* of literature, art, and drama to illustrate the projects and allow students to participate in the design process of sustainable educational programs,
- the *focus* on the educational and learning dimensions of sustainable development,
- the *contribution* to the innovative development of new and creative solutions to common local as well as global planet issues,
- the *benefit* of the potential to replicate the available environmentally friendly educational content, and
- the *support* of an evaluation in terms of innovation, success and sustainability.

7.3 A Conceptual Model for the Integration of ESD in a Smart Classroom Environment

In order to support sustainability education with the means that a smart classroom could offer, we should reconsider the physical and virtual learning space in line with sustainable development. This development implies the transformation of the classroom and the curriculum toward inquiry-based learning, a student-centered process, and an active and experiential learning approach that provides opportunities to learn from real sustainable practices (Zhu et al., 2016).

In the literature, one may find theoretical frameworks as a base for smart classroom environment development and frameworks for ESD implementation. An open-source one develops a smart classroom in several layers, using a range of devices and approaches (Tissenbaum & Slotta, 2009). The first layer includes an online database of student-generated, tagged, and socially connected learning objects. The second layer integrates the learning devices with the content. The third supports the visualization, sorting, and sharing of collaboratively generated artefacts.

A complete conceptualization of smart classrooms identifies three dimensions that must coexist in such spaces: technology, environment, and the processes carried out (Palau & Mogas, 2019). Technology includes hardware and physical technology, and software. The environment consists of architecture and environmental factors. The processes include the learning content, the processes performed by the actors and the processes and features that helped from the system.

Another conceptual model is based on three main phases: the interaction learning phase, the collaborative learning phase, and the smart analytics phase (Alhaboobi et al., 2019). The interaction learning phase includes the interaction between a lecturer and students and between students and devices. The collaborative learning phase focuses on the interaction between students for advancing to a higher level of understanding and knowledge. The smart analytics phase collects data to monitor and analyze student behaviors in the classroom and develop and choose the appropriate learning method.

The "SMART" conceptual model implies that an innovative classroom is a typical materialization of an intelligent learning environment and is the high-end form of a networked classroom, where the "intelligent" involves five dimensions: Showing, Manageable, Accessible, Real-time interactive and Testing (Huang et al., 2012). Therefore, a smart classroom involves and relates to the optimization of teaching content presentation, the convenient access to learning resources, the deep interactivity of teaching and learning, the contextual awareness and detection and the classroom layout and management.

UNESCO (2020) presents a new global framework on ESD, called ESD for 2030, to address the new opportunities and risks of SD posed by emerging technologies. The first main feature of ESD for 2030 is the emphasis given to the education's role: the need to transform itself. ESD aims to raise knowledge, awareness and action from three perspectives:

[1] *The cognitive learning dimension,* in order to understand sustainability challenges and their complex interlinkages and explore disruptive ideas and alternative solutions.

[2] *The social and emotional learning dimension,* in order to build core values and attitudes for sustainability and cultivate empathy and compassion for other people and the planet.

[3] T*he behavioral learning dimension,* in order to take practical action for sustainable transformations in the personal, societal and political spheres.

In terms of learning outcomes, the transformative sustainability learning (TSL) framework offers an organizing model to explicitly unite and embody the cognitive engagement, practical application and emotional connection practices of sustainability within the academic and the applied fields. After the development and conduction of three case studies on courses related to sustainability and citizenship, it was concluded that systems that were engaging students in a cognitive, psychomotor and efficient sphere enhanced TSL (Sipos et al., 2008).

In accordance with the frameworks for smart classroom development mentioned above and the sustainable development goals, I propose a conceptual model in this chapter to enhance the different types of classroom environments and increase the contribution of education to build a more fair and sustainable world. This model places the students and the teachers in the center and has four core components at its periphery (Figure 15)

[1] *the infrastructure*,

[2] *the evaluation – feedback*,

[3] *the sustainability content*, and

[4] *the motivation*.

These components are presented analytically in the next section.

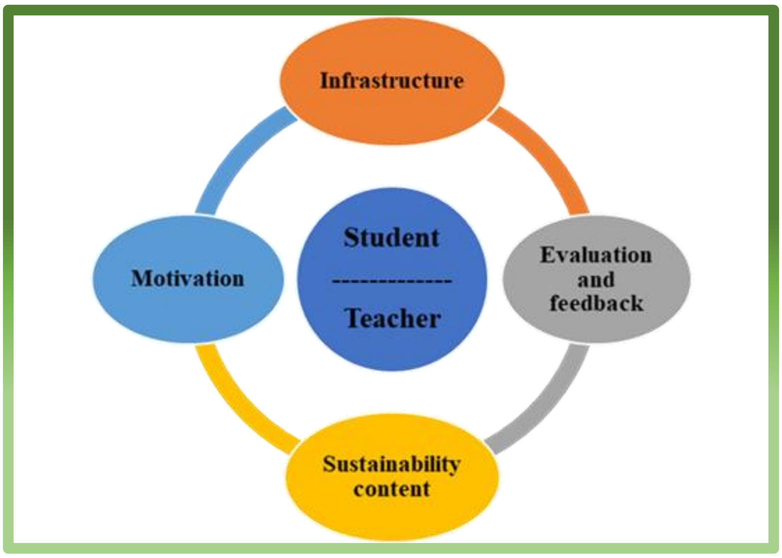


Figure 15. A conceptual model for the integration of the education for sustainable development in a smart classroom environment.

7.3.1 The Components of the Conceptual Model

The first component, *the infrastructure*, refers to the hardware components, devices or equipment. This kind of equipment may allow the real-time students' collaboration, research, and effective integration of information technology and digital resources into classroom teaching (Carson & Harder, 2016). The multimedia classroom environment should be upgraded and equipped with smart devices such as multi-screen touch displays and interactive whiteboards. In addition, wireless sensors could measure and monitor the students' and teachers' cognitive and behavioral processes or the environmental factors inside the room to provide input on the air quality, temperature, lighting and acoustics.

Moreover, a smart classroom should have facial, eye and motion-tracking recognition systems and the appropriate virtual simulation equipment. This equipment may help to teach abstract and complex concepts associated with sustainability since simulations reduce complexity and highlight salient aspects. At the same time, simulations reflect real-world situations that face communities, give a sense of reality, motivate students, and promote higher-order thinking skills (Tissenbaum & Slotta, 2019).

In addition, the "seeding" and "U-layout" classroom spatial arrangements should be used to support instructive classroom teaching (Liu et al., 2017). Moreover, the architecture and functional design must respect the basic principles of sustainability related to all the environmental factors and promote ecological methods and materials to reduce energy consumption, maximize sound absorption and ensure sustainable temperature control.

The second component, *the evaluation - feedback*, allows the tracking of the various activities' evolution in the classroom and the customization of the students' learning path related to their own learning profile in order to satisfy the different learning needs in the form of social equity, which is a core concept of sustainability. It involves students in the optimization of the educational process according to their answers in order to record the students' knowledge and experience, make the content relevant and use different teaching and learning processes. In some cases, the automatic assessment, generated by the appropriate software, is more objective as the teacher is not involved in the grading process, is faster because a repeating task is more adapted to computers, and, finally, is more reliable as antiplagiarism features are included (Nowotny et al., 2018). The provision of the evaluation or feedback includes - but is not limited - the following actions which may happen from the remote students in real-time with the local students simultaneously:

- *Complete in-classroom assignments* and submit corresponding files.
- *Discuss and evaluate the presented learning content* in each student's preferred language.
- *Participate in a poll* regarding a particular environmental issue.
- *Collect immediate feedback* from students regarding interest and the likeability of an activity.
- *Gather sensor data* automatically and record the students' learning behavior, performance, interest, participation, etc.

The third component, *the sustainability content*, includes the applications and emerging technologies used for the creation of the appropriate content that should be included in a curriculum addressing sustainable development. Sustainability education should support eco-friendly daily actions in school life, along with the educational contents of various school subjects, in order to enable the students to develop knowledge and awareness and take the appropriate actions to transform the whole society into a more sustainable one. Students need basic knowledge from the natural, social, and humanities sciences to understand the principles of sustainable development, the way they can be implemented, the values involved, and the consequences of their implementation. Students also must be provided with practical skills that will enable them to keep learning after they are through with school, find out a sustainable living, and live in an eco-friendly environment.

For this reason, I point out indicative curricular themes that may be used and adapted as "trigger points" to develop sustainability education further. These themes are:

- Environmental, economic and social sustainability.
- Natural resources management.
- Travel, transport and urban mobility.
- Climate change.
- Health and wellbeing.
- Sustainable and ethical tourism (Tilbury & Wortman, 2004).

Furthermore, sustainability in the curriculum requires a shift toward active, participative, and experiential learning methods that engage the students and make a real difference in their understanding, thinking, and ability to act. The utilization of this content includes pedagogical approaches or methods such as critical reflection (learning journals, discussion groups), systemic thinking and analysis (real-world critical incidents, project-based learning, stimulus activities), participatory learning (group or peer learning developing dialogue, experiential learning), thinking creatively for future scenarios (role play, real-world case studies) and collaborative learning (contributions from invited speakers, work-based learning, interdisciplinary projects).

The fourth component addresses *the motivation* of the students. It targets their potential to foster healthy environmental behavior in terms of easiness, engagement, and effectiveness of the learning environment since the learning outcome in the smart classroom almost meets or even is higher than the expectation generated for this learning environment (Sauvé, 2017). Therefore, this environment should provide a fast and convenient learning atmosphere and make the process of completing learning targets easy for the students.

In addition, the learning environment should stimulate and facilitate the students' learning interest and keep this interest and the corresponding level of participation at a relatively high state. Extra-curricular activities and special events should enhance and practice classroom learning about sustainability. The design and the development of the appropriate sustainability content should ensure an immediate and positive interplay and collaboration both between students and teachers, as well as between students, and motivate their enthusiasm. Furthermore, it should support personalized learning and present different learning resources tailored to the specific characteristics of each student. This desirable result may occur by tracking the student's learning progress and learning behavior.

The implementation of this conceptual model may reform the school education process by applying emerging information technologies to facilitate the efficacy and efficiency of the education system. This cultivation and education of students meet the needs for the transformation toward a sustainable society. Furthermore, the smart classroom use aims to inspire students to develop lifelong learning habits of continuous knowledge acquisition and eco-friendly attitudes to adapt themselves to society's evolving green paces.

7.4 Limitations of the Model and Future Suggestions

The proposed conceptual model addresses the support of ESD with the means that a smart classroom could offer. By taking advantage of modern science and technologies in different settings or approaches, it can provide and support sustainable learning services and experiences for students and teachers. These settings involve the incorporation of digital devices and learning software related to one or more sustainability elements, the inclusion of sensor networks that help with tracking classroom processes, and simulation equipment that reflects real-life problems.

A smart classroom can promote education equity by meeting all the students' learning needs and increasing learning performance by gathering and analyzing data generated from the students' learning process and learning activities. Using a variety of pedagogies associated with ESD also stimulates students to ask questions, explore, think critically, and offer insights to help decision-making for better and faster learning on sustainability. In addition, an intelligent classroom can provide more convenient teaching conditions for students and teachers and support active participation in modelling and transforming future earth scenarios toward sustainable practices.

Therefore, the infrastructure and resources must be adapted to the underlying pedagogical and sustainable aspects, giving a response to the educational needs for sustainability rather than being merely innovative but unconnected solutions. Furthermore, this situation implies that the integration of the sustainability educational part needs a holistic point of view related to the whole organization of the classroom (educational program, teaching methods and the infrastructure) instead of the adding of supplementary topics or themes on sustainability into the existing curriculum and educational projects.

One limitation to the implementation of a smart classroom with sustainable orientation and practices may be the investment and technology development costs, which are always high at the beginning, and lower over time. In addition, technology constraints such as potential problems with technology updates, upgrades and system maintenance, too many interlinked devices, data exchange protocols used, etc., may lead to unexpected significant complexity and consequent failures of the entire system. At the same time, new educational content and teaching and learning resources that integrate sustainability into the smart learning environment should be developed and tested.

For this reason, teacher training programs should focus on the development of the proper teaching and digital competencies in order to support the smart classroom's sustainable nature. Another limitation is the assumption that a smart classroom is a space that copes equally with any student's education level. However, it should be noted that some differences might exist, and research is needed to report on the actual effects of smart classrooms on students with different cognitive styles and levels.

It is essential in the future to create smart classroom spaces according to the proposed conceptual model in order to explore their impact and influence on the building of core values and attitudes for sustainability and the cultivation of environmental awareness among students and teachers. Furthermore, the students should perform summative and formative evaluations to collect sufficient data about the quality of smart classroom main components - hardware, software, technologies, and services – and conduct the necessary changes.

Study Two considered the components of the proposed framework regarding the support for the integration of sustainability in ICT secondary education as described in the following *Chapter 8*.

Chapter 8 – ESD in Secondary Education: Redesigning ICT Curricula toward Green Informatics and E-Waste Recycling

This chapter focuses on the integration of sustainability in upper secondary education and the importance of sustainability-based learning to enhance the environmental consciousness of young people. It presents the results based on the pupils-generated data collected from two studies that were conducted during the ICT lesson in Greek secondary schools. The first study is related to green informatics and the integration of sustainability into the ICT curricula, while the second is related to e-waste management and recycling. The research methodology and the results with discussion follow next. The chapter concludes with the limitations of the studies.

8.1 Introduction

ESD in secondary education can play a critical role in preparing pupils to address the complex challenges facing our world, including environmental degradation, social inequality, and economic instability. In order to achieve this, ESD should aim to empower pupils with the knowledge, skills, values, and attitudes necessary to adopt sustainable practices and contribute to a more equitable and sustainable future. To this end, the purpose of ESD concerns the promotion of an education whose main characteristics are the exploration of the environment, the building of skills and knowledge necessary to address complex environmental issues and the use of a variety of teaching methods, such as participation and cooperation (Jensen et al., 2021).

Nevertheless, while many nations around the world have embraced the need for ESD, only limited progress has been made at all educational levels (Hollingworth et al., 2018). Moreover, the available literature on the involvement of ICT at the level of secondary educational policies, pedagogical approaches, and, in general, the didactic utilization concerning ESD results is rather limited (Chowdhury & Koya, 2017; Ferreira et al., 2020). Some of the more prevalent challenges are

- a lack of *adequately trained teachers* to provide inspired ESD,
- the *disciplinary boundaries* between subject areas that persist, and
- a lack of *educational leadership* to support transformative pedagogies to address sustainability (Baena-Morales et al., 2020).

Furthermore, previous studies reveal that sustainability is under-represented in the curricula and, more specifically, in ICT curricula (Handelzalts, 2019; Mishra & Mishra, 2020). Moreover, most efforts to reform the ICT curricula by including *Green Informatics* have focused on the development of individual courses on sustainability.

On the contrary, there is a rich research activity concerning the utilization of ICT in teaching and learning in general (Aikens et al., 2016; Askell-Williams & Koh, 2020; Henderson & Tilbury, 2004; Philpott & Oates, 2017). While young people are typically more frequent and able users of technology, they are often fluent mainly in the use of technology for leisure and for accessing social media rather than for learning purposes (Rodríguez et al., 2012). In addition, many teachers feel insufficiently trained in using technology for learning purposes and lack competence in integrating technology and sustainability teaching; thus, they can act as a barrier to this combination.

From an institutional perspective, teachers and pupils will also face obstacles in implementing sustainable IT-based approaches if the institutional context is not supportive – either from an infrastructure or from a school culture perspective. To encourage young people to take action and contribute to a more sustainable future, it is essential that the teachers make sustainability issues an integral part of their curricula (Mogren et al., 2018). Therefore, the ICT connection and integration with a program focusing on ESD constitute a new field of applying ICT. Furthermore, the ICT and, in particular, the possibilities of learning platforms and motivating online tools, which are widely used for different educational purposes, can promote new interaction methods, experiential learning, and collaboration among pupils (Fauville et al., 2014).

In this chapter, I address the challenge of integrating ESD in secondary education in Greece through two significant principles and strategies: first, the ICT curricula redesign in order to ensure that sustainability concepts are integrated into official curricula standards and second, the incorporation of e-waste recycling into secondary education as a valuable initiative that can raise awareness about the environmental impact of e-waste and teach pupils the importance of responsible disposal and recycling.

For this reason, taking into consideration the complexity of the secondary education curricula, the diversity of learners regarding abilities, interests and learning styles, as well as the traditional schedule where pupils attend six to eight different courses throughout the day over an entire academic year, two separate studies were conducted that corresponded to the mentioned above challenges. In this way, each study has more clear and concise research questions, narrowing it down to a specific area of interest, helping pupils focus on this area and answer more precisely. The following sections present an introduction for each study and report the findings based upon the information gathered.

8.2 Analyzing Pupils' Opinions and Perceptions about Sustainability and Redesigning ICT Curricula toward Green Informatics

8.2.1 Sustainability in Schools

The school is considered an institution that is essential to contribute to SD (Wahyudin, 2018). This contribution can be possible for pupils as the school has the potential to promote and support this through teaching and other daily practices. Moreover, teaching sustainability in schools provides the pupils with the necessary attitudes, skills, knowledge and values in order as adults to lead to sustainable and inclusive growth and to a peaceful life for all individuals, to design and contribute to a sustainable tomorrow, to understand the importance of environmentally friendly practices and to make decisions that can maintain and improve the world that they live in (Demerath, 2018).

In order for the school to promote the importance of environmental responsibility and fostering a sense of stewardship for the planet, one may find many approaches that have been proposed from time to time, such as:

[1] *Teaching approaches* that can incorporate digital technologies and ICT to help pupils in acquiring sustainability initiatives and competencies (Bianchi et al., 2022).

[2] *Experiencing sustainability* (experiential learning) that can stimulate a change in mindset (i.e., promoting good practice on reducing waste, reusing, repairing or sharing among pupils) (Wamsler, 2020).

[3] *Cooperation* with the broader community participating in projects, i.e., for the transformation of the school buildings to align with sustainability (Tilbury & Galvin, 2022)

[4] *The whole school participation* finding the more general acceptance. Such an approach ensures that

- the programs emphasize the design and implementation of the ICT curricula that promote and reward attitudes and behaviors for a more sustainable future. In order to support this process, there is a need for a broad curricula reform to integrate sustainability concepts into existing courses in the curricula (Demerath, 2018),
- the management of buildings and campuses is conducted in a sustainable manner, with the aim of providing a conducive "sustainable learning space" that promotes resource efficiency, healthy food options, and green areas (Pouezevara et al., 2014),
- the school actively engages with the surrounding community and contributes to sustainable development efforts within its locality,
- the professional development of the teachers involves the accumulation of experience and the understanding of the concept of SD through self-reflection and through both formal and informal approaches. These approaches include training courses, workshops, conferences, reading

professional publications and watching videos about the ESD (Miao et al., 2017), and

- the teaching and learning methods are learner-centered, exploratory, and sustainability-oriented (Hilty & Aebischer, 2015).

Furthermore, this whole-school approach to ESD is linked to the creation of a collaborative climate between teachers and pupils, as well as to the need to highlight the "learning communities" at school and the professional development of teachers toward sustainability (Tilbury, 2016). However, creating a collaborative culture, which is the central goal for the development of a sustainable school, may not be easily achieved. Furthermore, being sustainable implies that the people's actions should cause either a slight or no environmental harm. These sustainable actions can be continued or can be sustained for an extended period. In this way, people can satisfy their own needs without compromising the potential of future generations to meet their needs.

Toward this direction, non-traditional, interactive education formats such as summer camps are a powerful tool to empower pupils to participate in environmental issues, i.e., climate action. This sustainable-oriented school approach of working teachers and young people together toward the same objective, employs a comprehensive access to sustainability education and thus encourages lasting change. This increased awareness globally has led to many schools applying for sustainability accreditations. Table 20 lists the characteristics a school should support to become sustainable (Breiting & Mayer, 2015; Mogren et al., 2018).

Table 20. Characteristics of a sustainable school

Improvement of environmental literacy in pupils
Removing toxic materials from places where pupils learn and play
Conservation of energy and natural resources
Saving taxpayer money
Decrement of the burden on municipal water to benefit the local community and region
Improvement of indoor air quality
Conservation of fresh drinking water and help in managing stormwater runoff
Employment of daylighting strategies and improvement of classroom acoustics
Encouragement of recycling
Reduction of demand on local landfills
Promoting habitat protection
Encouragement of waste management efforts to benefit the local community and region

Becoming a sustainable school brings innumerable benefits (Ferreira et al., 2020; Lin & Lee, 2018; Mathie & Wals, 2022). These include:

- *Interaction and engagement with the local community*: Environmentally friendly schools can work together with their local community to succeed in common goals. This way, their relationship is improved, and a more attractive prospect emerges to parents.
- *Improvement of well-being*: Pupils collaborate to achieve an environmentally friendly goal and develop many personal and social skills. In addition, they can be creative innovators displaying empathy, confidence and resilience. Schools can teach the pupils that sustainable actions can be both pleasant and rewarding.
- *Financial savings*: Turning off the lights and appliances when not in use and searching for low-energy consumption products may help schools reduce bills and save money.
- *A richer curriculum*: Teaching green subjects gives pupils many opportunities to get involved, think about environmental issues, solve problems and reflect on their own practices. Moreover, they can increase their social interactions and enhance their participation in making decisions based on ecological, social, cultural and economic values.

8.2.2. Sustainable Schools in Greece

In Greece, there are two programs in which a school can participate in order to be qualified as sustainable:

[1] *The Sustainable Greek School Program* (https://www.ellet.gr/en/project/sustainable-greek-school/) "we all care, we are all involved": This program promotes the school's concept of sustainability. A school may be considered sustainable if, through its daily operation, it can be a model of good practice for both pupils and society. It may also be regarded as sustainable if it provides pupils with the knowledge and cultivates their skills to become active members of a community capable of tackling social and environmental problems and shaping the future regarding social and ecological sustainability.

Therefore, a school can participate in this program trying to activate mechanisms for its transformation into a sustainable one based on eight proposed categorized-specific pillars of sustainability: Democracy and participation; Promoting Learning; Promotion of arts and culture; Sustainable building and courtyard; Energy saving/travel policy; Saving resources; Promoting Health; From the local to the planetary scale.

In order to achieve this transformation, the school should adopt a holistic approach as an organization where the teachers are encouraged to get progressively involved in the transformation processes of their school. In this context, the pedagogical and scientific team of the program organizes workshops and seminars, produces educational material, looks for the interaction of the schools of the program among them, and discreetly supports the schools that wish it.

[2] *The Sustainable School* (http://www.aeiforum.eu/index.php/en/): In this program, every school that wishes to be certified as a Sustainable School should start its actions around September and request the certification from May to June. By registering on the www.aeiforum.eu web page, the school should spread good practices, meet the sustainable school indicators (pedagogical, social, organizational and environmental), and have an updated website or blog to post its various actions.

8.2.3 Awareness and Empowerment Curricula – Connection with Sustainability

Establishing sustainability programs and behaviors in a school requires aligning organizational culture with the sustainability vision. To successfully deploy sustainability as a core component of organizational culture, sustainability must align with the school's established mission, be viewed from an interdisciplinary scope, and be effectively integrated into the curricula.

ICTs play an important role in promoting ESD in two ways: One way is *the facilitation of access to sustainability-related educational materials* (e.g., distance learning, educational networks and databases), and the other way is *the promotion and the empowerment of new interaction approaches which focus not only on the acquirement of knowledge but also on clarifying and highlighting values, changing behavior and participating in actions related to sustainability* (Lengthorn, 2018). Any action or learning process that cultivates awareness and provides opportunities for pupils to interact with their environment should be enhanced by techniques that encourage interaction, cooperation and interconnectivity.

Moreover, the use of ICT affects many aspects of the world in positive and negative ways, subsequently at a local, national, or global level. Individuals and communities influence green informatics through their behaviors and social and cultural interactions, and in turn, green informatics affects new cultural practices (Wahyudin, 2018). Therefore, a responsible and informed person should be aware of the digital world's social and environmental implications, including computing access and the carbon footprint data generated. In this direction, education for green informatics and integrating it into the curricula may influence culture, which in turn shapes how young people interact with and access computing and learn how computing can be helpful and harmful simultaneously.

A very recent analysis of European school curricula underlines that an awareness related to the significance of the social impact elements in ICT education is emerging (European Commission, 2022). This awareness aims to develop the ability of the pupils to understand that ICT affects people, society and the environment. Although ICT is still a relatively new field in school education, the title, the content and the focus of the associated school subjects vary across European countries. Therefore, analyzing existing competence and curricula associated with the learning outcomes contributes to building a common and shared understanding along with comparability. This analysis identifies the following principal areas of ICT as a scientific discipline: algorithms and programming, data and information, networks, computing systems, modelling and simulation, design and development of a system, people–system interface, awareness and empowerment, and finally, safety and security.

Concerning Greece, the primary and secondary education programs include learning outcomes related to all previously mentioned areas. More specifically, the Greek educational system provides a substantial number of teaching hours in the whole of senior secondary education for ICT subjects that are compulsory for all pupils. Pupils start learning ICT from the first grade of primary education as a separate, compulsory module. Moreover, ICT is usually taught as part of another mandatory subject, and teachers are free to decide on the teaching approach used for this purpose. In junior secondary education – K7 to K9 - ICT is taught as a distinct informatics discipline and is compulsory for all students in all grades. In senior secondary education – K10 to K12- teaching ICT is also a distinct discipline, and the majority include one compulsory informatics subject in all grades.

Furthermore, the Greek education system is planning the development of curricular reforms on ICT education with pilot projects, which are already taking place in some schools before further curricular reforms are implemented. For example, the project "Updating of curricula and creation of educational material in primary and secondary education" was implemented in some schools during 2020/2021 (https://eurydice.eacea.ec.europa.eu/national-education-systems/greece/teaching-and-learning-primary-education). Therefore, some learning outcomes relating to this area have already been gathered.

However, the term sustainability is underrepresented or does not appear in the ICT curricula. Introducing key knowledge and competencies for sustainability can be seen as an essential movement in the integration of sustainability in primary and secondary education. Therefore, the curricula should include conceptual education and practice in ICT to expose pupils to the various components of sustainability (Chowdhury & Koya, 2017). The dimensions of green informatics that should consist of and contribute to the ESD are:

- **[1]** The rise of environmental awareness.
- **[2]** The effective communication for ecological issues.
- **[3]** The reduction of energy consumption.
- **[4]** The environmental monitoring and surveillance systems, by the means to protect and restore natural ecosystems' potential.

Handelzalts (2019) suggests that the ideal approach to design and provide ICT curricula related to sustainability is to embed the values and principles of sustainability through a sustainable school approach that reorients existing curricula rather than an "add-on" approach, a theme or a special event. This style of curricula design is holistic and integrated. For example, projects involving sustainability in ICT applications, as part of the course to provide real-life inclusion of sustainability in the ICT module, should be used. In this direction, our research aims in the context of the ICT course to examine the pupils' knowledge of sustainability and their opinions regarding the introduction of sustainability in the ICT curricula.

Based on all previously mentioned, the purpose of the following study is to investigate the pupils' knowledge about sustainability and to examine their opinions and perceptions about the concept of sustainability and its integration into the ICT curricula.

8.2.4 Methodology

The study took into consideration the four components of the conceptual model presented in *Chapter 7* (Figure 15), namely the *infrastructure*, the *evaluation and feedback*, the *sustainability content* and the *motivation*. It was conducted in the context of the ICT curricula and, more specifically, in the *Data and Information* section with a total of 82 pupils (38 girls and 44 boys), 15-17 years old, of a public Lyceum (senior high school) in the region of Attica, Greece, during November 2022. The study took place in the computer laboratory (*infrastructure*) where the course was available online on the learning platform Moodle (https://moodle.org/) (*evaluation and feedback, sustainability content, motivation*), and pupils used tablets, computers, and smartphones with an Internet connection. The pupils completed an online 26-item questionnaire entitled *Questionnaire for the concept of sustainability and its integration into the ICT curricula* (Appendix F), uploaded onto the Moodle platform as a data collection tool to determine their prior knowledge about the subject of sustainability and green informatics. In addition, I wanted to explore their level of awareness and intentions toward integrating sustainability into the ICT curricula.

The questions used were close-ended, included multiple-choice and a five-point Likert scale from strongly disagree (1) to strongly agree (5), and open-ended. They were divided into seven distinct sections. The first section contained questions considering the demographics information of the pupils (gender, age and place of residence). The second section incorporated questions related to the knowledge and perceptions of the pupils about sustainability and green informatics. The third section covered the pupils' awareness of the environment, clean energy and sustainable development goals. The fourth section included questions about the intention of the pupils to engage in sustainability and green informatics. The fifth section explored the expectations of the pupils for embedding sustainability into the ICT curricula, and the sixth section examined the contribution of education to environmental awareness. Finally, the seventh section included the choices and the proposals of the pupils for the creation of a sustainable school.

8.2.5 Evaluation of the Validity of the Questionnaire

The Cronbach's α coefficient of reliability was used to measure the internal consistency of the questionnaire. A "high" value of α is frequently used as proof that the items assess an underlying (or latent) construct, along with the supporting arguments and perhaps other statistical measures. All the items ($\alpha=0.79$) reached the recommended limit of 0.80, even marginally (Nunnally & Bernstein, 1994).

For the evaluation of the results, I used

- descriptive statistical methods for summarizing information of the characteristics and distribution of the values in the sample and
- inferential statistical methods (one-sample t-test) for determining if the average of the five-point Likert scale questions of pupils is significantly greater or less than the neutral option (test value=3).

The appropriate normality test of Kolmogorov-Smirnov and Shapiro-Wilk was performed in advance to examine whether the sample size was sufficiently large (82>30) to assume the normality of the sample mean asymptotically (Curran-Everett, 2017; Hanusz & Tarasińska, 2015). The significance (alpha) level was set to 0.01.

8.2.6 Results and Discussion

A. Knowledge and Perceptions about Sustainability and Green Informatics

The results demonstrated that a considerable number of the pupils (N=56, 68.3%) had no or poor knowledge or had not heard about the concept of sustainability before. In contrast, an even more substantial number (N=63, 76.8%) had no or insufficient knowledge or had not heard about green informatics in their elementary and secondary schools so far. For the vast majority of the pupils (N=74, 90.2%), it was the first lesson they had dealt with sustainability. As expected, most pupils are interested in learning more about sustainability (N=66, 80.5%) and green informatics (N=68, 83.0%), respectively. However, pupils still consider that developing technology with minor consumption of resources (N=56, 68.3%), ensuring that our present society can be sustained in the future (N=43, 52.4%) and developing technology for a better world (N=35, 42.7%) may better describe the concept of sustainability.

Furthermore, pupils still believed that green informatics is more related to the following:

- Development of environmentally friendly technologies such as virtual energy management (Virtualization), recycling (Recycling), and teleworking (Telecommuting) (N=55, 67.1%).
- Reuse computing systems in an effective and efficient manner that simultaneously limits their environmental impact (N=54, 65.9%).

- Development of more energy and efficient computing systems so that they do not consume large amounts of energy (N=51, 62.2%).
- Development of innovative products, tools and services that contribute to the protection and renovation of the natural environment (N=34, 41.5%).

These responses point out that the students even intuitively managed to make sense of the concepts of sustainability and green informatics at a very satisfactory level. This result is aligned with UNESCO's (2017) conclusion that most people in the world today have an immediate and intuitive sense of the urgent need to build a sustainable future.

B. Awareness of the Sustainable Development Goals and the Use of Clean Energy

The results have also revealed that the vast majority of pupils (N=75, 91.5%) had never heard or have heard but do not know many things about the SDGs, while only the 8.5% (N=7) mentioned that they had heard and know about them. Figure 16 illustrates the survey results concerning the intention of the pupils to support organizations that are actively invested in renewable energy. These outcomes indicated that several pupils positively perceive the support of organizations being actively engaged with clean energy and renewable resources, emission reductions, biodiversity protection, and waste and water management.

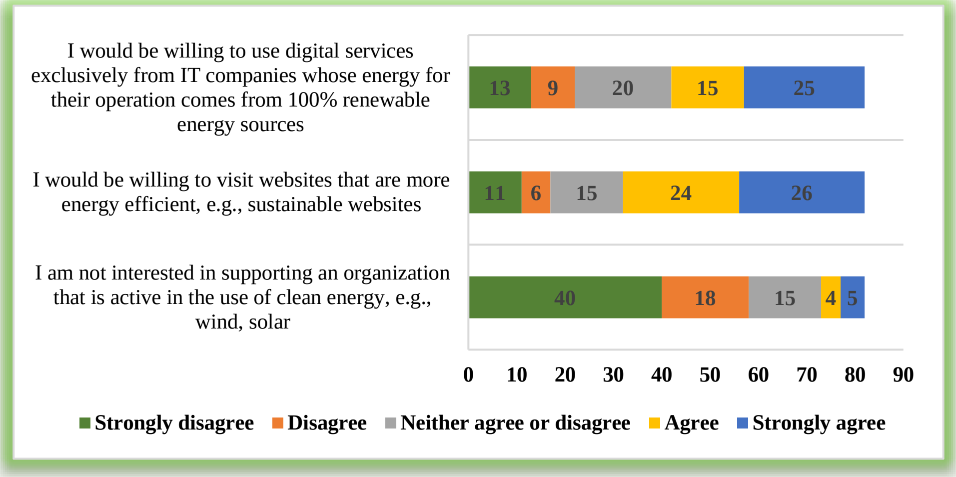


Figure 16. Intention of the pupils to support environmentally friendly organizations

C. Intention to Engage in Sustainability and Green Informatics

Table 21 shows that many pupils (N=48, 58.5%) intend to deal with green informatics, and even more, a substantial number of the pupils are willing to learn more about sustainability (N=52, 63.4%) and green informatics (N=55, 67.1%), respectively. In addition, most of the pupils (N=60, 73.2%) believed that the content related to green informatics should be included in school lessons.

Moreover, the data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 3 (neither disagree or neither agree): $t=3.23$, $p=0.002$, for the intention to green informatics; $t=4.55$, $p<0.01$, for learning more about sustainability and $t=4.49$, $p<0.01$ for green informatics; $t=6.06$, $p<0.01$ for the integration of green informatics into curricula.

An inference from these results could be that a high percentage of the pupils have understood or were being motivated to get involved with the concept of sustainability and green informatics, and this inference may provide an opportunity for the school community to influence and propagate a pro-environment behavior among pupils through lessons and activities.

Table 21. Intention of the pupils to engage in sustainability and green informatics (scale 1 = strongly disagree to 5 = strongly agree)

Items	Frequencies (%)					Descriptive statistics			Test Value = 3 (neither disagree or neither agree)		
	1	2	3	4	5	N	Mean	Standard Deviation	t	Sig. (2-tailed)	Mean Difference
I believe that it is appropriate to include content related to green informatics in school lessons	9.8	7.3	9.8	33.0	40.2	82	3.87	1.29	6.06	<0.01	0.87
I intend to deal with green informatics	12.2	11.0	18.3	35.4	23.2	82	3.46	1.30	3.23	0.002	0.46
I would be willing to improve the world around me by using environmentally friendly methods	6.1	7.3	12.2	14.6	59.8	82	4.15	1.25	8.31	<0.01	1.15
I would be willing to learn more about sustainability	9.8	12.2	14.6	28.0	35.4	82	3.67	1.33	4.55	<0.01	0.67
I would be willing to learn about green informatics	13.4	6.1	13.4	34.1	33.0	82	3.67	1.35	4.49	<0.01	0.67

D. Expectations for Embedding Sustainability into the ICT Curricula

Table 22 shows the means of the responses to questions regarding the embedding of sustainability into ICT courses (M1=0.33 (±1.23)) and in the school community (M2=4.00 (±1.16)). The data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 3 (neither disagree or neither agree): t=2.43, p=0.003 and t=7.84, p<0.01, respectively.

Table 22. Opinions of the pupils about the necessity of embedding sustainability into the ICT curricula (scale 1 = strongly disagree to 5 = strongly agree)

Items	Descriptive statistics		Test Value = 3 (neither disagree or neither agree)		
	Mean	Standard Deviation	t	Sig. (2-tailed)	Mean Difference
The integration of sustainability into ICT courses is necessary	3.33	1.23	2.43	0.003	0.33
The school must foster the principles of sustainability among the school community proactively	4.00	1.16	7.84	<0.01	1.00

Moreover, Figure 17 illustrates that about half of the pupils (N=44, 53.7%) have a positive view of integrating sustainability into the ICT curricula. Furthermore, the majority of the pupils (N=55, 67.1%) believed that the school should engage in general with sustainability in different ways.

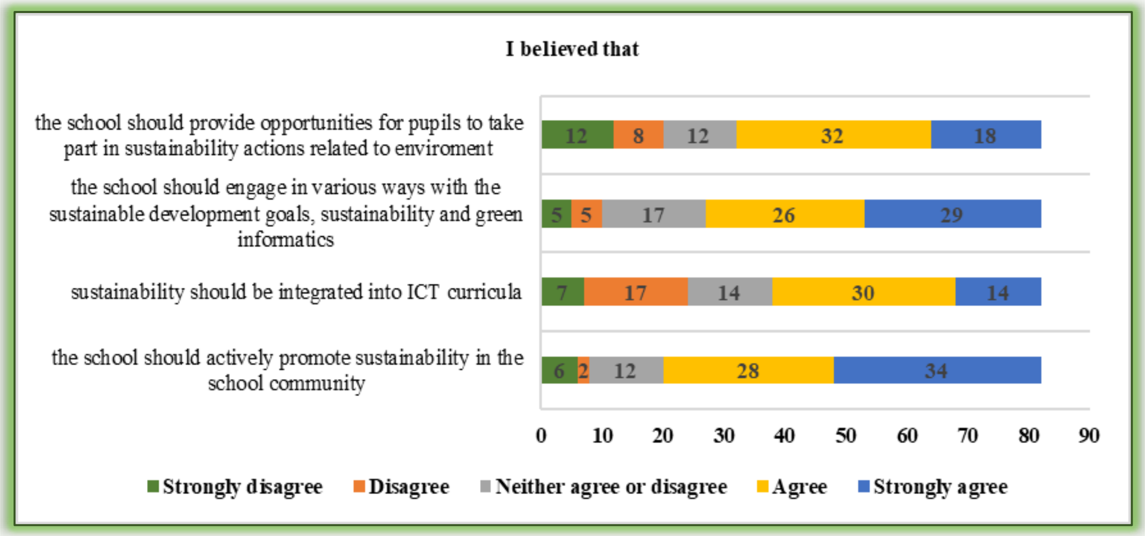


Figure 17. Expectations of the pupils for embedding sustainability into the ICT curricula

In comparison, 75.6% (N=62) of the pupils thought that the school should actively promote sustainability in the whole school community. The results also depict that several pupils recognize the necessity for integrating sustainability in the school community and positively accept the shift of the curricula toward sustainability and green informatics. Therefore, these outcomes highlight the importance of the development of a curricula framework for advancing and embedding sustainability into secondary education ICT curricula.

One such framework that introduces sustainability into the secondary education curricula should create opportunities for critical reflective thinking, values clarification, envisioning, and participation in decision-making. In particular, there is a need for learning that engages pupils with real-world issues, reframes teacher-learner relationships, promotes participatory learning and embeds responsibility as a learner outcome (Voelkel & Chrispeels, 2017). These practices go beyond the narrow perceptions of the pupils' engagement in sustainability, which implies pupils work in groups, conduct a project, or collect litter in their local community. Therefore, creating opportunities for the pupils' engagement in sustainability should be perceived as a vital goal of a whole school approach to sustainability.

The new participation opportunities where pupils can inform and influence the direction of an activity emerge from the following questions

- *what* pupils already know about sustainability,
- *who* they can work with to extend their understanding or experience further,
- *how* pupils wish to respond to environmental issues, and finally
- *what* action, if any, pupils would take.

In this sense, the engagement of pupils is about their empowerment and supports the development of pupils' competencies and engagement in change.

E. The Contribution of Education to Environmental Awareness

Table 23 shows the pupils' perceptions of the educational system's contribution to their environmental awareness. As one may notice in this Table, from 20.7% to 30.5% of the pupils neither agree nor disagree about the knowledge provided by the school related to sustainability. On the contrary, only 29.3% (N=24) and 13.4% (N=11) mentioned that school help pupils learn how to have a positive environmental impact and how ICT succeed in this impact, respectively.

In addition, about half of the pupils (N=38, 46.3%) consider that school does not help them learn more about green informatics. Moreover, according to the responses of the pupils, primary education has encouraged them the most to think and act in a more environmentally friendly manner, half of the pupils (N=41, 50%). In comparison, one to five pupils (N=16, 19.5%) believe that no level has supported it.

Table 23. Perceptions of the pupils about the contribution of the school to environmental awareness (scale 1 = strongly disagree to 5 = strongly agree)

I believe that my school helps me to learn how	Frequencies (%)					Descriptive statistics			Test Value = 3 (neither disagree or neither agree)		
	1	2	3	4	5	N	Mean	Standard Deviation	t	Sig. (2-tailed)	Mean Difference
Q1. I can have a positive environmental impact on the world around me	19.5	23.1	28.0	20.7	8.5	82	2.76	1.23	-1.80	0.002	-0.245
Q2. I make changes in my own lifestyle to help the environment	24.4	18.3	20.7	29.2	7.3	82	2.77	1.31	-1.61	<0.01	-0.23
Q3. ICT can contribute to have a positive environmental impact on the world around me	30.4	29.2	26.8	7.3	6.1	82	2.29	1.16	-5.52	<0.01	-0.71
Q4. ICT can help the environment, e.g., energy savings, greater efficiency of systems, reduction of greenhouse gas emissions	31.7	14.6	30.5	14.6	8.5	82	2.55	1.33	-3.08	0.003	-0.45

The data were subjected to the one-sample t-test, with the results for each of the four questions showing a significant difference from the fixed value 3 (neither disagree or neither agree): $t=-1.80$, $p=0.002$ for Q1, $t=-1.61$, $p<0.01$ for Q2, $t=-5.52$, $p<0.01$ for Q3 and $t=-3.08$, $p=0.003$ for Q4, respectively.

These results denote the inability of the educational system to create an ecologically literate and environmentally sensitive populace among young people. It should be pointed out that education on environmental sustainability should recognize and provide pupils with the knowledge that more complex social and economic issues maintain environmental quality, biodiversity, climate change and other sustainable development issues (Bamber, 2019).

F. Proposals for the Creation of a Sustainable School Network

Figure 18 shows the ways that pupils propose that their school could engage with the SDGs, sustainability and green informatics and create a sustainable school network. The organization and the implementation of different activities at school - one day or a week - concerning the concept of sustainability are the most popular choices for the pupils, with 75.6% (N=62) and 74.4% (N=61), respectively.

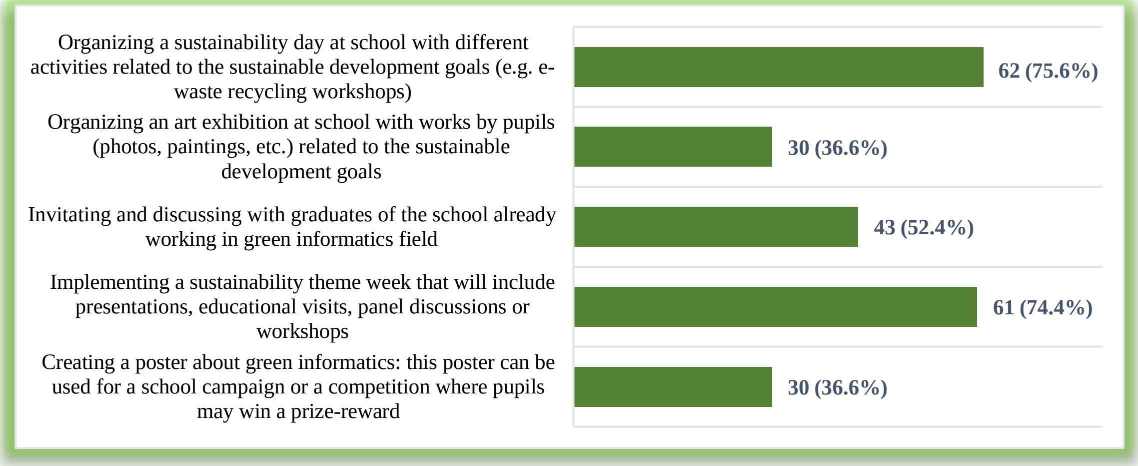


Figure 18. Proposals of the pupils for the engagement of their school with sustainability and green informatics

These proposals are an essential step to overcome the school's weakness to contribute to the education of the pupils regarding the environment and emerge the potential contribution of ICT to its protection as mentioned above. In this light, the pupils suggest organizing awareness activities in an inclusive manner so that these activities become a learning opportunity for the whole school community regarding environmental sustainability. This process of involving pupils, teachers, parents, and community stakeholders increases the responsibility of participants and the likelihood of these activities being successfully implemented.

8.3 Exploring Pupils' Knowledge and Awareness of E-Waste Recycling

8.3.1 E-waste Recycling and Management Programs in Schools

Schools are the primary locations where pupils can learn the importance of preserving nature and the benefits of recycling. In this way, they will potentially grow up to be responsible citizens and participate in making the earth greener and more sustainable. Table 24 lists the benefits and the importance of e-waste recycling that pupils should learn (Okoye & Odoh, 2014). In most primary and secondary educational systems, including Greece, e-waste recycling is not a compulsory course in the curriculum. Instead, it is taught on a voluntary basis in the form of a series of sustainability-oriented educational activities (Hoang & Kato, 2016; Kougias & Efstathopoulos, 2020; Rada et al., 2016). The teachers take over environmental actions, either through voluntary school programs or during compulsory lessons.

Table 24. Benefits and importance of e-waste recycling

Protects the health of human and animal
Saves energy
Reduced Mining of Virgin Resources
Generates revenue by creating jobs
Recovers precious metals and many raw materials (i.e., copper, lithium, tin, silver, gold)
Minimizing the costs of sending e-waste overseas
Reduces carbon footprints and greenhouse gas emissions
Conserves and preserves natural resources
Reduces environmental pollution
Prevent usage of landfills

Many schools actively participate in e-waste recycling via community-wide actions or via competitions held during a specific time: the school that recycled the most wins a prize. In addition, the schools can integrate sustainability issues related to e-waste recycling by teaching their pupils the importance of (Kougias & Efstathopoulos, 2020):

- *Maintaining* their electronic devices by taking a little more care of them, as they might last longer without having to trash them.
- *Donating* their electronic devices to people who cannot easily access them as another efficient way to dispose of unwanted electronics or e-waste without harming the environment.
- *Adopting the 3Rs* (Reduce, Reuse, Recycle) principle by encouraging everyone in schools to inculcate the continuous habit of practicing the 3Rs, contributing to better e-waste management and reinforcing the knowledge of positive environmental effects.
- *Participating* in refurbishing/redistribution programs of nonprofit organizations, which collect used PCs, refurbish them, and then distribute them to people who need them.

Furthermore, in order to foster sustainability and e-waste awareness and take action, the pupils can learn about these subjects through 21st-century skills-based education programs. These programs may integrate and implement the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity) principle along with ICT literacy in every educational activity that incorporates environmental sustainability into the curricula (Lazzarini et al., 2018). Therefore, the combination of ICT skills and knowledge with the vital support of instructions, curricula, and assessments in the learning environment of a computer laboratory may engage the pupils in the learning process (Chowdhury & Koya, 2017). Moreover, this combination may help them be much more environmentally friendly when they graduate and prepare to prosper in the globally and digitally interconnected world of today.

Having in mind that in order to promote environmental sustainability by means of e-waste recycling, it is necessary to raise environmental awareness among pupils, obviously, the success of a sustainability project in secondary education is considered very important. In this context, the following study aims via a two-stage sustainability/e-waste recycling project to explore the knowledge, attitudes, and level of awareness of secondary school pupils in Greece regarding e-waste management and to investigate their intention for e-waste recycling.

8.3.2 Methodology

The study took into consideration the four components of the conceptual model presented in *Chapter 7* (Figure 15), namely the *infrastructure*, the *evaluation and feedback*, the *sustainability content* and the *motivation*. The study was conducted in two stages, with the participation of 65 pupils (38 girls and 27 boys) 16 years old, of a public senior high school (Lyceum) in the region of Attica, Greece, during Spring 2022. The study took place in the computer laboratory where pupils used tablets, computers, and smartphones with an Internet connection (*infrastructure*).

The pedagogical approaches used are (*evaluation and feedback*, *motivation*):

[1] *Brainstorming*, where pupils are encouraged to focus on the topic of sustainability and contributed to the free flow of ideas regarding e-waste recycling.

[2] *Project-based learning*, where pupils got information by using online resources about the e-waste management problem and how this affects the sustainability of the planet. In addition, by using data, their knowledge and experience so far, pupils collaboratively did some mathematical calculations and produced some statistical data about the problem.

[3] *Personalization of learning*, where pupils were able to choose educational content and online resources which they liked the most.

[4] *Collaborative learning*, with a strong focus on teamwork.

[5] *Interdisciplinary instruction* where pupils examined and implemented a variety of activities, including subjects ranging from ethics of Internet (non-STEM) to Math (STEM).

[6] *Personalized assessment* where pupils received feedback in different ways during the lesson: peer review and teamwork assessment of their activity.

During the first stage, in the context of the ICT curriculum and, more specifically, in the *Networks* section for two (2) continuous lessons (90 minutes total), I have taken the following actions: First, I used *brainstorming*, where pupils formed pairs or groups of three. Then, in order to activate their prior knowledge on the subject, I asked the pupils to express their opinion about sustainability and e-waste recycling by using an online tool, such as Padlet (https://padlet.com/) (7 min). Afterwards, I made a *PowerPoint presentation* related to sustainability in education and the e-waste recycling problem (13 min) (*sustainability content*). The goal of the presentation was to inspire pupils to be responsible and cautious about environmental issues and understand the sustainability challenges related to ICT. After the presentation, the pupils used *online resources*. They searched *the educational content* provided for this purpose in order to realize why the procedure of e-waste management and recycling is so crucial (15 min). Next, the pupils *were motivated* by earning "green badges" to discover via web pages the regulations for the proper use and for recycling of electronic devices in Greece (10 min). In addition, they found out data and did *calculations* about the e-waste management situation in Greece. At the same time, with the means of a worksheet (e.g., MS Excel), they *exported results* and presented some *statistical reports* (15 min). Finally, the pupils worked in groups of three and made a *digital poster* using all the previous data (20 min). Then, they presented their work and *voted* for the most inspiring poster of the project (10 min).

During the second stage, after two weeks, the pupils completed a 20-item questionnaire entitled *Questionnaire for the e-waste management and the intention for e-waste recycling* (Appendix G) as a data collection tool to determine their prior knowledge about the subject of e-waste recycling and their current knowledge after the implementation of the first stage. Moreover, I wanted to explore their level of awareness, attitudes, and intentions toward e-waste recycling. The questions used were open-ended and close-ended (five-point Likert scale from strongly disagree (1) to strongly agree (5) and multiple-choice). The first section of the questionnaire included questions connected to the gender of the pupils and the number of ICT devices (mobile phone, tablet, computer/laptop) owned at present and during the last three (3) years. The second section recorded their perceptions about sustainability - sustainable ICT and the potential of integrating sustainability into the curricula. Finally, the third section included questions about attitudes, knowledge, perceptions, intention, and consequences of e-waste recycling.

8.3.3 Evaluation of the Validity of the Questionnaire

The Cronbach's alpha (α) value is 0.86, determining internal consistency reliability (Fornell & Larcker, 1981) and was used to measure the internal consistency of the questionnaire. A "high" value of α is frequently used as proof that the items assess an underlying (or latent) construct, along with the supporting arguments and perhaps other statistical measures.

For the evaluation of the results, I used

- descriptive statistical methods for summarizing information of the characteristics and distribution of the values in the sample and
- inferential statistical methods (one-sample t-test) for determining if the average of the five-point Likert scale questions of pupils is significantly greater or less than the neutral option (test value=3).

The appropriate normality test of Kolmogorov-Smirnov and Shapiro-Wilk was performed in advance to examine whether the sample size was sufficiently large (65>30) to assume the normality of the sample mean asymptotically (Curran-Everett, 2017; Hanusz & Tarasińska, 2015). The significance (alpha) level was set to 0.01.

8.3.4 Results and Discussion

The survey revealed that the vast majority of the pupils (N=63, 96.9%) own a mobile phone, 83.1% (N=54) own a computer or laptop, and about half (N=31, 47.7%) own a tablet. The survey also revealed that the majority of pupils (N=48, 73.8%) were bearers of three or more ICT products, especially personal computers and mobile phones, during the past three years. In addition, the analysis revealed that 36.9% (N=24) of the pupils owned three ICT products, while 23.1% (N=15) of them owned two. Only two (2) (3.1%) pupils mentioned that they owned only one product.

A. Perceptions about Sustainability - Integrating Sustainability into Education

The results demonstrated that a large number of the pupils (N=29, 44.6%) are concerned or think seriously (N=25, 38.5%) about their future regarding the environment and the consequences of global warming. In comparison, only 10.8% (N=7) feel comfortable, and 6.1% (N=4) do not care about it. The results have also revealed that only the 27.7% (N=18) had heard about the SDGs prior to our presentation, while the 32.3% (N=21) had never heard of them. For the vast majority of the pupils (N=51, 78.5%), it was the first lesson on sustainability. However, when seeking information about environmental issues (i.e., global warming), the results indicated that the primary sources are the Internet (N=51, 78.5%), the social networks (N=33, 50.8%) follow next, and the family (N=30, 46.2%) comes third.

The pupils still consider that the development of technology with a smaller consumption of resources (N=25, 38.5%), the ensuring that all life forms as we know them can be sustained in the long term (N=16, 24.6%), and the development of technology for a better world (N=13, 20%) may rather describe the concept of sustainability. Table 25 presents the perceptions of the pupils and their intention to learn and get involved with sustainability.

Table 25. Perceptions of the pupils about sustainability(scale 1 = strongly disagree to 5 = strongly agree)

	Frequencies (%)					Descriptive statistics			Test Value = 3 (neither disagree or neither agree)		
	1	**2**	**3**	**4**	**5**	**N**	**Mean**	**Standard Deviation**	**t**	**Sig. (2-tailed)**	**Mean Difference**
I have understood the concepts of sustainability	6.2	9.2	23.1	53.8	7.7	65	3.48	0.99	3.90	<0.01	0.48
I understand how sustainability can help the environment	3.1	1.5	20.0	49.2	26.1	65	3.94	0.90	8.41	<0.01	0.94
I have been motivated to get involved with sustainability	4.6	23.1	35.3	30.8	6.2	65	3.11	0.99	0.89	0.005	0.11
I want to help to improve the world around me by using environmentally friendly techniques	1.5	0.0	13.8	32.3	52.3	65	4.34	0.83	12.93	<0.01	1.34
I want to know more about sustainability	4.6	7.7	23.1	44.6	20.0	65	3.68	1.03	5.29	<0.01	0.68

More than half of the pupils have already been aware of the concept of sustainability (N=40, 61.5%), and they want to know more about it (N=42, 64.6%). In addition, although a high percentage of the pupils have understood or were being motivated to get involved with the concept of sustainability, some of them still disagree or they are neutral.

Moreover, the data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 3 (neither disagree or neither agree): $t=3.90$, $p<0.01$, for the understanding and $t=5.29$, $p<0.01$, for the willingness to know more about the concept of sustainability; $t=8.41$, $p<0.01$ for the vital role that sustainability can have to environment and $t=12.93$, $p<0.01$ for the wish by the pupils to use environmentally friendly techniques.

These results confirm that ESD may reinforce the pupils' sense of responsibility as future global citizens and may better prepare them for the world they will live in (Sauvé, 2017). This can happen because ESD addresses important thematic topics such as climate change and sustainable consumption, but it also advances value and skill-based learning. In this light, by applying action-oriented and problem-based learning, ESD supports the critical examination of worldviews to enable pupils to achieve sustainable living through practical, daily actions. At the same time, education should equip learners of all ages with the knowledge, skills and attitudes to take action for more sustainability and to understand and participate in the decision-making processes necessary to enact lasting and eco-friendly changes.

Figure 19 illustrates the opinions related to the need for the integration of sustainability into the curriculum and how the school can contribute to achieve environmental consciousness. As expected, the majority of pupils (N=60, 92.3%) believed that the concept of sustainability should be integrated into many aspects of the school community (Namusonga & Carter, 2020). Moreover, the data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 3 (neither disagree or neither agree): $t=-6.84$, $p<0.01$, for the weakness of the school to implement and support sustainable practices for the sake of the environment and the society; $t=6.33$, $p<0.01$ for the integration of sustainability into school subjects; and $t=15.13$, $p<0.01$ for the promotion of sustainability in the school community.

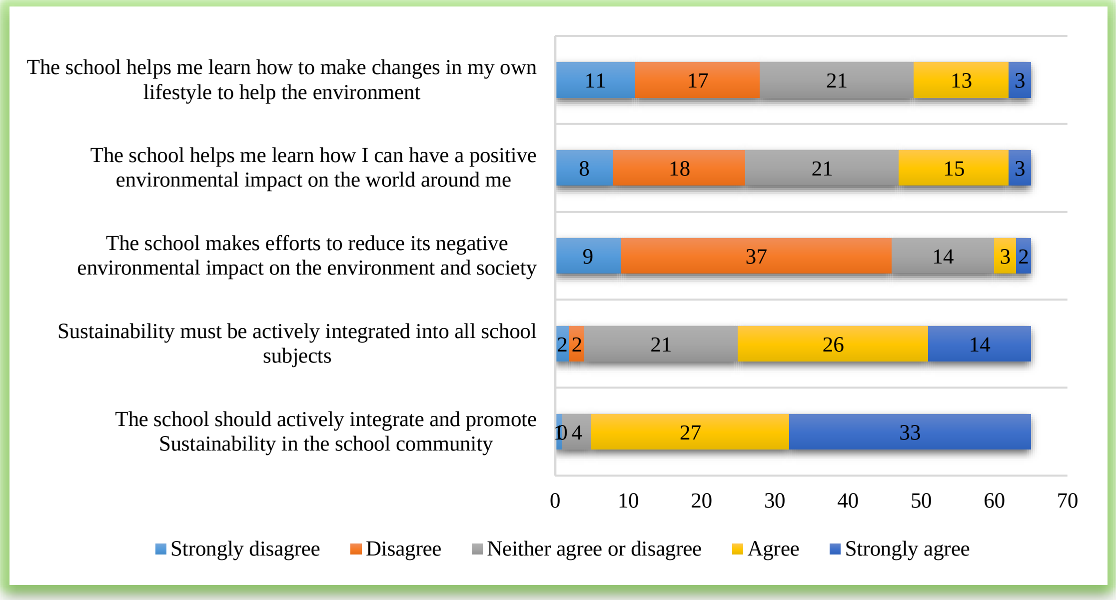


Figure 19. Opinions of the pupils on integrating sustainability in education

These results indicate that a high percentage of the pupils have understood or agreed that integrating sustainability into school subjects and the whole educational system not only provides pupils with a holistic understanding of environmental issues but also prepares them with the knowledge and skills to address these challenges in their future endeavors. To this end, interdisciplinary approaches and real-world applications can further enhance the effectiveness of sustainability in secondary education.

B. Prior Knowledge about E-Waste

The results indicate that prior to our presentation, most of the pupils had no or poor knowledge about e-waste: 18.5% (N=12) had never heard of this concept; 38.5% (N=25), although they had heard, they did not know exactly what e-waste was. On the contrary, only 16.9% (N=11) knew what e-waste was and tried carefully to dispose of this type of material.

C. Perceptions and Attitudes about E-Waste Recycling

Figure 20 shows the perceptions and attitudes of the pupils about e-waste recycling after they participated in the first stage of our study. Most pupils have positive perceptions of the environmental benefits (N=57, 87.7%) and the responsibility to the planet (N=59, 90.8%) that e-waste recycling contributes. In addition, 60% (N=39) have already implemented or have begun e-waste recycling, while 69.2% (N=45) believe that it is not an easy process. Moreover, the data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 3 (neither disagree or neither agree): $t=4.04$, $p<0.01$, for the implementation of e-waste recycling; $t=2.12$, $p=0.003$, for the provision of incentives; $t=12.01$, p<0.01 for the environmental benefits of e-waste recycling; and t=13.56, p<0.01 for the sense of responsibility regarding e-waste recycling.

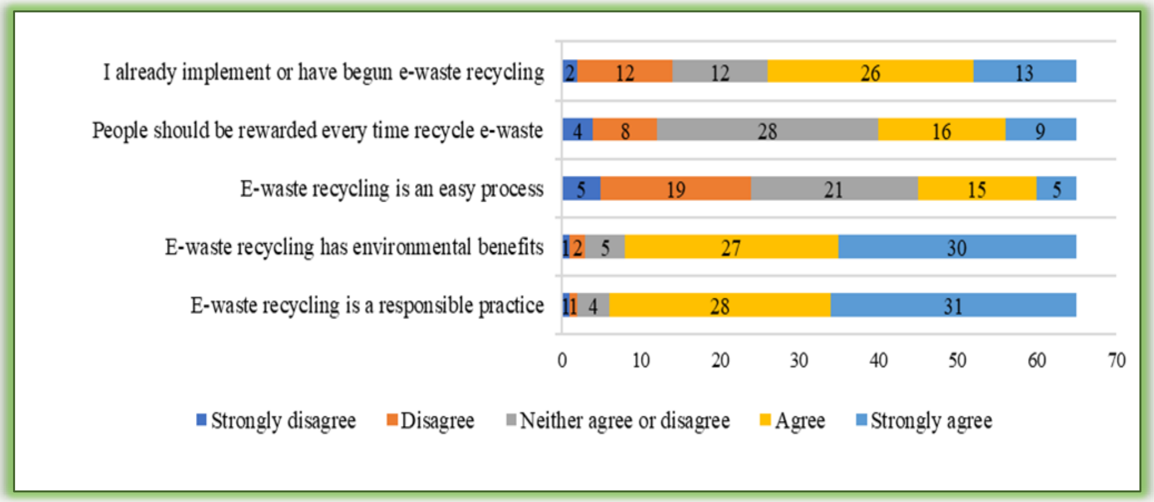


Figure 20. Perceptions and attitudes of the pupils about e-waste recycling

These outcomes denote that a high percentage of the pupils have understood or were being motivated to get involved with e-waste recycling. In addition, teachers can exploit this outcome to raise pupils' awareness of the rapidly increasing e-waste stream and to create a new generation of recycling *heroes*. This can be implemented by educating pupils, who in turn educate their parents and society as a whole about the importance of reintegrating e-waste into the circular economy. The overall aim is to reduce the society's footprint in terms of critical raw materials and to increase the recycling of e-waste.

D. Knowledge about E-Waste Recycling

Table 26 shows what pupils know about e-waste recycling. About half of the pupils (N=34, 52.4%) mentioned that they are unaware of existing policies or regulations regarding e-waste management. Only 16.9 % (N=11) mentioned that they are informed of such policies.

The results revealed that the vast majority of the pupils (N=55, 84.6%) have knowledge of the presence of hazardous and toxic materials in electronic ICT products. Interestingly, some pupils do not consider damaged (N=14, 21.5%) or end-of-life (N=8, 12.3%) ICT products as e-waste, while 20.0% (N=13) and 40.0% (N=26) were unsure, respectively. About 75.4% (N=49) of the pupils have good knowledge of the environmental and health effects of e-waste.

Furthermore, pupils are expected to be informed of the existence of hazardous and toxic materials in ICT products. Although previous studies showed that many pupils are unaware of this existence (Lucache et al., 2017; Ntona et al., 2015), the possible explanation might be the implementation of the two-stage sustainability/e-waste recycling project. In addition, Table 26 shows that many pupils are unaware of the government policies or regulations for e-waste management in Greece. However, the majority of them can easily find information about e-waste recycling practices. Moreover, most of the pupils shown severe concern about the initiatives not taken by the government or the local authorities, i.e., municipal. Therefore, they suggest organizing awareness campaigns, providing marginal or high rewards for e-waste disposal, and penalizing non-e-waste disposal and recycling.

Table 26. Knowledge of the pupils about e-waste recycling (scale 1 = strongly disagree to 5 = strongly agree)

	Frequencies (%)					**Descriptive statistics**			**Test Value = 3 (neither disagree or neither agree)**		
I am aware of	**1**	**2**	**3**	**4**	**5**	**N**	**Mean**	**Standard Deviation**	**t**	**Sig. (2-tailed)**	**Mean Difference**
the government regulations or policy for e-waste management in Greece	15.4	37.0	30.8	15.4	1.5	65	2.51	0.99	-4.03	<0.01	-0.50
the existence of toxic or hazardous materials in electronic IT products	1.5	7.7	6.2	50.8	33.8	65	4.08	0.92	9.40	<0.01	1.08
the impacts of e-waste on the public health, environment and natural resources	1.5	3.1	20.0	46.2	29.2	65	3.98	0.88	9.07	<0.01	0.99
how to recycle my e-waste	6.2	16.9	21.5	41.6	13.8	65	3.42	1.13	2.97	0.004	0.42
which electronic IT products can be recycled	6.2	13.8	21.5	43.1	15.3	65	3.49	1.12	3.55	<0.01	0.50

E. Intention on E-Waste Recycling

Table 27 shows that most of the pupils intend to deal with e-waste recycling and their appropriate management: 81.5% (N=53) intend to recycle; 67.7% (N=44) will make an extra effort to recycle; 76.9% (N=50) believe that it is a mistake not to recycle. Moreover, the data were subjected to the one-sample t-test, with the results in total showing a significant difference from the fixed value 3 (neither disagree or neither agree).

Table 27. Intention of the pupils on e-waste recycling and management (scale 1 = strongly disagree to 5 = strongly agree)

	Frequencies (%)					**Descriptive statistics**			**Test Value = 3 (neither disagree or neither agree)**		
	1	**2**	**3**	**4**	**5**	**N**	**Mean**	**Standard Deviation**	**t**	**Sig. (2-tailed)**	**Mean Difference**
I intend to recycle e-waste	3.1	3.1	12.3	47.7	33.8	65	4.06	0.93	9.17	<0.01	1.06
I will make an extra effort to recycle e-waste	4.6	4.6	23.1	41.6	26.1	65	3.80	1.03	6.24	<0.01	0.80
It is a mistake for me not to recycle e-waste	4.6	7.7	10.8	44.6	32.3	65	3.92	1.08	6.90	<0.01	0.92
It comes easily for me to find information regarding e-waste recycling	3.1	6.1	15.4	47.7	27.7	65	3.91	0.98	7.47	<0.01	0.91
The school should organize activities for e-waste management and recycling	1.5	4.6	9.2	40.0	44.6	65	4.22	0.91	10.77	<0.01	1.22

These outcomes demonstrate a positive perception about implementing e-waste recycling and the environmental benefits connected with high intention or extra effort to recycle. Consequently, cultivating the intention of e-waste recycling in pupils is essential for raising awareness and fostering environmentally responsible behaviors (Shyam et al., 2017).

F. Awareness about E-Waste Recycling

Table 28 presents the survey results concerning the awareness of the pupils on e-waste recycling. As one may notice, the majority of the pupils were of the opinion that e-waste recycling would reduce the level of e-waste produced (N=52, 80.0%), it is environmentally friendly (N=55, 84.1%), and it works reciprocally for the society (N=56, 86.2%).

Table 28. Awareness of the pupils on e-waste recycling (scale 1 = strongly disagree to 5 = strongly agree)

	Frequencies (%)					**Descriptive statistics**			**Test Value = 3 (neither disagree or neither agree)**		
E-waste recycling	**1**	**2**	**3**	**4**	**5**	**N**	**Mean**	**Standard Deviation**	**t**	**Sig. (2-tailed)**	**Mean Difference**
works reciprocally for the society	3.1	3.1	7.7	43.1	43.1	65	4.20	0.94	10.31	<0.01	1.20
is a new business opportunity or challenge	3.1	9.2	33.9	29.2	24.6	65	3.63	1.05	1.82	<0.01	0.63
promotes the right to repair and reuse an electrical IT device	4.6	12.3	37.0	27.7	18.4	65	3.43	1.08	3.23	0.002	0.43
supports the sustainability of the planet	1.5	3.1	10.8	37.0	47.7	65	4.26	0.89	11.44	<0.01	1.26
reduces the level of e-waste generated by the community today	3.1	4.6	12.3	35.3	44.6	65	4.14	1.01	9.06	<0.01	1.14

These results highlight the importance of the development of an awareness action plan on e-waste that should take into consideration the following perspectives:

- **[1]** The action plan should *aid the pupils to establish an interest* in increasing their awareness about environmental health and improve the quality of their nearest environment.
- **[2]** The action plan should *increase the knowledge and awareness* of the pupils regarding e-waste management, motivate action and obtain positive attitudes about it.
- **[3]** The action plan should *support continuation and progression* as the behavior changes toward green attitudes is a long-term procedure.
- **[4]** The action plan should *be linked with real-life community problems* and cater for these e-waste problems in the best way possible.

The outcomes are also in line with the literature, which indicates that the infusion of e-waste management in some general courses all pupils take in order to raise awareness and to help them manage e-waste (Yadav & Pathak, 2016; Zhang et al., 2019)

G. Means of Disposing Damaged or End-of-Life ICT Products

The pupils were also asked to point out how they tend to dispose of damaged or end-of-life ICT products they own. It was interesting to observe that half of the pupils (N=33, 50.8%) tend to deliver these products to a store and purchase a new one, while 20% (N=13) dump them in designated e-waste collection points. About 12.3% (N=8) of the pupils point out that they tend to give to another person or sell them, and only 6.2% (N=4) noted that they keep them at home. The study also demonstrated that three pupils (4.6%) tend to dispose of them in the sea or a river.

The study results also point out that several pupils do not consider damaged or end-of-life ICT products e-waste. This consideration is a big issue, as these pupils, as young adults, will be involved in numerous decisions about ICT supply and purchase in the future (So et al., 2019). The results also depicted that the factors preventing e-waste disposal include the lack of awareness programs, high-security concerns related to data breaches, nostalgic connection with the ICT product, and complicated disposal processes. Nonetheless, the pupils are willing to buy "green" ICT devices manufactured and used without harming the environment.

8.4 Limitations

The main limitations of both studies are the relatively small sample of pupils and the fact that they came from only one secondary school in Greece. These limitations imply that the research results must be interpreted with caution. Therefore, the following steps in the present studies, which have already begun to take place, include the design and teaching of sustainability modules using learning platforms (i.e., Moodle) in a larger sample of pupils from different schools. These modules will be integrated into the ICT curricula in order to explore further the pupils' awareness level and the potential positive change in their attitudes or actions toward sustainability and e-waste recycling, as well as the sustenance of this change.

Nevertheless, the questionnaires, although used to assess the development of sustainability competence in pupils, are not comprehensive assessment tools that tackle all the dimensions of the perceptions and opinions assessed but are based on essential indicators identified in the literature. In addition, the questionnaires are subject to a number of biases. Still, by piloting them with other pupils and rewriting them according to the feedback from both the teachers and the pupils, they may give a clear guidance to pupils on how to answer them correctly and minimize the randomly generated answers.

Chapter 9 – ESD in Higher Education: Implementing the SDGs and Embedding Sustainability into the ICT Curricula

This chapter presents the challenges of introducing sustainability in HEIs, outlines the principles for sustainability integration into the undergraduate ICT curricula and provides suggestions for the development of such curricula. Then, the impact of education on environmental awareness focusing on sustainability, energy conservation, attitudinal disposition, and e-waste management practices among ICT students at a Greek university is investigated. The research methodology for the processing of two questionnaires (pre-test and post-test data) distributed during two lectures regarding sustainability at a two-week interval is described, and the results with the discussion are listed.

9.1 Introduction - Embedding Sustainability and SDGs Values in ICT Higher Education

The primary focus for the support and the accomplishment of the SDGs by HEIs is on education by reorientating the curricula toward SD. Indeed, UNESCO (2018) indicates that SD education has the potential to attract more students due to its essential significance for the future. Furthermore, several studies suggest that including the topic of sustainability in the curricula may increase the recruitment and retention of minorities and women in engineering (Klotz et al., 2014). Thus, there exist many successful examples of sustainability-related content integration in fields like chemistry (Wissinger et al., 2021), accounting and business (Ebaid, 2022), civil engineering (Burke et al., 2018), environmental engineering (Tang & Sillanpää, 2018) and mechanical engineering (Okokpujie et al., 2019).

Furthermore, numerous studies (Biasutti et al., 2016; De Wit & Leask, 2017; Franco et al., 2019; Holm et al., 2015) confirm that sustainability-oriented curricula contribute to the environmental knowledge and promotion of environmental awareness of the students, which are the main drivers of environmentally friendly behavior. Moreover, a study has suggested that raising awareness could also contribute to and support the reduction of the carbon footprint of students (Valls-Val & Bovea, 2021).

Despite the previously mentioned examples of integrating sustainability issues into the curricula, one of the significant barriers to the broad incorporation of sustainable education in the HEIs is the fact that sustainability is seldom systematically embedded in the curricula, and at the same time, it is absent from the HEIs' overall strategy (Avila et al., 2017). Many HEIs still focus more on optimum land use, environmental planning, and resource management (i.e., improving energy efficiency, conserving resources, use of renewable energy and management of wastes) than on incorporating and infusing sustainability into the curricula.

For this reason, it is essential to establish social and environmental perspectives in the curricula of future graduates, also known as *sustainable curricula* or courses that include sustainability (Özkan & Mishra, 2015). These courses may:

- *Focus on a topic that differs from sustainability* but integrates a sustainability-related module or unit or addresses a sustainability challenge.
- *Include one or more sustainability-oriented* activities or actions or integrate sustainability issues throughout the course (Paul et al., 2020).

However, it can be estimated that a renewal of the undergraduate curriculum will take 15-20 years to embrace and fully integrate a significant new set of knowledge and skills related to sustainability (Desha & Hargroves, 2014). The HEIs should deploy a holistic pedagogy that focuses on learning content, following the learning outcomes, and on acquiring broader skills by stimulating learning and promoting core competencies (Adams et al., 2018; Holm et al., 2015). These competencies include collaboration, communication, and critical thinking skills, as well as the adoption of values and attitudes relevant to addressing the global SD challenges.

In addition, they should promote a sense of environmental responsibility and respect for social diversity (Argento et al., 2020). Finally, this holistic pedagogy should focus on learning processes and the learning environment by teaching and learning in an interactive, student-centered way that enables exploratory, action-oriented, transformative, and environmentally friendly learning (Kormos & Julio, 2020).

In light of the adoption of ESD and the integration of sustainability into the curricula, several studies that examine the understanding of the students regarding SD and their familiarity with key environmental legislations, policies, and standards indicate that the concept of sustainability is unclear for most students (Gomes et., al, 2021; Liu et., 2020). Moreover, researchers have noticed a deficiency of publications exploring what students actually know and perceive about sustainability (Stough et al., 2018; Alm et al., 2022). Research on the perceptions of the students about SD and sustainability usually focuses on their general perceptions of climate change, personal responsibility (SOS International, 2021), and sustainability knowledge. Moreover, survey results showed that students might exhibit a lack of motivation and willingness to engage in initiatives effectively and responsibly toward achieving sustainability (Mahmoud et al., 2020).

Although the students can provide innovative ideas or suggestions and contributions to the improvements in the current performance of HEIs, studies on the perceptions of the students toward the link between sustainability and HEIs are under-researched. Expósito & Sánchez (2020) discuss campus development planning based on the perceptions of the students, and Chaudhary & Dey (2021) explore sustainability practices of the HEIs from the perspective of the students, finding that sustainable practices predict student satisfaction. Kukkonen et al. (2018) analyze the priorities of the students for SD in higher education, highlighting that environmental aspects are perceived as principal factors while giving negligible significance to the introduction and development of curricula focusing on sustainability. Furthermore, there is no evidence related to the results of sustainability-oriented activities involving students, their perceptions regarding the role of HEIs in sustainability, and the factors influencing their involvement in sustainability (Lim et al., 2022).

In addition, although there is no direct documentation to support sustainability integration in ICT, the available literature indicates sufficient evidence of the positive impact of sustainability integration in non-ICT engineering disciplines (Weiss & Barth, 2019). Even though some studies highlight the importance of integrate sustainability units into the HEIs' educational programs in the different ICT disciplines aiming to prepare students to be capable and responsible informatics professionals and understand their role in building the sustainable society of tomorrow (Özkan & Mishra, 2015; Chaudhary & Dey, 2021), the existing literature on sustainability in the ICT curricula is rather limited and isolated (Mishra & Mishra, 2020).

Besides, despite the recorded need for a broad curricula reform, the majority of the efforts to change ICT curricula to include sustainability issues have primarily concentrated on the development of individual courses on sustainability (Novo & Murga-Menoyo, 2015; Kyle, 2020). Moreover, there is an apparent lack in the literature on formal assessment and evaluation mechanisms dealing with the perceptions and opinions of students about integrating sustainability into ICT curricula (Stough et al., 2018).

9.2 Background Information for the ESD on E-Waste and Cloud DCs

A common theme that has emerged in the academic literature is that there is a tremendous need for consumer awareness regarding the consumption and the disposal of e-waste as well as the consumers' recycling behavior. Various strategies have been identified to promote pro-environmental behaviors regarding recycling, including

- *the convenience* of recycling opportunities (Meneses and Palacio, 2005),
- *the reduction of the distance* to collection points, saving consumers on the time-cost (Rousta et al., 2015), and
- *monetary considerations* of recycling, including cost and incentives (Thøgersen, 2003).

At the same time, the literature implies that young consumers are a critical group as they are more often responsible for the decision-making around the disposal and replacement of their electronic devices than the older generations (Nowakowski, 2016). Several studies conducted with university students highlight the low level of awareness of young consumers about e-waste recycling in several countries and regions. In Australia, Islam et al. (2021) showed that although the students were aware of what e-waste is, there is a severe deficiency of knowledge related to collection points and current national recycling programs. In Northwest China, Ramzan et al. (2019) found that young consumers exhibit a low awareness level of e-waste regarding the laws, policies, recycling programs, and finally, formal and informal recycling sectors. In Turkey, students possess low-level knowledge regarding e-waste recycling and regulations (Deniz et al., 2019).

Edumadze et al. (2013), based on results in Ghana, report that poor public awareness is still one of the main barriers to pro-environmental behavior. The lack of recycling facilities and concerns for information security, referred to as privacy concerns, were identified as reasons why most university students preferred hoarding their devices instead of reusing or recycling (Zhang et al., 2019). Yushkova & Feng (2017), based on their observations in China and Germany, argue that while there is a positive intention to give mobile phones to recycling, there is still no established habit, and devices are stockpiled at home or given away. Dagiliūtė et al. (2019) mention that in Lithuania, "information provision remains the primary tool for e-waste management system efficiency from the consumer side", along with the existence of proper infrastructure.

Yushkova & Feng (2017) conclude that increasing the knowledge of young consumers about e-waste products and hazards may also be essential in increasing recycling behaviors. It has been remarked that in countries where environmental education has been included in the education curriculum, individuals are more concerned with social welfare and behave more environmentally friendly (Meyer, 2015). Nwagwu & Okuneye (2016) examined the perceptions of students about e-waste in Nigeria and found a correlation between awareness and the students' sex and class.

According to Borthakur & Singh (2021), student activists could utilize social media to spread knowledge and encourage proper e-waste management among their peers. Edumadze et al. (2013) recommended e-waste campaigns on campus as a tool to increase awareness and foster a culture that supports efficient management. The importance of the level of awareness is increased in light of results that confirm that the majority of the population is willing to participate in recycling programs and be involved in extended producer responsibility schemes (Wang et al., 2022).

Simultaneously, a rather large body of literature emphasizes the importance of and the vital need for HEIs to deliver renewable energy education at all levels around the world (Gródek-Szostak et al., 2021; Leal Filho et al., 2019; Lucas et al., 2018; Rodgers, 2021). Furthermore, access to power based on renewable energy sources can give a competitive edge and become instrumental in future-proofing the DCs, as there are several environmental implications relating to energy consumption originating from data processing and data storage (Katal et al., 2022). Therefore, promoting eco-energy awareness among young people is crucial since it is they who will be responsible for adopting and implementing energy-saving practices in the near future, starting with their own homes and, subsequently, the entire economy (Ogbuanya & Nungse, 2021).

Richard (2018) observed that energy wastage occurs in the Kenya HEIs as a result of a lack of students' awareness regarding the harmful effects of energy consumption, along with the fact that they have also not been trained on energy-saving methods. Wadha & Watkins (2018) noted that the students in Qatar had a low level of awareness regarding the negative impact of energy consumption and found that effective energy usage, monitoring, and environmental impact depend on users' awareness and education.

Eshiemogie et al. (2022) underline the crucial need to introduce renewable energy into the Nigerian engineering undergraduate curriculum and agree that the deployment of renewable energy courses in the curriculum would help the country toward a zero-carbon economy. Nevertheless, there is a gap that needs to be explored regarding what ICT students know and whether they are aware of renewable energy usage in DCs. Moreover, in the literature, there are no research articles that show any relevant activity in these regards.

In line with these results, this Thesis argues that the awareness and knowledge of university students are essential to make e-waste disposal and management successful, as the students comprise a significant percentage of the young and educated population. At the same time, the lack of environmental education in the area of renewable energy usage in DCs may be a critical factor that would lead the students to engage more actively in environmental practices.

Nevertheless, the ICT students, specifically, learn throughout their studies to apply and practice technical knowledge and skills in order to select, use, and manage appropriate digital technologies in their work environment. Consequently, the ICT students, by default, develop a thorough understanding of the software and hardware components and of the operations of relevant and sustainable use of ICT systems, including their procedures, functions, processes, and devices. Therefore, they may be able to set up the future green ICT trends regarding environmental protection and could take action as agents of change in both their present and future lives.

9.3 Implementing the SDGs by the HEIs

A sustainable university is an educational institution that prepares the young citizens of the world about SD, provides relative awareness of pressing societal issues, and minimizes the impact of campus operations on the environment and society (Zanellato & Tiron-Tudor, 2021). In addition, HEIs can encourage students and faculty to take action as they make sustainability a prime concern (SDSN, 2017).

Lertpratchya et al. (2017) provide three reasons for why it is essential that HEIs communicate sustainability effectively. First, many people attend HEIs despite the inherent inequalities in their background and social standing. Second, the most substantial number of students enrolled in HEIs are in their late adolescence (18 to 21), a critical period for identity development. Third, higher education is the last stage of education before entering the labor world, where graduates can have a significant career impact as professionals. Moreover, according to the latest International Association of Universities report (Van't Land & Herzog, 2017), the majority of the university staff has a medium (43%) or remarkably high (36%) knowledge about SDGs and links SD to fundamental environmental questions.

Nevertheless, the HEIs' engagement with the SDGs provides a unique opportunity to take a whole-of-university approach to solve a slew of significant challenges for humanity and can help HEIs in many creative and impactful ways: SDGs generate increased demand for sustainability-related education. Moreover, SGDs are inclusive and diverse enough to be integrated into programs for undergraduate, graduate or research degrees, such as class activities, lecture material, projects, assignments, and study trips (Verma et al., 2021; ISCN, 2018).

For this reason, HEIs should revise and update their curricula to face sustainability principles in the offered courses (Owens, 2017). In addition, SDGs provide a comprehensive and widely acknowledged guide toward a responsible university which should offer solutions-oriented approaches to global challenges (Latorre-Cosculluela et al., 2023). Finally, HEIs could search for and develop new funding streams by encouraging collaboration with new internal and external partners (Biasutti et al., 2016).

In general, HEIs can engage with the SDGs from a variety of perspectives, each with its own outcomes (Gual, 2019; Hallinger & Chatpinyakoop, 2019), namely

- *Recognition:* The identification and acknowledgement of what a university is already implementing to contribute to the SDGs can provide an inspiring narrative about the impact and give a substantial boost for additional action.
- *Opportunistic alignment:* The recognition of the value and significance of the SDGs by different areas across the university and finding opportunities to use them in order to incorporate them into specific activities and programs without having an overall strategy.
- *Organizing and embedding principles*: The inclusion of the SDGs principles into all relevant university governance structures and frameworks will drive SDGs to become a vital and integral part of the university.

The third perspective regarding the organization and incorporation of the SDGs principles requires a holistic approach to a sustainable university (Rieckmann, 2018; Pacis & Vanwynsberghe, 2020). This approach can provide a common language and platform for building a close collaboration between the university members in terms of the following five domains:

[1] *The education,* by reorienting the curricula toward SD. This education must provide students with the motivation, knowledge, and skills to understand and meet the challenges of the SDGs. In order to achieve this, the SDGs and the sustainability principles may be incorporated into all undergraduate and graduate courses as well as in graduate research training by HEIs. (De Wit & Leask, 2017; Van't Land & Herzog, 2017). In addition, HEIs may offer training on the SDGs to all lecturers, course coordinators and curricula developers. Furthermore, they may provide executive education and capacity-building programs on the SDGs for external stakeholders as the necessary abilities to address them (Novo & Murga-Menoyo, 2015). Finally, they may advocate state and national education policies that promote education for the SDGs and encourage students to co-create learning environments and opportunities that support SDGs learning.

[2] *The research,* by discovering answers to important social questions related to the SDGs and by providing opportunities for interdisciplinary innovations and solutions (UNESCO, 2014). The HEIs may support the development of skills and abilities to effectively achieve the SDGs since interdisciplinary research can address complex sustainability challenges and further knowledge on SD.

[3] *The operations,* by achieving a zero footprint for campus services and functionalities (Valls-Val & Bovea, 2021). The provision of opportunities for communicating knowledge and skills among students and professionals through measures such as energy conservation, waste reduction, water conservation, and sustainable transportation may help to address this challenge.

[4] *The community,* by empowering students and faculty to act on sustainability. The HEIs may support and encourage all student clubs and societies to become involved in the SDGs and participate in SDG-related activities and events (Lertpratchya et al., 2017; Expósito & Sánchez, 2020). They may also promote student volunteering activities that address the SDGs. At the same time, they can assist students in starting a network or club to mobilize the campus and student groups around the SDGs through projects, campaigns, and events (Lambrechts, 2016).

[5] *The Governance,* via the Ministry of Education, by prioritizing sustainability for the HEIs and incorporating operations aligned with the SDGs into the university reports. Furthermore, they may support students participating in regional, international and youth leadership SDG programs (United Nations, 2015).

9.3.1 Sustainability Competencies in Education

Based on the above-mentioned holistic approach, in order to further achieve a smooth engagement with the SDGs, the HEIs communities must acquire new competencies since global competencies like critical and creative thinking are too general to deal with the challenges faced in addressing sustainability. These competencies tackle sustainability challenges and foster skills and attitudes for effective problem-solving and performance tasks (Cebrián & Junyent, 2015).

For this reason, HEIs should offer an appropriate set of skills, knowledge, attitudes, and values necessary to enable the students of today, who will be the leaders of the future, to address complex sustainability issues and succeed in a sustainable future (Pacis & Vanwynsberghe, 2020). The transition toward a sustainable university depends on how faculty, staff, and students adopt behaviors and values that seek to accomplish the goal of “zero waste” and transform them into environmentally aware consumers.

Table 29 presents the sustainability competencies for the support of the design of courses and programs in sustainability, learning and teaching evaluations, and training faculty and staff, adapted from a literature-based study conducted by Wiek et al. (2011). These competencies support the definite need for HEIs to redesign the physical, virtual, and online learning environments and reform their curricula to inspire students to take action and be involved with the SDGs.

Nevertheless, it is imperative to recognize that there is not a single way for the HEIs to implement or support the SDGs. HEIs differ from one another in many ways, including size, structure, financial access, work already being done in SD, priorities, values, and the needs of the communities they serve. Consequently, the ways they choose to engage with the SDGs should reflect these differences and opportunities.

Table 29. Sustainability competencies in education

Acting fairly and ecologically: the ability to orientate oneself regarding justice, solidarity, and conservation values and take responsibility for one's actions or know alternative actions
Anticipatory thinking: the ability to develop visions, apply precautionary principles, and be able to deal with risks and changes
Use of media and communication: the ability to communicate in intercultural contexts, to deal with IT and to pass criticism to media
Cooperation in groups: the ability to learn from others, to deal with conflicts and to show understanding/sympathy
Critical thinking: the ability to reflect on one's values and actions and challenge practices, opinions, and norms
Empathy and change of perspective: the ability to recognize one's external point of view and to accept diversity
Evaluation: the ability to process evaluation standards and accomplish independent evaluations related to conflicts of interest and goals, contradictions, and uncertain knowledge
Interdisciplinary work: the ability to manage methods and knowledge of different disciplines and to operate on complex problems in interdisciplinary contexts
Planning and realizing innovative projects: the ability to show willingness for innovation, develop ideas and strategies and plan and execute projects
Participation: the ability to recognize areas of creativity and collaboration and to participate in the design of initiatives
Systemic thinking and handling of complexity: the ability to identify and understand connections

Table 30 presents a number of case studies of how HEIs worldwide are already implementing and supporting education for the SDGs, as nowadays HEIs are increasingly and consistently integrating sustainability into their campus infrastructure and operations (Lambrechts, 2016).

Table 30. Curricular initiatives for university students

Curricular initiatives	University -Country
Sustainability course – developing an open interdisciplinary sustainability course for all students https://www.helsinki.fi/en/news/news-and-press-releases/new-course-offers-sustainability-skills-students-all-fields	University of Helsinki - Finland
Infusing Education for Sustainable Development into Curricula: Efforts of the School of Education at The University of the West Indies (Mona Campus, Jamaica) https://blogs.upm.es/education4sdg/2020/05/09/infusing-education-for-sustainable-development-into-curricula-efforts-of-the-school-of-education-at-the-university-of-the-west-indies-mona-campus-jamaica/	The University of the West Indies – Jamaica
Integrating the UN SDGs into Resource Engineering Using an International, Collaborative Course Model https://www.mining.vt.edu/	Virginia Tech – The United States and Colombia
Developing Coursework and Supplementary Activities https://penniur.upenn.edu/ events/why-cities-roundtable-on-informality-as-a-way-of-life-challenges-to-sustainable-urban-development	The University of Pennsylvania – United States
Developing Intersectional Approaches to SDGs: Case of Migration https://blogs.upm.es/education4sdg/2021/09/06/developing-intersectional-approaches-to-sdgs-case-of-migration/	Yasar University – Turkey
Enhancing Universities' Sustainability Teaching and Practices (EUSTEPs) https://www.eusteps.eu/	Erasmus – European Union
Venice International University Globalization Program https://www.univiu.org/study /globalization-program	Venice International University – Italy
Games for the SDGs: Using participatory games as an experiential learning approach for responding to SDG challenges in Namibia https://cms.my.na/assets/documents /p1d2u9t5l75m29dvmtf1aknqs4.pdf	Namibian University – Namibia
Building a Community of Practice for Sustainability Literacy at TU Dublin https://blogs.upm.es/education4sdg/2021/07/26/building-a-community-of-practice-for-sustainability-literacy-at-tu-dublin/	Technological University Dublin – Ireland

9.4 Implementation of an ICT Course With Sustainable Development Topics

In response to the question regarding the development of the ICT curricula integrating sustainability issues, the main challenge identified in this incorporation is to ensure that the previously mentioned sustainability competencies (Table 29) are not integrated into the curricula on isolated occasions due to the individual initiatives of faculty, but instead, they are developed consistently and systematically throughout the curricula (Hadgraft & Kolmos, 2020). Therefore, ICT course content must have a section related to SD whenever relevant. Furthermore, it has been recommended that the fundamentals of SD and social responsibility be provided in the first semesters of the curriculum (Weiss & Barth, 2019). In that way, students can address the rest of the courses taking these concepts into consideration and facilitating the connections with other curricula subjects.

A primary teaching technique used in a course as such may be the collaborative problem-solving one (Bataeineh & Aga, 2022). The fact that sustainability in ICT is a relatively new concept and students might not have a strong understanding of it encourages this selection. Therefore, this technique will enhance their ability to understand and communicate in a group context, define sustainability issues, and propose solutions (Steinfeld & Mino, 2009). At the same time, pedagogical approaches should be developed ranging from passive learning in the class (e.g., formal lectures, guest lectures, forum-discussion panels, cases discussed by the instructor, online discussions, and film screenings) to passive learning out of the class (e.g., guided city tours, company visits, participation in roundtables-university stakeholder meetings).

Moreover, the deployment of active learning in class (e.g., group discussions with reporting, questions, brainstorming, teaching-learning conversations, voting, simulation games, cases presented by students, group work, self-study, project planning on the computer) and active learning out of the class (e.g., interviews, internships) pedagogical approaches should be encouraged (Stough et al., 2018; Franco et al., 2019; Mahmoud et al., 2020).

Finally, topics related to sustainability themes relevant to each course content should also be developed. The expected learning outcome at the end of a course is the students' awareness of green informatics; as a consequence, the students may deal with computer devices in an eco-friendly way (UNESCO, 2017). In addition, the students are expected to be capable of applying alternative green IT techniques that can be used to increase sustainability activities in their everyday lives.

At the same time, in order to estimate the level of student awareness, concern, and views about sustainable topics, the HEIs should assess mainly first-year students before teaching these topics (Alsina et al., 2017). Some indicative questions that may be considered for this reason are

- whether students *are aware* of any requirements to demonstrate sustainable awareness within their program of study,
- whether students *think* of their work's social and environmental impact as a future professional, and
- whether it is appropriate *to include content about sustainability* within the lessons that the students attend.

The primary results of the above-mentioned questions analysis will give some guidelines and clues that the HEIs should consider regarding the design and the reorientation of the ICT curricula toward sustainability. This design may incorporate topics according to the ACM/IEEE-CS and ACM/AIS curricula guidelines under the broad areas of:

- *Hardware* in terms of the longevity of systems; the cost-benefit comparison between upgrading and replacing (providing information about the energy requirements for the various approaches, as well as financial and environmental costs); the efficient system power saving and design features, etc.
- *Software* in the context of teaching programming and data structures using SD examples (i.e., specific applications to address SD-related issues and SD-related requirements included in software specifications for programming exercises).
- *Communication and interaction* in terms of distributed systems and networks for the support of SD; the IT support for concepts such as the paperless office.
- *Practice professionalism and ethical aspects* (case studies on choosing to follow SD best practices or save money at the expense of sustainability).
- *Sustainable finance* in terms of the software cost and licensing; the e-business and e-commerce of globalization; the role of the Internet in communications.

- *Theoretical mathematics* in terms of the least spanning tree; the graph theory (e.g., shortest path through a network; minimum spanning tree); the supply chain management (e.g., the traveling salesman problem).
- *Green computing* in terms of time to the failure and disposal of old hardware (e-waste recycling); the power usage of computers and ICT equipment; the requirements for regular updates in hardware; and the environmental costs for the support of the Internet era.
- *Social aspects* in terms of the actual impact of the daily use of computers in society.

By embedding sustainability issues into the ICT curricula, HEIs can help shape the next generation of ICT professionals who not only possess technical prowess but also understand the importance of creating technology that is environmentally responsible and socially equitable.

9.4.1 The Research Design of Embedding Sustainability into the ICT Curricula

The learning outcomes evaluation of the previously mentioned sustainability topics is a critical challenge that needs to be addressed. This evaluation can work for different purposes: collect information and record the progress and achievement of the students toward sustainable learning outcomes; spread the progress between students, identify strengths and areas for development, and apply this information to define learning goals; provide feedback regarding the success of learning and teaching procedures in order to help in the programming, implementation and improvement of these procedures (UNESCO, 2005).

For this reason, the following techniques can be used:

- *Large-scale assessments* of the students' learning outcomes.
- *Evaluation of learning results* at the individual level.
- *National assessments* aligned with national educational priorities related to sustainability.

In addition, the faculty should use a mix of more reflective and performance-based methods and traditional assessment methods (Casado-Aranda et al., 2021). These methods may include self and peer assessment that captures the insights of the students on SD aspects as a personal change toward addressing the sustainability challenges, a more profound understanding of sustainability issues, and engagement. Finally, the feedback from the faculty and the peers, as well as the self-evaluation (e.g., the use of portfolios), empower the students to monitor their own learning processes and identify possibilities for improvement (Basilotta-Gómez-Pablos et al., 2022).

In order to implement any change in ICT curricula, the direct or indirect cooperation of several key stakeholders of the HEIs, particularly faculty and students, is required. The challenges faced in attempting to embed SD education in curricula were directly related to the concept of the lecturers, the knowledge and attitude to the subject, the expectations of the students and syllabus constraints. The recommendations and guidelines provided by UNESCO (2005) for reorienting teacher education in order to address sustainability categorize the challenges faced by teacher-educators in the following:

[1] Institutional resources, support and awareness.
[2] Prioritizing sustainability in the educational community.
[3] Reforming education structures and systems.
[4] Establishing and maintaining partnerships.

In addressing such challenges in a Greek university regarding mainly the first and second categories, an explanatory study was conducted in the spring semester of 2022 during May following a modular and progressive approach for sustainability topics that do not require transformative changes in the computing courses. The study aimed to provide answers to the research objectives of the Study Two, namely, RO 2C, RO 2D and RO 2E, as described analytically in section 2.3. In order to strengthen the mentioned research questions when the study is actually being carried out, a number of sub-questions that are clearly connected and focused on the broader context and relevance of the research to be conducted are formulated. These sub-questions are researchable, manageable, logically ordered important sub-pieces as they allow us to answer the main research objectives in a step-by-step manner:

- To what extent does the integration of SD education in ICT curricula improve the knowledge of the ICT students about sustainability issues and the environmental impact of their studies?
- What are the perceptions of the ICT students regarding the contribution of university education to environmental awareness and the organization and promotion of sustainability activities in the university community?
- To what extent does an educational intervention affect the perceptions of the ICT students regarding the necessity for the inclusion of sustainability in the university ICT curricula?
- Does the integration of a unit sustainability-related in ICT curricula positively affect the intention of the ICT students to engage in sustainability and raise their awareness about green informatics?
- Does the provision of rewards positively affect the involvement and engagement of the ICT students with green informatics?
- To what extent does an educational intervention improve the knowledge of the students about e-waste and affect their intention to recycle them properly?
- What are the perceptions and attitudes of the ICT students regarding e-waste recycling?
- To what extent does an educational intervention affect the awareness of ICT students about e-waste recycling?
- To what extent does an educational intervention contribute to the environmental awareness of ICT students regarding renewable energy usage in order to reduce energy consumption in DCs?

9.5 Methodology

In order to answer the research objectives and the derived sub-questions mentioned above, an interventional study was conducted (Ranganathan, 2019). For this reason, I developed and implemented four independent green computing modules for the Computer Networks undergraduate course at the Department of Informatics of the University of Piraeus in Greece.

The content focused on green informatics and the implementation of a number of the SDGs, which have strong relevance to the academic ICT environment. In particular, I aimed to ensure that all students acquire the knowledge and skills needed to promote SD (SDG 4.7); increase the use of renewable energy through both international cooperation and expanded infrastructure and technology for clean energy (SDG 7); focus on the promotion of sustainable consumption and production patterns through innovations around an e-waste reduction, and an increase in recycling, reuse, and prevention practices (SDG 12); promote strategies and policies for the improvement of awareness-raising, education and institutional and human capacity on mitigation, impact reduction, early warning and adaptation to climate change (SDG 13) (United Nations, 2015).

- *Module 1:* Green computing introductory module, including general concepts and principles of sustainability and green computing, background and motivation for green computing, education for sustainable development, embedding sustainability into the ICT curricula, and green informatics.
- *Module 2:* Energy saving module, including algorithms for energy optimization and power saving techniques for wireless sensor networks, sleep mode algorithms and graph-theoretic algorithms for energy saving in IP networks (ESACON ESTOP ESOL GRiDA).
- *Module 3:* E-waste module, including electronic network devices, waste disposal and recycling, regulatory compliance, and environmental impact of e-waste
- *Module 4:* Energy Consumption in Cloud Computing Data Centers module, including why saving energy is vital to data centers, standard energy-saving practices in data centers and sustainable web design.

These modules were presented in the current Computer Networks class - a compulsory course in the fourth semester of the Department of Informatics - during two (2) lectures at a two-week interval over a four (4)-week period in May 2022: Module 1 and Module 2 were presented during the first lecture (week One), and Module 3 and Module 4 during the second lecture (week Four) (Table 31). This action provided the students with the chance to reflect and think about the benefits of the course and its content. The lecturers were developed with the following objectives:

[1] To provide students with the *principles* of issues relevant to green informatics.

[2] To increase the level of student *awareness, concern, and views* relevant to sustainable topics.

[3] To estimate their *reactions and intention* about integrating and teaching these topics into the ICT curricula eventually.

Table 31. Process followed for the educational intervention and the completion of the questionnaires

Time frame	Lecture	Phases of the lecture	Lecture modules
Week One	First Lecture	Phase A - Complete the pre questionnaire Phase B – Presentation of the modules	 Module 1 Module 2
Week Two Week Three	Interval		
Week Four	Second Lecture	Phase A – Presentation of the modules Phase B – Complete the post questionnaire	Module 3 Module 4

9.5.1 Data Collection – Instruments

The methodological approach for this experimental research was based on pre-test and post-test data from a nonrandomized control group of sixty students in order to compare and measure the degree of changes occurring as a result of the mentioned curriculum intervention (Table 32). The students provided their feedback anonymously by using two survey questionnaires entitled *Questionnaires for Embedding Sustainability into the ICT Curricula* (Appendix H), with most of the questions included being common: the first questionnaire (pre-test) was filled out at the very beginning of the first lecture, and the second (post-test) at the end of the second lecture. An identification code generated by the students in both questionnaires was used to match the pre-test and post-test data for the same student. In total, eight of the matching questionnaires were excluded from the final analysis because students did not fully answer the questions. For this reason, the remaining sample size was fifty-two students.

The development of the questionnaires began with a review of the relevant literature, taking into consideration findings and key points discussed in the Introduction. Then, the choice of items was based on the subject of the study, the problems involved, and the focus of the RQs described above. The items were close-ended (multiple-choice and 7-point rating scale from 1 = strongly disagree to 7 = strongly agree) and open-ended. Table 32 presents the structure of each questionnaire: the first questionnaire comprised seven sections (A, B, C, D, E, G and I) and included a total of forty-three items; the second questionnaire comprised nine sections (A, C, D, E, F, G, H, I and J) and included a total of forty-eight items. Sections A, C, D, E, G and I were common in each questionnaire, contained the same items and were used for the pre-test and post-test data in the research.

Table 32. Structure of the first (pre-test) and the second (post-test) questionnaire

Section	Number of items	Content related to the	Questionnaires First Pre-test	Second Post-test	Reference
A	4	demographics information of the student (gender, age, semester and place of residence)	✓	✓	
B	6	knowledge of the students prior to the lectures about sustainability, the SDGs, e-waste recycling and energy consumption in DCs	✓		Wang et al., 2018
C	7	knowledge of the students about sustainability issues and the environmental impact of their studies	✓	✓	Otto & Pensini, 2017
D	7	contribution of university education to environmental awareness and the expectations of the students about the inclusion of sustainability into the ICT curricula	✓	✓	Cebrián & Junyent, 2015
E	4	intention of the students to engage in sustainability and green informatics	✓	✓	Gao et al., 2017
F	2	effect of rewarding on the involvement of the students with green informatics		✓	
G	8	knowledge of the students and intention to engage in e-waste recycling and management	✓	✓	Marques & da Silva, 2017
H	7	perceptions, attitudes and awareness of the students about e-waste recycling and management		✓	Kumar, 2019
I	6	knowledge and awareness of the students about renewable energy usage in DCs	✓	✓	Eshiemogie et al., 2022
J	1	proposals of the students for the creation of a sustainable campus network		✓	

Prior to starting the main survey, the questionnaires were administered as a purposive sample to five students at another university to pre-test construct and face validity – the extent to which the measure used appeared to be reliable. This procedure was essential to assess the suitability of the questionnaires to the participants. Subsequently, the questionnaires were submitted to an expert (researcher and academician) for feedback to ensure the clarity of the questions, increase accuracy, and meet the study's focus and purpose. Then, they were administered for full-scale research.

In addition, the Cronbach's alpha coefficient of reliability was calculated to measure and validate the internal consistency of each used questionnaire. A "high" value of Cronbach's alpha is often cited as evidence that the items measure an underlying (or latent) construct (along with substantive arguments and possibly additional statistical measures). All the pre-questions (a=0.79) and all the post-questions (a=0.81) were very close to or surpassed the recommended limit of 0.80 (Nunnally & Bernstein, 1994). The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 27.

9.5.2 Statistical Analysis Techniques and Evaluation of the Methodology

Further to the Cronbach's alpha coefficient of reliability, as previously mentioned above, descriptive and inferential statistical methods were applied to secondary variables, called constructs, in order to evaluate the effect of the above-described intervention. These constructs expressed specific meaning groups of the primary variables of both questionnaires. They were produced properly by calculating the average value of the original variables after the reverse questions had been appropriately recoded in order to explore their cumulative effect between the lectures. In addition, the constructs also expressed specific dimensions of sustainability in the ICT curricula, such as *sustainability knowledge*, *university contribution*, *sustainable curricula*, *sustainability intention* (Table 33), *e-waste recycling knowledge*, *e-waste recycling intention, renewable energy usage in DCs knowledge, renewable energy usage in DCs* *awareness* (Table 34), *e-waste recycling perceptions, e-waste recycling attitudes* and *e-waste recycling economic effects awareness* (Table 37). These dimensions correspond to the sub-questions mentioned previously, and they are presented analytically in the Results and Discussion section.

Table 33. Sections C, D and E constructs derived from the statistical analysis of pre-test and post-test data (scale 1 = strongly disagree to 7 = strongly agree)

Constructs – Corresponding section	Items		Frequencies (%)							Descriptive statistics		
			1	2	3	4	5	6	7	N	Mean	Standard Deviation
Sustainability knowledge Section C	I know the concept of sustainability	Pre	17.3	13.5	17.3	17.3	17.3	5.8	11.5	52	3.67	1.92
		Post	0.0	1.9	9.6	21.2	44.2	17.3	5.8	52	4.83	1.08
	I know how green informatics can be applied to other fields of science	Pre	28.8	36.5	17.3	9.6	3.8	3.8	0.0	52	2.35	1.31
		Post	0.0	5.8	9.6	50.0	15.4	7.7	11.5	52	4.44	1.29
	The subject of my studies has no potential impact on the environmental pillar of sustainability	Pre	21.2	17.3	5.8	32.7	11.5	7.7	3.8	52	3.35	1.75
		Post	17.3	17.3	40.4	15.4	1.9	7.7	0.0	52	2.90	1.35
	The subject of my studies has no potential impact on the social pillar of sustainability	Pre	17.3	17.3	9.6	36.5	13.5	5.8	0.0	52	3.29	1.50
		Post	17.3	17.3	32.7	9.6	13.5	9.6	0.0	52	3.13	1.55
	I am interested in the environmental impact of my work as a future IT professional	Pre	19.2	3.8	9.6	13.5	21.2	11.5	21.2	52	4.33	2.13
		Post	0.0	1.9	15.4	13.5	23.1	34.6	11.5	52	5.08	1.33
University contribution Section D	The university provides opportunities for students to participate in actions to limit the negative effects it brings on the environment	Pre	17.3	21.2	34.6	23.1	3.8	0.0	0.0	52	2.75	1.12
		Post	0.0	0.0	1.9	5.8	50.0	28.8	13.5	52	5.46	0.87
	The university should organize informational activities regarding the sustainability	Pre	0.0	0.0	1.9	17.3	30.8	23.1	26.9	52	5.56	1.13
		Post	0.0	0.0	1.9	9.6	48.1	25.0	15.4	52	5.42	0.94
	My studies do not help me learn how to make a positive environmental impact on the world around me	Pre	5.8	1.9	5.8	15.4	38.5	21.2	11.5	52	4.88	1.48
		Post	3.8	0.0	5.8	1.9	50.0	26.9	11.5	52	5.21	1.26
Sustainable curricula Section D	The university should actively promote sustainability in the university curricula	Pre	1.9	0.0	11.5	11.5	28.8	26.9	19.2	52	5.23	1.38
		Post	0.0	1.9	7.7	3.8	55.8	13.5	17.3	52	5.23	1.15
	I believe that sustainability should be integrated into all university subjects	Pre	7.7	11.5	13.5	23.1	15.4	17.3	11.5	52	4.25	1.78
		Post	0.0	1.9	21.2	11.5	51.9	3.8	9.6	52	4.63	1.21
	The study of e-waste management should be included in the curricula	Pre	1.9	5.8	5.8	23.1	34.6	17.3	11.5	52	4.81	1.39
		Post	0.0	1.9	9.6	1.9	28.8	42.3	15.4	52	5.46	1.20
Sustainability intention Section E	I want to be involved in green informatics	Pre	3.8	13.5	19.2	34.6	23.1	1.9	3.8	52	3.81	1.31
		Post	0.0	0.0	3.8	3.8	34.6	46.2	11.5	52	5.58	0.89
	I would like to help improve the world around me by using environmentally friendly techniques	Pre	0.0	0.0	7.7	17.3	36.5	30.8	7.7	52	5.13	1.05
		Post	0.0	0.0	1.9	7.7	48.1	19.2	23.1	52	5.54	1.00
	I want to learn more about sustainability and green informatics	Pre	0.0	0.0	7.7	11.5	23.1	25.0	32.7	52	5.63	1.27
		Post	0.0	0.0	3.8	0.0	44.2	38.5	13.5	52	5.58	0.87

Table 34. Sections G and I constructs derived from the statistical analysis of pre-test and post-test data (scale 1 = strongly disagree to 7 = strongly agree)

Constructs – Corresponding section	Items		Frequencies (%)							Descriptive statistics		
			1	2	3	4	5	6	7	N	Mean	Standard Deviation
E-waste recycling knowledge Section G	I am aware of the implications of e-waste recycling on natural resources and the environment	Pre	13.5	25.0	21.2	15.4	13.5	7.7	3.8	52	3.29	1.66
		Post	7.7	7.7	13.5	1.9	44.2	19.2	5.8	52	4.48	1.63
	I am aware of the implications of e-waste recycling on human health	Pre	25.0	17.3	26.9	13.5	7.7	5.8	3.8	52	2.94	1.67
		Post	0.0	7.7	26.9	0.0	34.6	13.5	17.3	52	4.71	1.60
	I know the Greek policy or regulations on the management of e-waste	Pre	53.8	19.2	9.6	1.9	7.7	1.9	5.8	52	2.19	1.78
		Post	17.3	34.6	9.6	36.5	1.9	0.0	0.0	52	2.71	1.19
	I am aware of the existence of toxic/hazardous materials in IT electronic products	Pre	13.5	1.9	9.6	17.3	19.2	19.2	19.2	52	4.62	1.94
		Post	0.0	1.9	3.8	7.7	44.2	21.2	21.2	52	5.42	1.14
	The electronic IT products that have reached end-of-life are considered e-waste	Pre	1.9	3.8	9.6	51.9	11.5	9.6	11.5	52	4.42	1.34
		Post	0.0	7.7	7.7	1.9	28.8	21.2	32.7	52	5.46	1.54
	The damaged IT electronic products are considered e-waste	Pre	7.7	1.9	13.5	51.9	11.5	11.5	1.9	52	4.00	1.29
		Post	7.7	11.5	26.9	28.8	17.3	5.8	1.9	52	3.62	1.37
E-waste recycling intention Section G	I intend to recycle e-waste	Pre	11.5	19.2	25.0	3.8	17.3	13.5	9.6	52	3.75	1.90
		Post	0.0	0.0	11.5	1.9	38.5	21.2	26.9	52	5.50	1.24
	I am interested in recycling e-waste	Pre	7.7	7.7	11.5	11.5	23.1	19.2	19.2	52	4.69	1.85
		Post	0.0	9.6	1.9	1.9	23.1	19.2	44.2	52	5.73	1.56
Renewable energy usage in DCs knowledge Section I	The adoption of renewable energy sources reduces the level of greenhouse gas emissions	Pre	1.9	5.8	17.3	34.6	15.4	7.7	17.3	52	4.48	1.55
		Post	0.0	1.9	1.9	21.2	28.8	44.2	1.9	52	5.17	0.98
	The adoption of renewable energy sources is profitable	Pre	0.0	5.8	17.3	46.2	15.4	7.7	7.7	52	4.25	1.23
		Post	0.0	0.0	11.5	19.2	46.2	15.4	7.7	52	4.88	1.06
	The adoption of renewable energy sources is not dangerous for health and the environment	Pre	5.8	13.5	13.5	32.7	13.5	1.9	19.2	52	4.17	1.77
		Post	3.8	11.5	13.5	15.4	26.9	17.3	11.5	52	4.48	1.66
Renewable energy usage in DCs awareness Section I	The adoption of renewable energy sources supports the sustainability of the planet	Pre	1.9	7.7	9.6	28.8	17.3	28.8	5.8	52	4.62	1.44
		Post	0.0	0.0	1.9	7.7	32.7	44.2	13.5	52	5.60	0.89
	The adoption of renewable energy sources is beneficial to society	Pre	1.9	1.9	5.8	42.3	17.3	13.5	17.3	52	4.81	1.40
		Post	3.8	1.9	26.9	15.4	26.9	21.2	3.8	52	4.38	1.43
	The adoption of renewable energy sources creates jobs and benefits local communities	Pre	21.2	13.5	7.7	40.4	13.5	3.8	0.0	52	3.23	1.50
		Post	3.8	1.9	26.9	34.6	15.4	9.6	7.7	52	4.15	1.39

More specifically, the central tendency and variability measures were calculated for quantitative variables and percentages for categorical variables (Bersimis et al., 2022). In addition, the paired samples t-test for equality of means for dependent samples was applied in the eight constructs (Table 35) mentioned above (David & Gunnink, 1997). The appropriate normality test of Kolmogorov-Smirnov & Shapiro-Wilk had preceded even if the sample size was sufficiently large (52>30) in order to assume the normality of the sample mean asymptotically (Hanusz & Tarasińska, 2015; Curran-Everett, 2017). The significance (alpha) level was set to 0.01.

Table 35. Paired sample statistics (scale 1 = strongly disagree to 7 = strongly agree)

Constructs	Mean	Standard Deviation	Paired differences						
			Mean	Standard Deviation	95% confidence interval of the difference		t	Df	P-value (2-tailed)
					Lower	Upper			
Sustainability knowledge Pre-test	3.40	0.68	-0.68	0.85	-0.92	-0.44	-5.79	51	<0.01
Sustainability knowledge Post-test	4.08	0.71							
University contribution Pre-test	4.40	0.77	-0.97	1.05	-1.26	-0.67	-6.62	51	<0.01
University contribution Post-test	5.37	0.74							
Sustainable curricula Pre-test	4.76	1.26	-0.35	1.45	-0.75	0.06	-1.73	51	0.09
Sustainable curricula Post-test	5.11	0.81							
Sustainability intention Pre-test	4.86	0.81	-0.71	1.07	-1.00	-0.41	-4.74	51	<0.01
Sustainability intention Post-test	5.56	0.69							
E-waste recycling knowledge Pre-test	3.57	0.89	-0.82	0.89	-1.07	-0.57	-6.61	51	<0.01
E-waste recycling knowledge Post-test	4.40	0.80							
E-waste recycling intention Pre-test	4.69	1.85	-0.92	2.12	-1.51	-0.33	-3.12	51	0.003
E-waste recycling intention Post-test	5.61	0.97							
Renewable energy usage in DCs knowledge Pre-test	4.30	0.91	-0.54	1.19	-0.88	-0.21	-3.28	51	0.002
Renewable energy usage in DCs knowledge Post-test	4.85	0.83							
Renewable energy usage in DCs awareness Pre-test	4.22	0.77	-0.49	1.11	-0.80	-0.18	-3.20	51	0.002
Renewable energy usage in DCs awareness Post-test	4.71	0.67							

9.6 Results and Discussion

9.6.1 Students Demographics Information – Section A

The two questionnaires were filled out by fifty-two students: thirty-five men (67.31%) and seventeen women (32.70%). The students were mostly full-time ICT students (N=50, 96.20%) and overall young, with an age range of 19-20 for 84.62% (N=44) of them, 21–25 for 11.54% (N = 6), while one student was 47 (1.92%) and another one 58 (1.92%). In addition, most students had the Attica region as their place of residence (N=34, 65.39%), while the 34.62% (N=18) of them lived outside of Attica.

9.6.2 Prior Knowledge About Sustainability, SDGs, E-Waste Recycling and Energy Consumption in DCs – Section B

For the vast majority of the students (N=48, 92.30%), this was the first educational unit they had attended regarding sustainability. The results indicate that prior to our intervention, the majority of the students had either poor or no awareness of the SDGs: 61.54% (N=32) had never heard of them, while 34.62% (N=18), although they had heard, they did not know exactly what SDGs was. On the contrary, only 3.85% (N=2) of the students claimed that they have heard and know what SDGs are about. These results highlight a deficient level of understanding of the concept of SDGs and indicate that the concept of sustainability has not been sufficiently developed in HEIs.

Simultaneously, only 15.40% (N=8) of the participants reported that they knew something about the term e-waste, 32.70% (N=17) had heard vaguely but did not know what it was about, while a majority of 51.90% (N=27) had never even heard the term. At the same time, only 23.01% (N=12), namely about one in four students, recycle e-waste. These findings reveal that the intention is relatively low as the consumers are unaware of the e-waste impact on the environment. This perception confirms the decisive role of knowledge and awareness in the implementation of e-waste recycling and management (Decharat & Kiddee, 2022). In terms of the energy consumption in DCs, a larger group (61.50%, N=32) had never heard about this issue, while the 26.90% (N=14) had just heard without knowing what it was about, and only 11.50% (N=6) claimed to be aware of it.

These results may be considered as evidence and cause some concern that ICT students are not well informed about the concept of e-waste recycling and the environmental implications of DCs while their ICT studies are covering these technologies. This observation is in line with past studies, which suggest that the university is expected to provide tools for the integration of e-waste recycling and management in some of the general courses taken by all students in order to raise awareness and help deal with e-waste (Brindhadevi et al., 2023; Ilankoon et al., 2018; Marques & da Silva, 2017; Meneses & Palacio, 2005).

Moreover, subjects such as sustainable informatics or green computing could be added to HEIs as compulsory courses to stimulate emerging practices and related innovation, i.e., e-waste production containing fewer toxic chemicals. This observation also aligns with a recommendation by (Dagiliūtė et al., 2019), who indicated that legislation and education were vital pillars to effective e-waste recycling and management and reduced e-waste-related issues.

Nonetheless, the results indicated that the students' primary information sources for environmental issues (i.e., global warming, etc.) are the Internet (N= 49, 94.23%), the social networks (N= 31, 59.62%), and their teachers-educators (N=22, 42.31%). These findings confirm the decisive role of the social media in influencing and shaping awareness about environmental sustainability among students (Tafesse, 2022). Yet, they provide a significant potential for the HEIs to fully leverage the ubiquity of social media in order to extend and promote how the students and faculty perceive environmental sustainability.

Figure 21 shows the perceptions of the students regarding the contribution of the educational system to their environmental awareness. As one may notice in this figure, most students have been encouraged by primary education to think and act in a more environment-friendly manner (N=33, 63.46%). On the contrary, only 7.69% (N=4) believe that the university has supported this knowledge. These results may be considered as evidence, and they comply with the literature review mentioned above about the weak integration of SD education in ICT education and the apparent weakness of Greek universities in spreading sustainability issues in higher education.

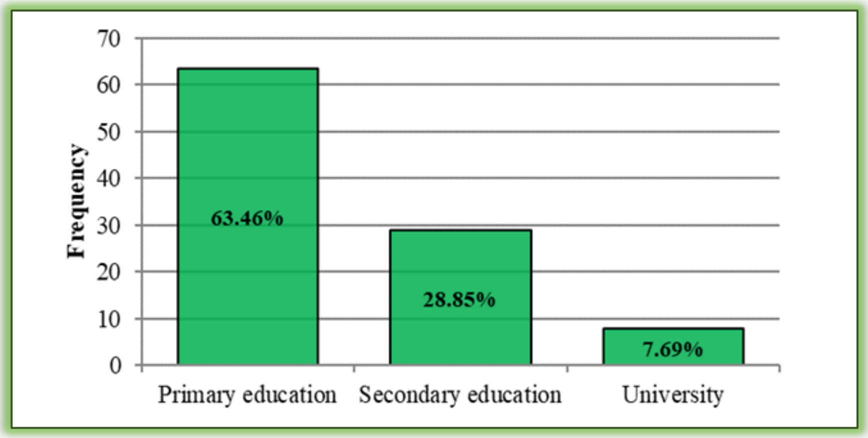


Figure 21. Contribution of education to the environmental awareness of the students

9.6.3 Knowledge About Sustainability Issues and the Environmental Impact of ICT Studies – Section C

The statistical analysis of the students' responses to section C questions has revealed one construct, namely, *sustainability knowledge*. As shown in Table 33, five of the questions contribute to the development of this construct, which reflects the understanding of the students about the concept of sustainability issues and the environmental impact of their ICT studies. The mean pre-test score for the sustainability knowledge of the students is 3.40 (±0.68), while the mean post-test score is 4.08 (±0.71) (Table 35). The t-test for paired samples was performed on these data, and the findings revealed a statistically significant gain ($t=-5.79$; $p<0.01$). The effect size (Cohen's d) is 1, which implies that the post-test scores are slightly more than a standard deviation better than the pre-test scores (Cohen, 1988). This is considered a large effect size and ascertains the significant increment of the knowledge about sustainability and the environmental impact of the ICT studies. It is important to note that most of the students (N=48, 92.31%) expressed their willingness to obtain more knowledge about SD. These results may be considered a good indicator that encourages HEIs to integrate sustainability issues into ICT education.

Nevertheless, it should be noted that the theoretical knowledge of the students should also be supported with frequent real practices in some subjects, e.g., experiencing an e-waste management system by embedding green environmental tools into the campus. According to the study results, environmental knowledge has some influence on the development of eco-friendly behavior. This indication is aligned with past studies that mention that promoting sustainability knowledge in the university can further strengthen the attitudes of the students toward sustainable development, thus affecting sustainable behavior (Tilbury, 2016; Žalėnienė & Pereira, 2021). Therefore, HEIs play an active role in promoting sustainable behavior development. Meanwhile, sustainable education in HEIs should stress teaching sustainability knowledge and the cultivation of a sustainable attitude among university students.

9.6.4 Perceptions Regarding the Contribution of University Education to Environmental Awareness – Section D

The statistical analysis of the students' responses to section D questions has revealed one construct, namely, *university contribution*. As shown in Table 33, three of the questions contribute to the development of this construct, which reflects the perceptions of the students regarding the contribution of university ICT education to environmental awareness and the organization and promotion of sustainability activities in the university community. The mean pre-test score for the university contribution is 4.40 (±0.77) (neutral response option). This neutral option shows students who are ignorant about or indifferent to the subject and supports the previous results shown in Figure 21 about the weak integration of SD issues in university ICT education. The mean post-test score is 5.37 (±0.74) (Table 35), with the results showing a statistically significant gain (t=-6.62; p<0.01). The effect size (Cohen's d) is 1.26, which is considered a high effect size and ascertains the significant increment in the perception of the students about the contribution of the university to ESD.

This positive perception caused by our intervention, as well as what the students expressed in the previous questions regarding their interest in SD and their willingness to obtain more education about it, imposes on the HEIs the inevitability of reconsidering their approach to sustainability-provided ICT education. It should also be noted that a significant 19.1% of the students do not express concern for and willingness to participate in sustainability-related informational activities. This result aligns with the literature (Kyle, 2020; Cheung et al., 2021) and implies the need for the HEIs to enhance their environmental sustainability practices and improve the visibility of these practices for students to embrace and commit to them.

9.6.5 Perceptions Regarding the Necessity for the Inclusion of Sustainability in the University ICT Curricula – section D

The statistical analysis of the students' responses to the section D questions has revealed one more construct, namely, *sustainable curricula*. As shown in Table 33, three of the questions contribute to the development of this construct, which reflects the perceptions of the students regarding the necessity for the inclusion of sustainability in the university ICT curricula. The mean pre-test score for sustainable curricula is 4.76 (±1.26), while the mean post-test score is 5.11 (±0.81) (Table 35). The t-test for paired samples was performed on these data, and the findings revealed a non-statistically significant but relatively high gain (t=-1.73; p=0.09). The corresponding effect size (Cohen's d) is 0.28, which is considered a small to medium effect size. The previously mentioned result, which is not considered statistically significant, even marginally, may highlight a certain trend in the readiness of the students to learn more about sustainability issues. This trend could be an incentive for HEIs to integrate SD issues into ICT education.

In fact, the results presented in our study are in line with the results of a number of previous studies conducted in other countries, which confirmed the perception of the students about the importance of SD for their future careers and, thus, the existence of benefits to the surrounding society (Boyce et al., 2019; Gomes et al., 2021; Liu et al., 2020). Moreover, the emerging outcomes suggest a need to reorient the current ICT curricula of the bachelor degrees to focus more on sustainability and e-waste management. This sustainable reorientation can possibly take effect with actions such as: allowing students to take elective courses on sustainability; providing systematic and planned education for SD to faculty; strengthening the link between the social and the natural sciences; inviting guest lecturers to deliver sessions about sustainability and e-waste topics (Utama et al., 2018).

9.6.6 Intention to Engage in Sustainability and Raise their Awareness about Green informatics – Section E

The statistical analysis of the students' responses to the section E questions has revealed one construct, namely, *sustainability intention*. As shown in Table 33, three of the questions contribute to the development of this construct, which reflects the intention of the students to engage in sustainability and raise their awareness about green informatics. The mean pre-test score for sustainability intention is 4.86 (±0.81), while the mean post-test score is 5.56 (±0.69) (Table 35). The t-test for paired samples was performed on these data, and the findings revealed a statistically significant gain (t=-4.74; p<0.01). The effect size (Cohen's d) is 0.88. This is considered a large effect size, and thus, the significant increment of the intention of the students to engage in sustainability is ascertained.

The findings implied that the substantial increment in the knowledge about the sustainability of the students might positively affect their intention to engage in sustainability, hence confirming previous studies that mention that environmental knowledge is essential in influencing individual intention and behavior toward sustainability (Fabi et al., 2017; Swaim et al., 2014). Similarly, Gkargkavouzi et al. (2019) reported that intention is the best predictor of environmental behavior.

It should also be noted that environmental knowledge helps students make intentional and practical environmental actions and affects their environmental well-being, attitude, and socio-cultural norms (Hallinger & Chatpinyakoop, 2019). Indeed, people are willing to engage in sustainable behavior when they are more confident in their abilities and skills. For this reason, promoting sustainability knowledge in the university can further strengthen the attitudes of the students toward sustainable development, thus affecting sustainable behavior (Otto & Pensini, 2017). Hence, educational planners should pay more attention to and promote environmental knowledge and how to integrate it with other fields of knowledge in universities in order to cultivate the green intentions of the students.

9.6.7 The Provision of Rewards Positively Affects the Involvement and Engagement of the Students With Green Informatics – Section F

Table 36 shows the means of the responses to questions Q1 (M1=5.75 (±1.41)) and Q2 (M2=5.83 (±1.34)). These questions from section F reflect the effect of rewarding the involvement of the students with green informatics. The data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 4=neither disagree or neither agree (t=8.93; p<0.01) and (t=9.84; p<0.01), respectively.

Table 36. The effect of rewarding on the involvement and engagement of the students with green informatics (scale 1 = strongly disagree to 7 = strongly agree)

Items – Section F	Test Value = 4 (neither disagree or neither agree)							
	Mean	Standard Deviation	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Q1. Supporting sustainability is nice to be rewarded, e.g. vouchers for every electronic device I recycle	5.75	1.41	8.93	51	<0.01	1.75	1.36	2.14
Q2. E-waste recycling should reward the person who implements it	5.83	1.34	9.84	51	<0.01	1.83	1.45	2.20

These results indicate that rewards for actions focused on sustainability may have a significant positive impact on the overall sustainable behavior of the students. The results are aligned with past studies that reported how rewards encourage students to take socially responsible and environmentally sustainable well-being actions (e.g., using more efficient, sustainable means of transportation) (Žalėnienė & Pereira, 2021; Holst, 2022).

The literature also mentions that the reward allows HEIs to recognize the valuable contribution each person makes to the overall sustainable adjustment of the campus (Biasutti et al., 2016; Alsina et al., 2017; Kukkonen et al., 2018). To this approach, it is recommended that HEIs should design and implement interactive, rewarding programs. These programs reward faculty and students for the behaviors that improve individual and university-wide sustainability and well-being, make sustainability involvement and engagement relevant to the campus environment and stress the collective impact that the actions of the faculty and students can have.

9.6.8 Knowledge and Intention to Engage in E-Waste Recycling and Management – Section G

The statistical analysis of the students' responses to the questions of section G has revealed two constructs, namely, *e-waste recycling knowledge* and *e-waste recycling intention*.

E-waste recycling knowledge, which has been developed from six questions (Table 34), reflects the understanding of the students about e-waste recycling. The mean pre-test score was 3.57 (±0.89), while the mean post-test score was 4.40 (±0.80) (Table 35). A paired samples t-test showed that there was a significant (t=-6.61; p<0.01) and very strong (Cohen's d=1.37) difference in scores knowledge about e-waste recycling before and after the educational intervention. The literature mentions that this knowledge can provide an impetus to a more proactive e-waste recycling behavior for young adults if the contextual information regarding the product lifecycle and its origin, disposal and its impact on the environment is made common knowledge (Kumar, 2019). Moreover, Deniz et al. (2019) imply that the level of knowledge of the students affects e-waste management practices. At the same time, Islam et al. (2021) mention that when students associate e-waste recycling with a positive contribution to the environment and society, their recycling output is bound to rise.

Nevertheless, knowing about the negative impacts of e-waste on the human health and the environment is not a prerequisite for appropriate e-waste management techniques. Therefore, the HEIs should establish institutional e-waste policies, point out designated e-waste collection points, and develop primary recycling plants in order to cultivate more positive attitudes, knowledge and awareness toward e-waste recycling and management.

E-waste recycling intention, which has been developed from two questions (Table 34), reflects the willingness of the students to engage in e-waste recycling. The mean pre-test score was 4.69 (±1.85), while the mean post-test score was 5.61 (±0.97) (Table 35). A paired samples t-test showed that there was a significant (t=-3.12; p=0.003) but moderate (Cohen's d= 0.50) difference in scores on intention to engage in e-waste recycling before and after the educational intervention. These results showed that the increase in knowledge had a significant positive influence toward e-waste recycling intention. This result was in parallel with a finding by Wang et al. (2018) that revealed that the e-waste recycling intention is relatively low as the consumers are unaware of the e-waste impact on the environment. In addition, the e-waste recycling intention of the students is essential to promote pro-environmental behavior, such as energy conservation or e-waste recycling and management (Wang et al., 2022).

This suggestion implies that the theoretical knowledge of the students should also be supported with regular e-waste management measures, e.g., experiencing the availability of visible in-campus electronic, paper, plastic and other essential waste disposal containers. This remark underlines the critical role of the HEIs' e-waste recycling and management system in finding a solution to the current unsustainable practice by integrating green environmental instruments into their campuses. Moreover, the emerging statistics indicate a compelling need to incorporate sustainability and e-waste disposal methods in the current curricula of the bachelor’s degrees offered by the HEIs. This incorporation can be possibly achieved by inviting guest lecturers to deliver modules on sustainability and e-waste-related topics, by allowing students to take elective classes on sustainability, by providing systematic and planned sustainability training to educators and by encouraging the link between the social and the natural sciences (Holst, 2022).

9.6.9 Perceptions, Attitudes and Awareness of E-waste Recycling and Management – Section H

The statistical analysis of the students' responses to the questions of section H has revealed three constructs, namely, *e-waste recycling perceptions* (three questions) (M=5.28 (±0.92)), *e-waste recycling attitudes* (three questions) (M=4.61 (±1.14)) and of *e-waste recycling economic effects awareness* (two questions) (M=5.04 (± 1.49)) (Table 37). The data were subjected to the one-sample t-test, with the results showing a significant difference from the fixed value 4 (neither disagree or neither agree): t=10.02, p<0.01, Cohen's d=1.04 for *e-waste recycling perceptions*; t=3.85, p<0.01, Cohen's d=0.53 for *e-waste recycling attitudes*; t=5.05, p<0.01, Cohen's d=0.70 for *e-waste recycling economic effects awareness*.

An inference from these results could be that there is an opportunity to influence and propagate a pro-environment behavior among young adults through university programs and activities. Furthermore, it can be implied that the gained knowledge contributes to the positive perceptions and attitudes of the ICT students toward participation in e-waste recycling. Decharat & Kiddee (2022) reached a similar conclusion, as knowledge significantly influenced the attitudes of people toward recycling and their willingness to engage in recycling programs.

It is interesting to notice that ICT students recognize the positive financial consequences of proper e-waste recycling and management after the educational intervention. This result further states that if young people, as consumers, are empowered with the relevant information regarding environmental concerns when making purchasing decisions, they can influence and extend the lifecycle of their chosen products. Therefore, one of the recommendations of this study is that a change can be brought about in the behavior of young consumers if the contextual information regarding the product lifecycle, its origin, disposal, and impact on the environment is made common knowledge. This knowledge, coupled with web-based information on the rules and policies, take-back systems and recycling facilities, can provide an impetus to a more proactive e-waste recycling behavior.

These results align with another study by Yadav & Pathak (2016) that observed that when young adults associate e-waste recycling with a positive contribution to society and the environment, their recycling output is bound to rise.

Table 37. Perceptions, attitudes and awareness of students about e-waste recycling (scale 1 = strongly disagree to 7 = strongly agree)

Constructs	Items	Test Value = 4 (neither disagree or neither agree)			
		Mean	Standard Deviation	t	Sig. (2-tailed)
E-waste recycling perceptions	Recycling reduces the level of e-waste generated by society E-waste recycling is beneficial for the environment E-waste recycling works in a rewarding way for the society	5.28	0.92	10.02	<0.01
E-waste recycling attitudes	If I wanted to, I would have no problem managing to recycle e-waste I have already implemented e-waste recycling People should be rewarded for e-waste recycling	4.61	1.14	3.85	<0.01
E-waste recycling economic effects awareness	E-waste recycling offers good quality products to others at affordable prices E-waste recycling is profitable	5.04	1.49	5.05	<0.01

9.6.10 Knowledge and Awareness about Renewable Energy Usage in DCs – Section I

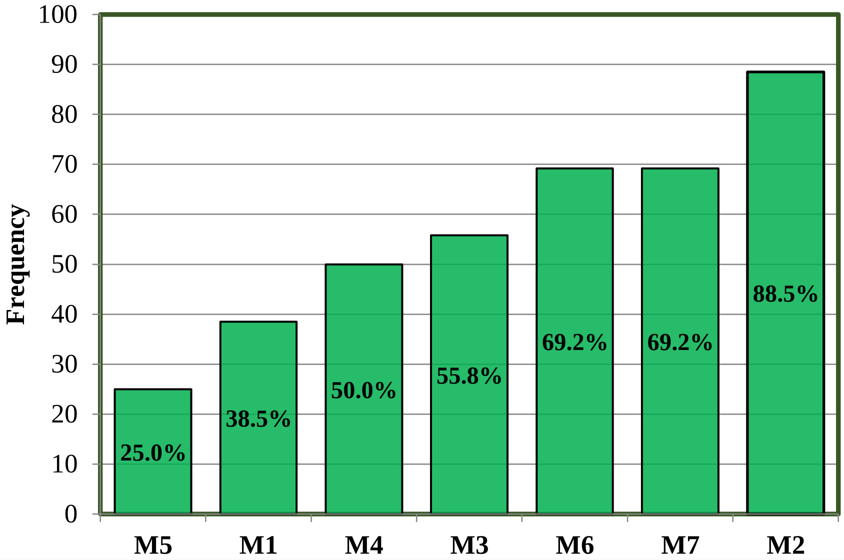
The statistical analysis of the students' responses to the questions of section I has revealed two constructs, namely, *renewable energy usage in DCs knowledge* and *renewable energy usage in DCs awareness*.

Renewable energy usage in DCs knowledge, which has been developed from three questions (Table 34), reflects the students' understanding about the consumption of huge amounts of electrical energy in DCs and the fact that this contributes to high carbon footprints and operational costs to the environment and the necessity for the usage of renewable energy. The mean pre-test score was 4.30 (±0.91), while the mean post-test score was 4.85 (±0.83) (Table 35). A paired samples t-test showed that there was a significant (t=-3.28; p=0.002) and moderate (Cohen's d=0.59) difference in scores on knowledge about energy usage in DCs before and after the educational intervention.

Renewable energy usage in DCs awareness, which has been developed from three questions (Table 34), reflects the level of consciousness and the attitudes toward green cloud computing solutions that can simultaneously reduce the environmental impact and minimize operational costs. The mean pre-test score was 4.22 (±0.77), while the mean post-test score was 4.71 (±0.67) (Table 35). A paired samples t-test showed that there was a significant (t=-3.20; p=0.002) but moderate (Cohen's d= 0.65) difference in scores on being awake and aware of energy usage in DCs before and after the educational intervention. Being aware of energy usage in DCs and, therefore, of the negative impact of the energy waste use behavior can measure the students' attitude to energy conservation (Gródek-Szostak et al., 2021). Yet, the attitude of young people toward environmental care is influenced by several factors, including education and knowledge about the environment (Fachrudin & Fachrudin, 2021). In addition, a positive attitude toward energy conservation on campus and in society, in general, should start as early as possible.

9.7 Suggestions by the Students for Creating a Sustainable Campus Network – Section J

The question of the last section J, «Note the ways or actions in which you would like the university to engage with the SDGs, Sustainability and Green Informatics – Creating a Sustainable University Network», aimed to record the proposals of the students on how to integrate SD issues into ICT education and create a sustainable university network. Figure 22 presents the suggestions of the students and illustrates the preference rate per suggestion. It is obvious from these data that five of the seven proposals receive a preference rate of 50% or more. This result is evidence of the students' lively interest in engaging with sustainability and their potential support for environmental activities.



M2: Creation of a website with content about the actions that foreign HEIs around the world are already taking about sustainability in ICT education
M7: SDGs day with different activities related to the SDGs (e.g., workshops on e-waste recycling or sustainable food)
M6: Lecture series or documentaries about the importance and necessity to adopt SDGs
M3: Implementation of theme semester, including talks, video screenings, excursions, panel discussions or workshops
M4: Invitation and discussion with alums from the HEIs who are working on the SD
M1: SDGs poster creation which can be used for a campaign on campus or a competition where students can win a prize
M5: SDGs art exhibition presenting photographs, paintings, or sculptures that involve the SDGs

Figure 22. Suggestions of the students for creating a sustainable campus network

Although some studies argue that engineering students are less eager to participate in actions to support the environment than other types of students, i.e., students in Humanities (Biasutti & Frate, 2017; Kukkonen et al., 2018), our results present a positive sustainability perspective. But, again, this exposes the need for engineering and ICT education to emphasize sustainability issues in the curricula. Consequently, in order for students to actually participate in these sustainability actions proposed by themselves, the HEIs campuses should provide infrastructures to support and facilitate these actions. Finally, and more importantly, HEIs should create opportunities where students could be involved by themselves in the greening of campus initiatives.

9.8 Limitations

One limitation of this research is the fact that the presented experiment was conducted in only one department of one Greek university. Therefore, the results may differ in another university with a different context and academic experience, as the sample was only undergraduate students. In addition, the outcomes might not apply to all Greek ICT students. Another limitation can be the fact that the sample size was not large due to the challenging academic adaptation of students after the complete removal of the restrictions applied for two years regarding the COVID-19 pandemic. Nevertheless, the sample is adequate to assume that each variable's sample mean is asymptotically normally distributed; therefore, parametric inferential statistical methods can be applied.

Chapter 10 – Overall Discussion, Conclusions and Perspectives for Future Research

This chapter presents an overall discussion of the purpose and the research objectives of the PhD Thesis. The conclusions section summarizes the results of the study corresponding to the research and provides policy recommendations for embedding sustainability in the ICT education. The chapter concludes with the perspectives for future research.

10.1 Overall Discussion

A broadened understanding of ICT education practiced across formal, non-formal and informal education creates a strong mechanism for supporting the students' social and learning transformation. This transformation implies synergies between ICT education and other critical elements of an environment, which should enable the support of the sustainability and the implementation of the SDGs. The other elements involve the lifelong learning, the professional career development, the community learning, and the public participation. Concerning the support of sustainability and its relation with ICT, this PhD Thesis advocates that the ICT education is of utmost importance in achieving the SDGs and in facilitating the transition toward a sustainable future. This transition is primarily due to the possibility of directly enabling sustainability competencies among young individuals.

Therefore, the efficacy of ICT education is linked to equip learners with sustainability competencies and empower them to become responsible participants in a sustainable society. The effectiveness of the process of sustainability transformation is contingent upon the utilization of appropriate pedagogies by educational institutions or study programs, provided in a way that these pedagogies or programs align with the chosen competencies. Hence, SD pedagogies exhibit distinct attributes, including the active involvement of the learner (student-centeredness), the facilitation of diverse perspectives and worldviews (pluralism), the collaboration between peers and educators to address problems and tasks (collaborative problem-solving), the critical examination of values, beliefs, and actions (critical pedagogy), and the formulation and execution of action plans in real-world scenarios (project-based learning).

A shift from conventional educational methods, such as lecture-based instruction or direct teaching through demonstration and practical application, is necessary for all these approaches (UNESCO, 2018). Bamber (2019) emphasizes the significance of transdisciplinary communities of practice in generating novel knowledge and facilitating transformative practices in the field of ESD. These communities utilize smart, virtual, and physical learning environments and demonstrate adaptability in aligning their operations with a sustainability-oriented setting.

In parallel, the educators at every level of education have challenges when faced with the need to acquire proficiency in novel teaching methods associated with ESD, which can be challenging and may generate resistance toward implementing ESD altogether. At the same time, the global education goal SDG 4 covers an ambitious range of targets, including the pledge to "ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes" and to "eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations" by 2030 (United Nations, 2015). Therefore, secondary and tertiary education must lead the way to SD because they drive social change by preparing a future workforce, creating new knowledge and using research to link business and community (UNESCO, 2009).

This PhD Thesis worked toward the implementation of ESD with the support and collaboration of ICT. To the best of my knowledge, it is the first study that examines ESD in light of ICT design education in a holistic sense by considering current practices, views and needs of multiple groups of pupils and students in out-of-school and in-school ICT education. Reflecting on the purpose of the research, the two primary studies (Study One and Study Two) sought to respond to seven nested research objectives.

Study One addresses the out-of-school or informal ICT education, and the first objective was to propose an enriched theoretical and conceptual framework named Eco-Persuasive-Mobile-Application (EPMA) in order to support the assessment of the behavioral travel change of the young users and the adoption of a sustainable traveling attitude (RO 1A). The second research objective was to explore the practicality of this framework by creating two transit apps which embed the functionality of EPMA and assess and capture the travel attitudes, beliefs, perceptions, and intentions of the young users in the direction of actively engaging in sustainable traveling practices (RO 1B).

Study Two addresses the in-school or formal ICT education with the first two research objectives concerning the secondary education: to explore the knowledge, attitudes, and level of awareness of the secondary school pupils in Greece regarding e-waste management and to investigate their intention for e-waste recycling (RO 2A) and in parallel to introduce "sustainable" ICT curricula into secondary education by exploring their opinions and perceptions about the concept of sustainability and its integration into the ICT curricula (RO 2B).

The following three research objectives concern the higher education: to examine the contribution of education to the environmental awareness of the students at a Greek university and their perceptions regarding the necessity for the inclusion of sustainability into the ICT curricula (RO 2C); to explore the perceptions and the attitudes of the ICT students on the environmental implications of e-waste recycling and energy usage on DCs (RO 2D); to assess the level of knowledge and awareness of the ICT students as well as their intention to get involved with and participate in these sustainability-related issues (RO 2E).

For this reason, it was advocated that the adoption of sustainable practices by ICT learners might be sustainable if they are conscious of the feedback from their interaction with the environment and aware of environmental policy issues related to their knowledge and studies. The review of literature highlighted the need for implementing ESD in secondary and higher education and understanding the impact of sustainability values on the design of ICT curricula indicated four significant problems and, at the same time, challenges in the ICT education concerning ESD:

[1] *The first challenge* is the lack of sustainability-related ICT courses and modules. Many educational institutions still follow traditional curricula structures that may not easily accommodate emerging topics like sustainability. There might be a resistance to change or a lack of understanding about the importance of integrating sustainability into various disciplines due to concerns about increased workload, unfamiliarity with new topics, or a perception that sustainability is irrelevant to their field of study. In addition, some educators and institutions may not fully grasp the urgency and significance of sustainability issues.

There could be a lack of awareness about the environmental, social, and economic challenges that necessitate a sustainable approach. Yet, the development and implementation of new courses or modules require resources, including faculty expertise, updated teaching materials, and potentially new infrastructure. Many institutions may face financial constraints that hinder their ability to invest in sustainability education.

Moreover, traditional academic structures often involve disciplinary silos, making it challenging to integrate interdisciplinary topics such as sustainability. Therefore, the collaboration between different departments and faculties is essential for a comprehensive and holistic approach to sustainability education. Finally, in some educational systems, there is a strong focus on standardized testing, which may lead educators to prioritize topics that are directly assessed. This pressure can discourage the integration of broader, interdisciplinary subjects like sustainability into the ICT curricula.

[2] *The second challenge* is the lack of government-specific policies or frameworks via the Ministry of Education in the prioritization of sustainability in educational institutions. This lack is a common issue in various parts of the world, where the integration of sustainability into education systems may face challenges. One possible explanation for the reason that may happen is a lack of understanding at the ministry level about the importance of sustainability in education and its long-term benefits for society.

Furthermore, the Ministry of Education may not provide directives, funding, incentives or specific mandates in order for the educational institutes to be actively engaged to implement sustainable practices in their operations, curricula, and infrastructure. At the same time, a lack of incentives or standardized reporting requirements for the educational institutes to collaborate with industry, NGOs, and other stakeholders in order to address sustainability challenges may discourage sustainability efforts or progress and limit their participation.

[3] *The third challenge* is that the current teaching activities cannot fully contribute to the integration of sustainable content into the ICT curricula. The overall structure and design of the ICT curricula may not inherently support the integration of sustainable content. Obviously, if the curricula are rigid or lack flexibility, the educators may face challenges in incorporating sustainability-related topics into their courses. At the same time, the educators may struggle to integrate sustainable content if they do not have access to up-to-date and relevant resources. This access could include textbooks, online materials, case studies, and other educational tools specifically designed to incorporate sustainability into the ICT education. In order for sustainable content to be fully integrated, students should be engaged and aware of the importance of sustainability in the context of ICT.

For this reason, teacher efforts may be hampered if students are not receptive or do not understand the relevance of sustainable practices. Moreover, the educators may not be adequately trained to integrate sustainability concepts into their ICT courses. Therefore, professional development opportunities focused on sustainable practices in ICT education are crucial to empower teachers with the necessary knowledge and skills.

Furthermore, the support of educational institutions is essential for successfully integrating sustainability into ICT curricula, which involves policy changes, resource allocation, and a broader institutional commitment. These ICT curricula should also align with industry needs and trends. If the industry is not yet emphasizing sustainability in its practices, the educators may feel less inclined to integrate sustainable content into their courses. Yet, teaching sustainability in ICT may require collaboration with other departments or disciplines, such as environmental science, business, or ethics. The integration process may be hindered if there is a lack of collaboration across disciplines. Finally, the assessments play a significant role in shaping the focus of teaching activities. If assessment methods do not include or emphasize sustainable practices, teachers may not prioritize teaching sustainable content.

[4] *The fourth challenge* is that the educators lack a holistic view of sustainability knowledge, which constitutes a significant challenge, as sustainability is a crucial topic in today's world. The potential reasons for this gap are:

- *Limited training*: The educators might not have received adequate training in sustainability during their own education.
- *Outdated curricula*: The educational materials and curricula may not adequately cover sustainability topics.
- *Lack of resources*: The educators may face challenges and obstacles in accessing resources and materials that cover sustainability.
- *Misconceptions*: The educators may not fully understand the breadth and significance of sustainability.
- *Institutional support*: Lack of institutional support or recognition for integrating sustainability into the curricula.
- *Limited interdisciplinary approach*: The concept of sustainability is inherently interdisciplinary, but educators may be confined to siloed subject areas.
- *Lack of motivation*: The educators might not see the immediate relevance or urgency of teaching sustainability.
- *Student engagement*: If students are not actively interested in or involved with sustainable practices, the educators may not prioritize it.

By addressing these issues, educational institutions can work toward closing the knowledge gap and ensuring that educators are well-equipped to teach and promote sustainability in their classrooms.

10.2 Conclusions and Recommendations

The major contribution of this study is the mapping and the delimitation of the global research trend regarding the challenges faced by educational institutions with a focus on secondary and tertiary education supporting the transformations required in view of achieving the SDGs and, more specifically, cultivating environmental awareness and persuade young travelers toward more sustainable travel options progressively and the integration of sustainability issues into the ICT curricula. Furthermore, this study provides experimental validation about the effect of SD education in formal and informal education and on the involvement and engagement of ICT students in sustainability. This area is relatively underdeveloped empirically and theoretically, as there is a lack of sufficient studies that investigate sustainable interventions in the ICT curricula in secondary and higher education. In response, the results underpinned the positive role of the integration of green informatics into the ICT curricula in order for students to engage in sustainability and raise their awareness about green informatics.

Addressing the abovementioned challenges requires a holistic approach involving educational policymakers, ICT curricula designers, teachers, and students. *It is not just about changing teaching activities; it is about transforming the entire educational ecosystem to align with sustainability principles.* To understand fully this ecosystem of learning for sustainability, one should look not only at learning that takes place in the school but also at learning that takes place out-of-school.

Study One made use of mobile transit apps to progressively educate and persuade young travelers toward more sustainable travel options. According to the proposed theoretical framework EPMA, which corresponds to the RO 1A, this can be achieved with the collection and evaluation of the personal and travel data of the users, namely the rewarding feedback. These actions continuously enhance travel services as well as the ease of use and effectiveness of the app. Although the young people own a smartphone/tablet, they rarely use mobile transit apps. The idea of a mobile transit app that works effectively and rewards the users for their environmentally friendly behavior appears to be welcome and very promising. Furthermore, education from the early years for adopting ecological consciousness and awareness should be an issue that our society should consider very seriously.

The results of our study, which correspond to the RO 1B, indicate that young people have a positive attitude toward the daily use of the two designed - for the purpose of Study One – mobile transit apps mockups with the *Set a Journey planner*, *Collect points/Get rewards* and *Play Eco-Games* are the most popular features alongside with a bright colored background and an avatar-helper. All these features could assist young people to become environmentally conscious and increase their ecological knowledge and awareness. In addition, the gender seems not to affect the potential use of these apps. Moreover, participants are willing to change their travelling habits toward more sustainable options and intend to use these apps for this change. In fact, they recommended their friends to do the same.

The assessment has also revealed that the participants are willing to regularly provide feedback and get rewards to evaluate the impact of the app's systematic use and improve the travel services offered. In addition, there was a strong connection between triggering for testing the app and the possible continuation of its use when participants could discover more healthy and sustainable travel options and get rewards. Besides, given the plethora of mobile transit apps, if participants perceived them as easy to use and effective, it would improve their intention to use them for navigation purposes to be engaged and to foster a long-life eco-friendly attitude.

Moreover, the privacy and personal data protection related to the data collection during the use of the app and the anonymity concern many users. Finally, they pointed out the limitation of data sharing within the network of the participants and the data usage only for the primary purpose of the mobile transit app. Besides, the personal data protection and use only for the mobile app's primary purpose, along with the option of anonymity and limitation of data sharing within a student's own network, must be a mandatory functional feature.

Study Two deals with the topic of integrating SD issues into ICT curricula in secondary and higher education to reach the goals of the UN 2030 Agenda.

Firstly, with regard to the space dedicated primarily to teaching or learning activities and where the formal educational process takes place, the concept of the smart classroom was explored in terms of ICT support and development, environmental conditions and procedures. This concept may be considered as a means to support ESD and identify how the characteristics of a smart classroom can effectively lead to the implementation of ESD methodologies in the teaching practice.

For this reason, this PhD Thesis proposes a conceptual model for the support of sustainability education with the means that a smart classroom could offer. This model enables collaboration, the access to and exchange of sustainability-related content, the knowledge sharing and successful interaction between students and teachers. These features can lead to a practical implementation of ESD processes and innovative methodologies that help reframe the learning environment toward ESD. As the smart classroom is a relatively new and emerging research area, in early development, it poses a considerable difficulty in providing definitive specifications and empirical evidence on its implementation.

Furthermore, it is essential to note that both investment and technical development can serve as contextual constraints in various locations and countries. The development of smart classrooms is now at an early stage, with a relatively small number of these educational settings existing globally, primarily due to the limitations mentioned above. The establishment of learning environments that facilitate empirical investigation is crucial for examining the effects they have on the advancement of student-centered instructional and learning approaches. There is a scarcity of empirical evidence about the influence of a smart classroom on the cultivation of sustainability competencies. An additional empirical investigation is required to examine the impact of the smart classroom on facilitating processes and practices related to ESD.

Concerning secondary education and the challenge of integrating SD issues into ICT curricula, Study Two found that regarding e-waste recycling and management and the pupils' intention for e-waste recycling, which correspond to the RO 2A, the knowledge and awareness levels of the pupils about e-waste management were deficient. Therefore, the study recommends that education for e-waste recycling awareness is vital in achieving environmental skills, behavior and attitudes consistent with environmental protection and sustainable development. This recommendation is in line with the literature, which implies that the education of children can cause a permanent behavioral change and the development of positive values and attitudes, which they can use in order to influence the negative behaviors of other people (De Jager, 2015; Sammalisto & Lindhqvist, 2008).

In addition, awareness is crucial for the sensitization of the pupils' opinions on environmental issues and challenges. Educating pupils on the importance of sustainability and environmental protection is one of the most efficient methods to reduce e-waste globally and to protect nature. Simultaneously, concerning the integration of the concept of sustainability into the ICT curricula, which corresponds to the RO 2B, although the pupils' knowledge about sustainability was also insufficient, they were willing to learn more and get involved with it.

Moreover, the pupils showed a positive perception of green informatics and the integration of sustainability into the ICT curricula. Green informatics enhances the sustainability of computing through manufacturing lower-impact products, reduced energy consumption of computers and data centers, and better end-of-life management and recycling. In addition, the use of green informatics tools, services and technologies can contribute to environmental protection, sustainability and education. Yet, green informatics cannot substitute people's attitudes and behaviors, which still constitute the most critical factor for protecting the planet and for promoting sustainability.

The study results also indicated that many pupils have the intention and want to contribute to e-waste recycling as they understand its purpose and the environmental benefits. Furthermore, most pupils mention that schools need to attempt knowledge, skills and practices about e-waste management and recycling. These practices can be integrated into the school curricula and be compulsory for all pupils taking courses related to ICT. For this reason, the research recommends that the ICT curricula should be redesigned in order to integrate the principles of sustainability. These principles can be an impulse for innovation and a vehicle for pupils shifting toward more eco-friendly attitudes. Furthermore, these sustainable curricula should be embedded in every aspect of the school community, leading to a sustainable-oriented school supported and implemented with the help of ICT.

Concerning higher education and the challenge of integrating SD issues into ICT curricula, the review of related literature revealed that a holistic approach toward a sustainable university, which can support and contribute to the successful implementation of the SDGs, is required. This approach, among others, involves the inclusion of sustainability issues in the ICT curricula that also provide significant opportunities for HEIs to impact longer-term sustainability in society. HEIs should develop sustainable knowledge, values, and understanding among students in ways that will help shape the viewpoints and attitudes of future citizens, leaders, and policymakers. This inclusion aims to produce a new generation of ICT professionals with the skills and competencies that enable them to deal with sustainability-related issues after graduation.

Toward this direction, the experimental research examined the integration of SD issues in ICT education in a Greek university from the perspectives of the ICT students. The results were based on the processing of two questionnaires (pre-test and post-test) distributed during two lectures regarding green informatics at a two-week interval through an educational intervention. The research assessed the integration of sustainability issues in ICT education from various viewpoints. These viewpoints included the extent of the knowledge of the ICT students had about the concept of sustainability and the perceptions of the ICT students regarding the contribution of university education to environmental awareness. Yet, the necessity for the inclusion of sustainability in the university ICT curricula.

The research also aimed to explore the intention of the ICT students to engage in sustainability because of the education intervention and the potential effect of the reward on the involvement and engagement of the students with green informatics. Moreover, I explored the effect of integrating environmental education issues about e-waste recycling and management practices and the energy usage of DCs into the ICT university curricula.

The outcomes of the study, which correspond to the RO 2C, denoted that although the majority of the ICT students had heard about the concept of sustainability from the media and acknowledged the importance of SD for the society, they had a deficient level of understanding of the concept of SDGs because of the apparent weakness in incorporating sustainability issues in ICT education in Greece. On the other hand, they showed a significant increment of knowledge regarding sustainability and the environmental impact of ICT studies. In any case, the study outcomes revealed that the ICT students were unsatisfied with the contribution of the university toward sustainability. For this reason, they proposed different awareness activities (Figure 22) to support their engagement with sustainability in an inclusive manner. These activities may allow the whole university community to implement SD education successfully.

The study results also provided insights for Greek universities to reorient their ICT curricula in order to integrate sustainability issues. Upon the completion of our educational intervention, the ICT students showed a positive attitude toward integrating green informatics issues into their ICT education. They claimed that the appropriate method to integrate these issues into ICT education is to incorporate them into the relevant courses in their current ICT curricula. The success of this potential integration may contribute to achieving the goals of the 2030 Agenda for SD by graduating IT professionals who can deal with sustainability issues, thus increasing the value and effectiveness of the universities in Greece.

The findings, which correspond to the RO 2E of the study, proved that the direct effect of the educational intervention on the intention of the ICT students to engage in sustainability was significant. This result highlighted that intention might be enhanced through sustainability-oriented practices implemented by the HEIs and might be supported further with the implementation of rewarding programs that HEIs offer. Furthermore, this evidence denoted that embedding SD education and SDGs values into ICT curricula yielded positive results on the students both in the short and the long term as it

- *improved their knowledge* about sustainability and the environmental impact of their studies,
- *supported the process* of becoming a university sustainable; hence, participating in sustainability initiatives undertaken by the university would enable them to develop skills in dealing with sustainability issues in their lives, and
- *enhanced their intention* to be connected with their environment and their community.

Figure 23 lists some suggestions to improve academic activities or the sequence of the courses in order to integrate the sustainability concept as a fundamental element of every ICT discipline and enhance the efficiency of the subject. These suggestions imply that embedding sustainability into the curricula does not merely mean an add-on of new content to enhance the existing knowledge base of sustainability. It denotes the need to infuse sustainability principles into existing courses (i.e., programming, networking, and database management) and to identify key sustainability concepts relevant to ICT (i.e., energy efficiency, electronic waste management, digital inclusion, and privacy concerns) as a cross-cutting theme throughout the ICT curriculum, rather than creating a separate course. Consequently, it is important to automatically initiate a transformational routine, where there is an expectation that knowledge will be facilitated toward developing sustainable behaviors.

Learning Objectives: Define clear learning objectives related to sustainability. For instance, students should understand the carbon footprint of data centers, the importance of energy-efficient coding practices, or the ethical implications of AI and automation.

Collaborative Projects: Assign group projects that require students to develop ICT solutions addressing sustainability challenges. This could involve creating apps for tracking personal carbon footprints, designing smart systems for energy management, or developing technology for disaster response.

Case Studies and Examples: Incorporate real-world case studies and examplesthat highlight the environmental and societal impacts of ICT. This could include examining the life cycle of electronic devices, exploring the digital divide, or analyzing the environmental cost of cloud computing.

Guest Speakers and Industry Involvement: Invite guest speakers from industry, NGOs, and government agencies to provide insights into sustainability practices in the ICT sector. This helps students connect theoretical concepts with real-world applications.

Ethical Considerations: Discuss ethical dilemmas related to ICT, such as privacy breaches, biased algorithms, and the potential for technology to exacerbate societal inequalities.

Practical Labs: Create hands-on labs where students can measure energy consumption of different computing devices, optimize code for efficiency, or analyze the environmental impact of different software solutions.

Capstone Projects: Introduce a capstone project that challenges students to develop a comprehensive ICT solution that addresses a sustainability issue. This project could integrate technical skills with a deep understanding of environmental and social impacts.

Resource Materials: Compile a collection of resources, including readings, videos, and reports, that focus on the intersection of ICT and sustainability. These resources can supplement the curriculum and provide further exploration opportunities for interested students.

Continuous Update: Given the rapidly evolving nature of technology and sustainability challenges, regularly update the curriculum to reflect the latest trends, developments, and best practices

Assessment: Develop assessment methods that evaluate students' comprehension of sustainability concepts, their ability to apply these concepts to ICT scenarios, and their critical thinking skills in addressing ethical and environmental concerns.

Figure 23. Suggestions to improve academic activities or courses sequence to embed sustainability in ICT curricula

This infusion across the disciplines will help ICT students think critically about their local environment, foster problem-solving, and prepare students to find solutions to complex sustainability problems related to the field of their studies. The complexity of the issues the world faces today, both locally and globally, demands a cross or interdisciplinary approach. Still, such an approach is not easily implemented unless interdisciplinarity becomes an established practice in higher education. Interdisciplinarity is thus related to the general trend toward infusing sustainability into existing courses rather than creating stand-alone courses explicitly designed to address sustainability-related concepts.

Moreover, the outcomes of the study, which correspond to the RO 2D, denote that although the majority of the ICT students had a deficient level of knowledge of the concept of e-waste recycling and energy usage in DCs after the intervention, they showed a significant increase in knowledge and awareness regarding them. In addition, the direct effect of the educational intervention on the intention of the students to engage in e-waste recycling was also significant. This intention will potentially lead to energy savings, conservation practices, and effective use of natural resources. Interestingly, this study also revealed that ICT students had a positive perception and attitude about e-waste recycling and recognized the positive financial consequences of proper e-waste recycling and management after the educational intervention.

The existing literature claims a high generation of e-waste and suggests the provision of renewable energy education at all levels worldwide. It is, therefore, imperative and a strong recommendation based on the study results, that all the stakeholders must work together to establish energy conservation awareness, attitudinal disposition, and e-waste management practices of ICT students and to make the young people - as they not only are responsible for the decision-making around disposal but also use and replace their electronic devices more often than the older generations – aware of the environmental impact of the ICT usage. Furthermore, the results of the study advocate the need to work in order to increase the awareness of everyone involved in HEIs and maximize the energy-saving potential of the ICT students.

An effective tool for the implementation of an energy efficiency awareness program which could embed a good attitude toward energy saving is the integration of energy courses into the ICT curricula by connecting school subjects and curricular and classroom learning with real-world societal issues (Hidayat, 2015). These courses may improve the awareness among ICT students and the broader community on the energy consumption of DCs and how each individual can change the amount of energy DCs use. These changes include the encouragement of young people to reduce their data storage and, accordingly, the energy output of data centers by deleting their unwanted and unnecessary data regularly (e.g., junk mail), by clearing their browser history, by saving files in their hard drive rather than in the cloud, and by deleting duplicate photos and videos.

Moreover, the suggested courses may ensure a sustainable power sector growth, support pro-environmental behavior and influence energy conservation on campus. In this light, the HEIs must launch widespread awareness programs to raise the ICT students' knowledge about environmental issues and values. These programs will highlight the advantages of participating in a formal e-waste collection process, the social dimensions and importance of community involvement, students' capacity to participate, e-waste contamination, potential dangers of illegal disposal and recycling in the backyard, and the benefits of organized recycling and management.

Several suggestions can be proposed to enhance the issue of e-waste recycling and energy usage of DCs in the academic community, especially among ICT students. First, campaigns organized by the HEIs emphasizing individual responsibility to conduct environmentally friendly sorting and separation of household garbage as well as other behaviors in decreasing household waste, particularly in terms of e-waste, might help students better achieve their intentions. In addition, these campaigns and training should include the unofficial collection and recycling market. Reducing informal disposal and minimal recycling would be easier if the informal collection sector had high environmental awareness. Second, e-waste collection bins should be placed all over campus, where young people can access them easily.

10.3 Perspectives for Future Research

Further research could focus on the development of a mobile transit app beta version according to the designed mobile apps mockups, which embed the proposed framework EPMA stages and features in order to measure the actual impact and effect on travel change behavior when applying persuasive techniques and test its usability and functionality. Constraints on the eco-design and the development process should be defined to prevent potential or foreseeable consequences as a result of the app's misuse. The design of the app should consider first how the system responds according to the applied persuasive strategies, e.g., immediate feedback provision after the desired travelling change occurs. It should also consider how the system responds to either normal or any unexpected situation, e.g., limited Internet access or first-mile/last-mile challenges. Finally, the system should be automatically updated to content changes according to last-minute changing mobility patterns, or to potential bugs in order to avoid unsustainable behaviors, e.g., smartphone misuse.

Other opportunities to take this research forward could focus on the creation of smart classroom spaces according to the proposed conceptual model in order to explore their impact and influence on the building of core values and attitudes for sustainability and the cultivation of environmental awareness to ICT students and teachers. Furthermore, the students should perform summative and formative evaluations to collect sufficient data about the quality of smart classroom main components - hardware, software, technologies, and services – and conduct the necessary changes.

In the context of revealing key issues regarding the implementation of ESD in ICT secondary education, the following steps in the present study should include the design and teaching of sustainability modules using learning platforms (i.e., Moodle) that will be integrated into the ICT curricula in order to explore the pupils’ awareness level and the potential positive change in their attitudes or actions toward sustainability. These actions could contribute to identifying specific strategies and providing clues that relate to the successful integration of sustainable–oriented practices in ICT curricula.

In terms of further enhancing the generalization of the findings and incorporating the ICT sustainable curricula in the HEIs, future studies should replicate the educational intervention in different types of HEIs. Furthermore, future research could examine the effect of the implementation of the students' suggestions (Figure 22) for creating a sustainable campus network in adding value to the education of ICT students and the social responsibility of the university. In order to comprehend the more significant trends in these environmental issues, further cross-sectional studies involving a balanced composition of undergraduate and postgraduate student groups across the nation are needed.

Moreover, additional research is required on related topics, including enhancing faculty and staff roles in providing active advising ways to extend sustainability consciousness among Greek ICT students. These topics may include, among others, investing in innovative education approaches to improve the students’ sustainable behavior.

Moreover, since the majority of students use digital technologies extensively, the HEIs should collaborate closely with the appropriate governmental organizations to develop a platform or an app (i.e., *SMART E-WASTE RECYCLING*) to make sure that students are well-informed and aware of the location of the e-waste collection centers nearby and rewarding them to actively contribute to regaining activities (i.e., cash payments, bonuses, discounts, coupons). Finally, environmental education should be incorporated into ICT curricula to cultivate values that promote resource sustainability, responsible use, and ecological preservation. As a result, students should be continuously motivated to engage in recycling behavior.

References

Adams, R., Martin, S., & Boom, K. (2018). University culture and sustainability: Designing and implementing an enabling framework. *Journal of Cleaner Production*, 171, 434-445. https://doi.org/10.1016/j.jclepro.2017.10.032

Adejumo, O. A., & Oluduro, O. F. (2021). Ticking time bomb: Implications of the COVID-19 lockdown on e-waste management in developing countries. *UCL Open Environment*, 3(1). https://doi.org/10.14324/111.444/ucloe.000023

Aguilera, A., & Boutueil, V. (2019). *Urban Mobility and the Smartphone*. Elsevier.

Aikens, K., McKenzie, M., & Vaughter, P. (2016). Environmental and sustainability education policy research: A systematic review of methodological and thematic trends. *Environmental Education Research*, 22(3), 333-359. https://doi.org/10.1080/13504622.2015.1135418

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Prentice-Hall.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Al-Hunaiyyan, A., Al-Sharhan, S., & Alhajri, R. (2017). A new mobile learning model in the context of the smart classrooms environment: A holistic approach. *International Journal Of Interactive Mobile Technologies,* 11(3), 39-56. https://doi.org/10.3991/ijim.v11i3.6186

Al-Sharhan, S.(2016). Smart classrooms in the context of technology-enhanced learning (TEL) environment. In K. Alshahrani, & M. Ally (Eds.), *Transforming Education in the Gulf Region: Emerging Learning Technologies and Innovative Pedagogy for the 21st Century*. Routledge.

Al-Turjmana, F., & Malekloob, A. (2019). Smart parking in IoT-enabled cities: A survey. *Sustainable Cities and Society*, 49. https://doi.org/10.1016/j.scs.2019.101608

Alfawareh, H. M., & Jusoh, S. (2014). Smartphones usage among university students: Najran University case. *International Journal of Academic Research*, 6 (2), 321-326. https://doi.org/10.7813/2075-4124.2014/6-2/B.48

Alfawareh, H. M., & Jusoh, S. (2017). The use and effects of smartphones in higher education. International *Journal of Interactive Mobile Technologies*, 11(6), 103-111. https://doi.org/10.3991/ijim.v11i6.7453

Alhaboobi, Z. A. F., Yousif, S.T., & Shawkat, A. R. (2019). Intelligent classroom a conceptual model for the effective use of Internet of Things technique. *Proceedings of the 2nd Scientific Conference of Computer Sciences (SCCS),* pp. 116-120. University of Technology – Iraq. https://doi.org/10.1109/SCCS.2019.8852612

Alhassan, M. D., & Adam, I. O. (2021). The effects of digital inclusion and ICT access on the quality of life: A global perspective. *Technology in Society*, 64, 101511. https://doi.org/10.1016/j.techsoc.2020.101511

Alm, K., Beery, T. H., Eiblmeier, D., & Fahmy, T. (2022). Studentsˈ learning sustainability – implicit, explicit or non-existent: A case study approach on studentsˈ key competencies addressing the SDGs in HEI program. *International Journal of Sustainability in Higher Education*, 23(8), 60-84. https://doi.org/10.1108/IJSHE-12-2020-0484

Alsina, Á., Ayllón, S., Colomer, J., Fernández-Peña, R., Fullana, J., Pallisera, M., & Serra, L. (2017). Improving and evaluating reflective narratives: A rubric for higher education students. *Teaching and Teacher Education*, 63, 148–158. https://doi.org/10.1016/j.tate.2016.12.015

Amekudzi, A. A., Khayesi, M., & Khisty, J. C. (2015). Sustainable development footprint: A framework for assessing sustainable development risks and opportunities in time and space. *International Journal of Sustainable Development*, 18(1/2), 9–40. https://doi.org/10.1504/IJSD.2015.066786

Anagnostopoulou, E., Magoutas, B., Bothos, E., Schrammel, J., Orji, R., & Mentzas, G. (2017). Exploring the links between persuasion, personality and mobility types in personalized mobility applications. *Lecture Notes in Computer Science*, 10171, 107–118. https://doi.org/10.1007/978-3-319-55134-0_9

Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., & Mentzas, G. (2018a). Persuasive technologies for sustainable mobility: State of the art and emerging trends. *Sustainability*, 10(7), 2128. https://doi.org/10.3390/su10072128

Anagnostopoulou, E., Urbančič, J., Bothos, E., Magoutas, B., Bradesko, L., Schrammel, J., & Mentzas, G. (2018b). From mobility patterns to behavioural change: Leveraging travel behaviour and personality profiles to nudge for sustainable transportation. *Journal of Intelligent Information Systems*, 54, 157–178. https://doi.org/10.1007/s10844-018-0528-1

Andersson, A., Hiselius, L. W., & Adellb, E. (2018). Promoting sustainable travel behavior through the use of smartphone applications: A review and development of a conceptual model. *Travel Behaviour and Society*, 11, 52-61. https://doi.org/10.1016/j.tbs.2017.12.008

Annan-Diab, F., & Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the sustainable development goals. *International Journal of Management Education*, 15(2), 73-83. https://doi.org/10.1016/j.ijme.2017.03.006

Argento, D., Einarson, D., Martensson, L., Persson, C., Wendin, K., & Westergren, A. (2020). Integrating sustainability in higher education: A Swedish case. *International Journal of Sustainability in Higher Education*, 21(6), 1131–1150. https://doi.org/10.1108/IJSHE-10-2019-0292

Armstrong, N. (1993). Independent mobility and childrenʹs physical development. In M. Hillman (Eds.), Children, Transport and the Quality of Life (pp. 35–43*). Policy Studies Institute*.

Arnott, B., Rehackova, L., Errington, L., Sniehotta, F., Roberts, J., & Araujo-Soares, V. (2014). Efficacy of behavioural interventions for transport behaviour change: Systematic review, meta-analysis and intervention coding. *International Journal of Behavioral Nutrition and Physical Activity*, 11(133). https://doi.org/10.1186/s12966-014-0133-9

Askell-Williams, H., & Koh, G. A. (2020). Enhancing the sustainability of school improvement initiatives. *School Effectiveness and School Improvement*, 31(4), 660-678. https://doi.org/10.1080/09243453.2020.1767657

Avila, L. V., Filho, W. L., Brandli, L., Macgregor, C. J., Molthan-Hill, P., Ozuyar, P. G., & Moreira, R. M. (2017). Barriers to innovation and sustainability at universities around the world. *Journal of Cleaner Production*, 164, 1268–1278. https://doi.org/10.1016/j.jclepro.2017.07.025

Baena-Morales, S., Martinez-Roig, R., & Hernádez-Amorós, M. J. (2020). Sustainability and educational technology—A Description of the teaching self-concept. *Sustainability*, 12(24), 10309. https://doi.org/10.3390/su122410309

Baker-Eveleth, L., & Stone, R. W. (2020). Userʹs perceptions of perceived usefulness, satisfaction, and intentions of mobile application. *International Journal of Mobile Communications*, 18(1), 1–18. https://doi.org/10.1504/IJMC.2020.104431

Baldassarre, M. T., Caivano, D., Dimauro, G., Gentile, E., & Visaggio, G. (2018). Cloud computing for education: A systematic mapping study. *IEEE Transactions on Education*, 61(3), 234-244. https://doi.org/10.1109/TE.2018.2796558

Bamber, P. (2019). *Teacher education for sustainable development and global citizenship: critical perspectives on values, curriculum and assessment*. Routledge.

Bamberg, S. (2013). Applying the stage model of self-regulated behavioral change in a car use reduction intervention. *Journal of Environmental Psychology*, 33, 68-75. https://doi.org/10.1016/j.jenvp.2012.10.001

Bandura, A. (1977). *Social Learning Theory*. Prentice-Hall.

Barker, V. (2009). Older adolescents' motivations for social network site use: The influence of gender, group identity, and collective self-esteem. *CyberPsychology & Behavior*, 12, 209-213. https://doi.org/10.1089/cpb.2008.0228

Barkley, J. E., Lepp, A., & Salehi-Esfahani, S. (2015). College students' mobile telephone use is positively associated with sedentary behavior. *American Journal of Lifestyle Medicine*, 10(6), 437–441. https://doi.org/10.1177/1559827615594338

Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L. A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, 19(8). https://doi.org/10.1186/s41239-021-00312-8

Bataeineh, M., & Aga, O. (2022). Integrating sustainability into higher education curricula: Saudi Vision 2030. *Emerald Open Research*, 4, 19. https://doi.org/10.35241/emeraldopenres.14499.1

Berkhout, F., & Hertin, J. (2001). *Impacts of information and communication technologies on environmental sustainability: Speculations and evidence*. Brighton.

Bennetts, S. K., Cooklin, A. R., Crawford, S., D' Esposito, F., Hackworth, N. J., Green, J., Matthews, J., Strazdins, L., Zubrick, S. R., & Nicholson, J. M. (2018). What influences parents' fear about children's independent mobility? Evidence from a state-wide survey of Australian parents. *American Journal of Health Promotion*, 32(3), 667–676. https://doi.org/10.1177/0890117117740442

Bersimis, S., Bersimis, F., & Sahlas, A. (2022). *Introduction to Statistics and Probability* (2nd Edition). Tziola & Sons SA Publications (Greek Language).

Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. (2022). *GreenComp – The European sustainability competence framework.* M. Bacigalupo, & Y. Punie (Eds.), Publications Office of the European Union.

Biasutti, M., De Baz, T., & Alshawa, H. (2016). Assessing the infusion of sustainability principles into university curricula. *Journal of Teacher Education for Sustainability*, 18(2), 21-40. https://doi.org/10.1515/jtes-2016-0012

Biasutti, M., & Frate, S. (2017). A validity and reliability study of the Attitudes toward sustainable development scale. *Environmental Education Research*, 23(2), 214–230. https://doi.org/10.1080/13504622.2016.1146660

Blevis, E. (2007). Sustainable interaction design: Invention & disposal, renewal & reuse. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '07), 503–512. https://doi.org/10.1145/1240624.1240705

Borthakur, A., & Singh, P. (2021). The journey from products to waste: A pilot study on perception and discarding of electronic waste in contemporary urban India. *Environmental Science and Pollution Research*, 28, 24511–24520. https://doi.org/10.1007/s11356-020-09030-6

Bothos, E., Apostolou, D., & Mentza, G. (2013). Choice architecture for environmentally sustainable urban mobility. *Extended Abstracts on Human Factors in Computing Systems* (CHI '13), 1503–1508. https://doi.org/10.1145/2468356.2468624

Bothos, E., Prost, S., Schrammel, J., Röderer, K., & Mentzas, G. (2014). Watch your emissions: Persuasive strategies and choice architecture for sustainable decisions in urban mobility. *PsychNology Journal,* 12(3), 107 – 126.

Boukerche, A., & De Grande, R.E. (2018). Vehicular cloud computing: Architectures, applications, and mobility. *Computer Networks*, 135, 171-189. https://doi.org/10.1016/j.comnet.2018.01.004

Boyce, G., Narayanan, V., Greer, S., & Blair, B. (2019). Taking the pulse of accounting education reform: Liberal education, sociological perspectives, and exploring ways forward. *Accounting Education*, 28(3), 274-303. https://doi.org/10.1080/09639284.2019.1586552

Breiting, S., & Mayer, M. (2015). Quality criteria for ESD Schools: Engaging whole schools in education for sustainable development. In R. J. Zucker, & R. Mathar (Eds.), *Schooling for Sustainable Development in Europe. Schooling for Sustainable Development* (vol. 6), Springer. https://doi.org/10.1007/978-3-319-09549-3_3

Brindhadevi, K., Barceló, D., Lan Chi N. T., & Rene, E. R. (2023). E-waste management, treatment options and the impact of heavy metal extraction from e-waste on human health: Scenario in Vietnam and other countries. *Environmental Research*, 217, 114926. https://doi.org/10.1016/j.envres.2022.114926

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From classroom into the real world. *International Journal of Sustainability in Higher Education*, 11, 308–324. https://doi.org/10.1108/14676371011077540

Buliung, R. N., Larsen, K., Faulkner, G., & Ross, T. (2017). Childrenˈs independent mobility in the City of Toronto, Canada. *Travel Behaviour and Society*, 9, 58–69. https://doi.org/10.1016/j.tbs.2017.06.001

Burke, R. D., Dancz Antaya, C. L., Ketchman, K. J., & Bilec, M. M., Boyer, T. H., Davidson, C., Landis, A. E., & Parrish, K. (2018). Faculty perspectives on sustainability integration in undergraduate civil and environmental engineering curriculum. *Journal of Professional Issues in Engineering Education and Practice,* 144(3). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000373

Çakirlar, E., Salih, A., & Turan, L. (2018). Awareness of secondary school students about renewable energy sources. *Renewable Energy*, 116(A), 741-748. https://doi.org/10.1016/j.renene.2017.09.034

Online document Cambridge Dictionary-Cambridge University Press, (2020). *Acceptance*. Retrieved October 13, 2023, from https://dictionary.cambridge.org/dictionary/english/acceptance

Cano, E.V., & Sevillano-García, M. L. (2018). Ubiquitous educational use of mobile digital devices. A general and comparative study in Spanish and Latin America. *Journal of New Approaches In Educational Research*, 7(2), 105–115. https://doi.org/10.7821/naer.2018.7.308

Casado-Aranda, L.-A., Sánchez-Fernández, J., Montoro-Ríos, F. J., & Horcajadas, M. I. A. (2021). Evaluation of the work-integrated learning methodology: Teaching marketing through practitioner experience in the classroom. *Mathematics*, 9(17), 2164. https://doi.org/10.3390/math9172164

Cebrián, G. & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability*, 7(3), 2768-2786. https://doi.org/10.3390/su7032768

Cebrián, G., Palau, R., & Mogas, J. (2020). The smart classroom as a means to the development of ESD methodologies. *Sustainability*, 12(7), 3010. https://doi.org/10.3390/su12073010

Cellina, F., Bucher, D., Veiga Simão, J. P. R., Rudel, R., & Raubal, M. (2019). Beyond limitations of current behaviour change apps for sustainable mobility: Insights from a user-centered design and evaluation process. *Sustainability*, 11(8), 2281. https://doi.org/10.3390/su11082281

Cellina, F., Simão, J. V., Mangili, F., Vermes, N., & Granato, P. (2023). Sustainable mobility persuasion via smartphone apps: Lessons from a Swiss case study on how to design point-based rewarding systems. *Travel Behaviour and Society*, 31, 178-188. https://doi.org/10.1016/j.tbs.2022.12.001

Ceulemans, K., Molderez, I., & Van Liedekerke, L. (2015). Sustainability reporting in higher education: a comprehensive review of the literature and paths for further research. *Journal of Cleaner Production*, 106, 127-143. https://doi.org/10.1016/j.jclepro.2014.09.052

Chang, B., Lee, S., & Kim, B. (2006). Exploring factors affecting the adoption and continuance of online games among college students in South Korea: Integrating uses and gratifications and diffusion of innovation approaches. *New Media & Society*, 8(2), 295–319. https://doi.org/10.1177/1461444806059888

Chankseliani, M., & McCowan, T. (2021). Higher education and the sustainable development goals. *Higher Education*, 81, 1–8. https://doi.org/10.1007/s10734-020-00652-w

Chau, A., Stephens, G., & Jamieson, R. (2004). Biometrics acceptance –perceptions of use of biometrics. *Proceedings of the Australasian Conferences on Information Systems (ACIS 2004),* 28.

Chaudhary, S., & Dey, A. K. (2021). Influence of student-perceived service quality on sustainability practices of university and student satisfaction. *Quality Assurance in Education*, 29(1), 29-40. https://doi.org/10.1108/QAE-10-2019-0107

Cheung, S. K. S., Kwok, L. F., Phusavat, K., Yang, H. H. (2021). Shaping the future learning environments with smart elements: Challenges and opportunities. *International Journal of Educational Technology in Higher Education*, 18(16). https://doi.org/10.1186/s41239-021-00254-1

Chen, A. N., Castillo, J. G. D., & Ligon, K. (2015). Information and Communication Technologies (ICT): Components, dimensions, and its correlates. *Journal of International Technology and Information Management,* 24(4), 2. https://doi.org/10.58729/1941-6679.1051

Chowdhury, G., & Koya, K. (2017). Information practices for sustainability: Role of iSchools in achieving the UN Sustainable Development Goals (SDGs*). Journal of the Association for Information Science and Technology*, 68, 2128–2138. https://doi.org/10.1002/asi.23825

Chowdhury, S., & Ceder, A. (2016). Usersˈ willingness to ride an integrated public-transport service: A literature review. *Transport Policy*, 48, 183–195. https://doi.org/10.1016/j.tranpol.2016.03.007

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd Edition). Routledge.

Curran-Everett, D. (2017). Explorations in statistics: The assumption of normality. *Advances in Physiology Education*, 41(3), 449-453. https://doi.org/10.1152/advan.00064.2017

Dagiliūtė, R., Zabulionis, D., Sujetovienė, G., & Žaltauskaitė, J. (2019). Waste of electrical and electronic equipment: Trends and awareness among youths in Lithuania. *Waste Management & Research*, 37(1), 95-101. https://doi.org/10.1177/0734242X18806999

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance*. MIS Quarterly*, 13(3), 319–340. https://doi.org/10.2307/249008

De Almeida Neris, V. P., da Hora Rodrigues, K. R., & Lima, R. F. (2014). A Systematic review of sustainability and aspects of human-computer interaction. In M. Kurosu (Eds.), *Human-Computer Interaction. Applications and Services*. HCI 2014. Lecture Notes in Computer Science (vol. 8512, pp. 742–753). Springer.

De Jager, T. (2015). A proposal to integrate the management of electronic waste into the curriculum of primary schools. *Eurasia Journal of Mathematics, Science & Technology Education*, 11(3), 443-454. https://doi.org/10.12973/eurasia.2015.1340a

De Medeiros, J. F., Da Rocha, C. G., & Duarte Ribeiro, J. L. (2018). Design for sustainable behavior (DfSB): Analysis of existing frameworks of behavior change strategies, expertsˈ assessment and proposal for a decision support diagram. *Journal of Cleaner Production*, 188, 402-415. https://doi.org/10.1016/j.jclepro.2018.03.272

De Wit, H., & Leask, B. (2017). Reimagining the curriculum for the 21st century. In Global University Network for Innovation (Eds.) *Higher education in the world, 6: Towards a socially responsible university; balancing the global with the local* (pp. 222–235). GUNi.

Debnath, B., Roychoudhuri, R., & Ghosh, S. K. (2016). E-waste management – A potential route to green computing. *Procedia Environmental Sciences*, 35, 669-675. https://doi.org/10.1016/j.proenv.2016.07.063

Decharat, S., & Kiddee, P. (2022). Assessment of knowledge, attitude, perceptions and risk assessment among workers in e-waste recycling shops. *Environmental Analysis Health and Toxicology*, 37(1), e2022003. https://doi.org/10.5620/eaht.2022003

Delors, J. (1996). *Learning: The treasure within*. Report to UNESCO of the international commission on education for the twenty-first century. UNESCO.

Demerath, P. (2018). The emotional ecology of school improvement culture: Charged meanings and common moral purpose. *Journal of Educational Administration*, 56(5), 488-503. https://doi.org/10.1108/JEA-01-2018-0014

Deniz, P. O., Aydın, Ç. Y., & Kiraz, E. D. E. (2019). Electronic waste awareness among students of engineering department. *Cukurova Medical Journal*, 44(1), 101-109. https://doi.org/10.17826/cumj.440498

Desha, C., Hargroves, K. C. (2014). A Peaking and tailing approach to education and curriculum renewal for sustainable development. *Sustainability*, 6(7), 4181-4199. https://doi.org/10.3390/su6074181

DiSalvo, C., Sengers, P., & Brynjarsdottir, H. (2010). Mapping the landscape of sustainable HCI. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI ˈ10), 1975–1984. https://doi.org/10.1145/1753326.1753625

Duarte, A.J., Malheiro, B., Arnó, E., Perat, I., Silva, M.F., Fuentes-Durá, P., Guedes, P., & Ferreira, P. (2020). Engineering education for sustainable development: The European project semester approach. *IEEE Transactions on Education*, 63(2), 108-117. https://doi.org/10.1109/TE.2019.2926944

Dutzik, T., Madsen, T., & Baxandall, P. (2013*). A new way to go: The transportation apps and vehicle-sharing tools that are giving more Americans the freedom to drive less*. U.S. PIRG Education Fund Frontier Group.

Ebaid, I. E. S. (2022). Sustainability and accounting education: Perspectives of undergraduate accounting students in Saudi Arabia. *Journal of Applied Research in Higher Education*, 14(4), 1371-1393. https://doi.org/10.1108/JARHE-05-2021-0183

Edumadze, J. K., Tenkorang, E. Y., Armah, F. A., Luginaah, I., & Edumadze, G. E. (2013). Electronic waste is a mess: Awareness and proenvironmental behavior among university students in Ghana. *Applied Environmental Education & Communication*, 12(4), 224-234. https://doi.org/10.1080/1533015X.2013.876250

Ercan, O., & Bilen, K. (2014). A research on electronic waste awareness and environmental attitudes of primary school students. *The Anthropologist*, 17(1), 13–23. https://doi.org/10.1080/09720073.2014.11891410

Eshiemogie, S. O., Ighalo, J., & Banji, T. (2022). Knowledge, perception and awareness of renewable energy by engineering students in Nigeria: A need for the undergraduate engineering program adjustment. *Cleaner Engineering and Technology*, 6, 100388. https://doi.org/10.1016/j.clet.2021.100388

Online document European Commission (2022). *Informatics education at school in Europe. Eurydice report.* Retrieved September 19, 2023, from https://www.minedu.gov.gr/publications/docs2022/Informatics_education_Report.pdf

Online document European Parliament (2023, April 12)*. E-waste in the EU: Facts and figures* (infographic). Retrieved August 22, 2023, from https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93325/e-waste-in-the-eu-facts-and-figures-infographic

Expósito, L. C. & Sánchez, J. G. (2020). Implementation of SDGs in university teaching: A course for professional development of teachers in education for sustainability for a transformative action. *Sustainability*, 12(19), 8267. https://doi.org/10.3390/su12198267

Fabi, V., Di Nicoli, M. V., Spigliantini, G., & Corgnati, S. P. (2017). Insights on pro-environmental behavior towards post-carbon society. *Energy Procedia*, 134, 462–469. https://doi.org/10.1016/j.egypro.2017.09.604

Fachrudin, H. T., & Fachrudin, K. A. (2021). Factors influencing energy conservation application in green campus design based on green behavior. *International Journal of Energy Economics and Policy*, 11(4), 511-520. https://doi.org/10.32479/ijeep.11355

Fagas, G., Gammaitoni, L., Gallagher, J. P., & Paul, D. J. (Eds.). (2017). *ICT - Energy concepts for energy efficiency and sustainability*. InTech.

Fauville, G., Lantz-Andersson, A., & Säljö, R. (2014). ICT tools in environmental education: Reviewing two newcomers to schools. *Environmental Education Research*, 20(2), 248-283. https://doi.org/10.1080/13504622.2013.775220

Fernández-Llorca, D., Mínguez, R. Q., Alonso, I. P., Fernández López, C., García-Daza, I., Sotelo, M. A., & Cordero, C. A. (2017). Assistive intelligent transportation systems: The need for user localization and anonymous disability identification. *IEEE Intelligent Transportation Systems Magazine*, 9(2), 25-40. https://doi.org/10.1109/MITS.2017.2666579

Ferreira, M., Martinsone, B., & Talić, S. (2020). Promoting sustainable social emotional learning at school through relationship-centered learning environment, teaching methods and formative assessment. *Journal of Teacher Education for Sustainability*, 22(1), 21-36. https://doi.org/10.2478/jtes-2020-0003

Filho, W. L., Jim Wu, Y. C., Brandli, L. L., Veiga Avila, L., Azeiteiro, U. M., Caeiro, S., & Madruga, L. R. R. G. (2017). Identifying and overcoming obstacles to the implementation of sustainable development at universities. *Journal of Integrative Environmental Sciences*, 14(1), 93-108. https://doi.org/10.1080/1943815X.2017.1362007

Filho, W. L., Salvia, A. L., do Paço, A., Anholon, R., Quelhas, O. L. G., Rampasso, I. S., Ng, A., Balogun, A. L., Kondev, B., & Brandli, L. L. (2019). A comparative study of approaches towards energy efficiency and renewable energy use at higher education institutions. *Journal of Cleaner Production*, 237, 117728. https://doi.org/10.1016/j.jclepro.2019.117728

Fogg, B. J. (1997). *Charismatic computers: Creating more likable and persuasive interactive technologies by leveraging principles from social psychology*. Doctoral dissertation. Stanford University.

Fogg, B. J. (2002). Persuasive technology: Using computers to change what we think and do. *Ubiquity*, 5. https://doi.org/10.1145/764008.763957

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error, *Journal of Marketing Research*, 18(1), 39–50. https://doi.org/10.2307/3151312

Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*. UNU/UNITAR – co-hosted SCYCLE Programme, ITU & ISWA, Bonn/Geneva/Rotterdam.

Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., & Takemoto, A. (2019). Higher education for sustainable development: Actioning the global goals in policy, curriculum and practice. *Sustainability Science*, 14, 1621–1642. https://doi.org/10.1007/s11625-018-0628-4

Froese, A. D., Carpenter, C. N., Inman, D. A., Schooley, J. R., Barnes, R. B., Brecht, P. W., & Chacon, J. D. (2012). Effects of classroom cell phone use on expected and actual learning. *College Student Journal*, 46(2), 323- 332.

Fyhri, A., Hjorthol, R., Mackett, R. L., Fotel, T. N., & Kyttä, M. (2011). Childrenˈs active travel and independent mobility in four countries: Development, social contributing trends and measures. *Transportation Policy*, 18(5), 703–710. https://doi.org/10.1016/j.tranpol.2011.01.005

Gabrielli, S., Maimone, R., Forbes, P., Masthoff, J., Wells, S., Haverinen, L., Primerano, L., Bo, G., & Pompa, M. (2013). *Designing motivational features for sustainable urban mobility*. Extended Abstracts on Human Factors in Computing Systems (CHI ˈ13), 1461–1466. https://doi.org/10.1145/2468356.2468617

Gabrielli, S., Forbes, P., Jylhä, A., Wells, S., Sirén, M., Hemminki, S., Nurmi, P., Maimone, R., Masthoff, J., & Jacucci, G. (2014). Design challenges in motivating change for sustainable urban mobility. *Computers in Human Behavior*, 41, 416–423. https://doi.org/10.1016/j.chb.2014.05.026

Gandini, P., Marchionni, G., Studer, L., & Maja, R. (2019). Sustainable and aware mobility explained to children. *Sustainability*, 11(23), 6668. https://doi.org/10.3390/su11236668

Gebresselassie, M., & Sanchez, T. W. (2018). Smart tools for socially sustainable transport: A review of mobility apps. *Urban Science*, 2(2), 45. https://doi.org/10.3390/urbansci2020045

Gilal, F. G., Shah, S. M. M., Adeel, S., Gilal, R. G., & Gilal, N. G. (2022). Consumer e-waste disposal behaviour: A systematic review and research agenda. *International Journal of Consumer Studies*, 46, 1785–1803. https://doi.org/10.1111/ijcs.12767

Gkargkavouzi, A., Halkos, G., & Matsiori, S. (2019). How do motives and knowledge relate to intention to perform environmental behavior? Assessing the mediating role of constraints. *Ecological Economics*, 165, 106394. https://doi.org/10.1016/j.ecolecon.2019.106394

Gligorić, N., Uzelac, A., & Krco, S. (2012). Smart classroom: Real-time feedback on lecture quality. *Proceedings of the 2012 IEEE International Conference on Pervasive Computing and Communications Workshops* (PERCOM Workshops), 391–394. https://doi.org/10.1109/PerComW.2012.6197517

Gomes, S., Jorge, S., & Eugenio, T. (2021). Teaching sustainable development in business sciences degrees: Evidence from Portugal. *Sustainability Accounting, Management and Policy Journal*, 12(3), 611-634. https://doi.org/10.1108/SAMPJ-10-2019-0365

González-Zamar, M. D., Abad-Segura, E., López-Meneses, E., & Gómez-Galán, J. (2020). Managing ICT for sustainable education: Research analysis in the context of higher education. *Sustainability*, 12(19), 8254. https://doi.org/10.3390/su12198254

Online document Goodwin, K. (2012). *Use of tablet technology in the classroom. N.S.W. curriculum and learning innovation centre*. Retrieved August 22, 2023, from https://cpb-ap-se2.wpmucdn.com/global2.vic.edu.au/dist/1/42368/files/2014/04/iPad_Evaluation_Sydney_Region_exec_sum-1pjdj70.pdf

Goosey, E., & Goosey, M. (2019). The materials of waste electrical and electronic equipment. In V. Goodship, A. Stevels, & J. Huisman (Eds.), *Waste Electrical and Electronic Equipment (WEEE) Handbook* (2nd ed., pp.231-262). Woodhead Publishing.

Gordon, N. (2010). Education for sustainable development in Computer Science. *Innovation in Teaching and Learning in Information and Computer Sciences*, 9(2), 1-6. https://doi.org/10.11120/ital.2010.09020003

Gródek-Szostak, Z., Malinowski, M., Suder, M., Kwiecień, K., Bodziacki, S., Vaverková, M. D., Maxianová, A., Krakowiak-Bal, A., Ziemiańczyk, U., Uskij, H., et al. (2021). Energy conservation behaviors and awareness of Polish, Czech and Ukrainian students: A case study. *Energies,* 14(18), 5599. https://doi.org/10.3390/en14185599

Gual, C. (2019). Are universities ready to have a real impact on achieving the sustainable development goals (SDGs)? In *Implementing the 2030 agenda at higher education institutions: Challenges and responses* (pp. 41–43). Barcelona: GUNi.

Guerini, M., Stock, O., & Zancanaro, M. A. (2007). Taxonomy of strategies for multimodal persuasive message generation. *Applied Artificial Intelligence*, 21(2), 99–136. https://doi.org/10.1080/08839510601117169

Gupta, T., Kar, N., Mishra, W., & Loudon, G. (2022). *Persuasive design for sustainable mobility. Proceedings of the 12th Indian Conference on Human-Computer Interaction* (IndiaHCI '21), 123–127. https://doi.org/10.1145/3506469.3506490

Hadgraft, R.G., & Kolmos, A. (2020). Emerging learning environments in engineering education. *Australasian Journal of Engineering Education*, 25(1), 3-16. https://doi.org/10.1080/22054952.2020.1713522

Håkansson, C., & Finnveden, G. (2015). Indirect rebound and reverse rebound effects in the ICT-sector and emissions of CO_2. *Proceedings of the 29th International Conference on Informatics for Environmental Protection (EnviroInfo 2015)*. https://doi.org/10.2991/ict4s-env-15.2015.8

Hallinger, P., & Chatpinyakoop, C. (2019). A bibliometric review of research on higher education for sustainable development, 1998–2018. *Sustainability*, 11(8), 2401. https://doi.org/10.3390/su11082401

Handelzalts, A. (2019). Collaborative curriculum development in teacher design teams. In J. Pieters, J. Voogt, & N. P. Roblin (Eds.), *Collaborative curriculum design for sustainable innovation and teacher learning* (pp. 159-173). Springer. https://doi.org/10.1007/978-3-030-20062-6_9

Hanusz, Z., & Tarasińska, J. (2015). Normalization of the Kolmogorov–Smirnov and Shapiro–Wilk tests of normality. *Biometrical Letters*, 52(2), 85-93. https://doi.org/10.1515/bile-2015-0008

Hao, J., Wang, Y., Wu, Y., & Guo, F. (2020). Metal recovery from waste printed circuit boards: A review for current status and perspectives. *Resources, Conservation and Recycling*, 157, 104787. https://doi.org/10.1016/j.resconrec.2020.104787

Hardeman, W., Johnston, M., Johnston, D., Bonetti, D., Wareham, N., & Kinmonth, A. L. (2002). Application of the theory of planned behaviour in behaviour change interventions: A systematic review. *Psychology and Health*, 17(2), 123-158. https://doi.org/10.1080/08870440290013644a

Harten, N., & Olds, T. (2004). Patterns of active transport in 11–12 year old Australian children. *Australian and New Zealand Journal of Public Health*, 28(2), 167-172. https://doi.org/10.1111/j.1467-842X.2004.tb00931.x

Helbig, C., Kolotzek, C., Thorenz, A., Reller, A., Tuma, A., Schafnitzel, M., & Krohns, S. (2017). Benefits of resource strategy for sustainable materials research and development. *Sustainable Materials and Technologies*, 12, 1-8. https://doi.org/10.1016/j.susmat.2017.01.004

Henderson, K., & Tilbury, D. (2004). Whole-school approaches to sustainability: An international review of sustainable school programs. *Australian Research Institute in Education for Sustainability*.

Hidayat, E. S. (2015). The role of education in awareness enhancement of takaful: A literature review. *International Journal of Pedagogical Innovations*, 3(2), 107-112. https://doi.org /10.12785/IJPI/030203.

Higón, D. A., Gholami, R., & Shirazi, F. (2017). ICT and environmental sustainability: A global perspective. *Telematics and Informatics*, 34(4), 85-95, https://doi.org/10.1016/j.tele.2017.01.001

Hillman, M., Adams, J., & Whitelegg, J. (1990). *One false move … A study of children's independent mobility*. PSI Publishing.

Hilty, L. M., & Aebischer, B. (2015). ICT for sustainability: An emerging research field. In L. Hilty, & B. Aebischer (Eds.), *ICT innovations for sustainability. Advances in intelligent systems and computing* (vol. 310, pp. 3–36). Springer. https://doi.org/10.1007/978-3-319-09228-7_1

Hoang, T. T. P., & Kato, T. (2016). Measuring the effect of environmental education for sustainable development at elementary schools: A case study in Da Nang city, Vietnam. *Sustainable Environment Research,* 26, 274–286. https://doi.org/10.1016/j.serj.2016.08.005

Holgersson, S., Steenari, B. M., Björkman, M., & Cullbrand, K. (2018). Analysis of the metal content of small-size Waste Electric and Electronic Equipment (WEEE) printed circuit boards—part 1: Internet routers, mobile phones and smartphones. *Resources, Conservation and Recycling*, 133, 300-308. https://doi.org/10.1016/j.resconrec.2017.02.011

Hollingworth, L., Olsen, D., Asikin-Garmager, A., & Winn, K. M. (2018). Initiating conversations and opening doors: How principals establish a positive building culture to sustain school improvement efforts. *Educational Management Administration & Leadership*, 46(6), 1014-1034. https://doi.org/10.1177/1741143217720461

Holm, T., Sammalisto, K., Grindsted, T. S., & Vuorisalo, T. (2015). Process framework for identifying sustainability aspects in university curricula and integrating education for sustainable development. *Journal of Cleaner Production*, 106, 164-174. https://doi.org/10.1016/j.jclepro.2015.04.059

Holst, J. (2022). Towards coherence on sustainability in education: A systematic review of Whole Institution Approaches. *Sustainability Science*, 18, 1015–1030. https://doi.org/10.1007/s11625-022-01226-8

Hu, H., Sun, Z., Liu, R., & Yang, X. (2019). Privacy implication of location-based service: Multi-class stochastic user equilibrium and incentive mechanism. *Transportation Research Record*, 2673(12), 256–265. https://doi.org/10.1177/0361198119859322

Ibáñez- Forés, V., Martínez-Sánchez, V., Valls-Val, K., & Bovea, M. D. (2022). Sustainability reports as a tool for measuring and monitoring the transition towards the circular economy of organisations: Proposal of indicators and metrics. *Journal of Environmental Management*, 320, 115784. https://doi.org/10.1016/j.jenvman.2022.115784

Ilankoon I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., Petersen, J., et al., (2018). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, 82, 258-275. https://doi.org/10.1016/j.wasman.2018.10.018

Online document International Sustainable Campus Network, (2018). *Sustainable campus best practices*. Retrieved September 23, 2023, from https://www.iau-hesd.net/sites/default/files/documents/iscn-report-2018-web.pdf .

Isaksson, E., Naeve, A., Lefrère, P., & Wild, F. (2017). Towards a reference architecture for smart and personal learning environments. In E. Popescu, M. K. Khribi, R. Huang, M. Jemni, N. S. Chen, & D. G. Sampson (Eds.), *Innovations in smart learning*. Springer.

Islam, M. T., Dias, P., & Huda, N. (2021). Young consumersˈ e-waste awareness, consumption, disposal, and recycling behavior: A case study of university students in Sydney, Australia. *Journal of Cleaner Production*, 282, 124490. https://doi.org/10.1016/j.jclepro.2020.124490

Ismagilova, E., Hughes, L., Rana, N.P., & Dwivedi, Y. K. (2022). Security, privacy and risks within smart cities: Literature review and development of a smart city interaction framework. *Information Systems Frontiers*, 24, 393–414. https://doi.org/10.1007/s10796-020-10044-1

Online document ISO 9241-11, (2018). *Ergonomics of human – system interaction — Part 11: usability: definitions and concepts*. Retrieved October 13, 2023, from https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

Issa, T., & Isaias, P. (2022). Usability and Human–Computer Interaction (HCI). In T. Issa, & P. Isaias (Eds), *Sustainable Design* (pp 19-36). Springer.

Online document ITU, (May 2020). *Connect 2030 – An agenda to connect all to a better world*. Retrieved August 7, 2023, from https://www.itu.int/en/mediacentre/backgrounders/Pages/connect-2030-agenda.aspx

Jensen, V., Benavot, A., & Mckenzie, M. (2021). *Learn for our planet: A global review of how environmental issues are integrated in education*, UNESCO.

Jiang, D., Wang, Y., Lv, Z., Wang, W., & Wang, H. (2020). An energy-efficient networking approach in cloud services for IoT networks. *IEEE Journal on Selected Areas in Communications*, 38(5), 928-941. https://doi.org/10.1109/JSAC.2020.2980919

Jormanainen, I., Toivonen, T., & Nivalainen, V. (2018). A smart learning environment for environmental education. In M. Chang (Eds.), *Challenges and solutions in smart learning*. Springer.

Kahraman, Z. E. H. (2010). Using user-centered design approach in course design. *Procedia - Social and Behavioral Sciences*, 2(2), 2071-2076. https://doi.org/10.1016/j.sbspro.2010.03.283

Online document Kamargianni, M., Matyas M., & Schäfer, A. (2015). A. feasibility study for mobility as a service concept for London. Retrieved August 21, 2023, from https://www.ucl.ac.uk/bartlett/energy/sites/bartlett/files/maas.pdf

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A critical review of new mobility services for urban transport. *Transportation Research Procedia*, 14, 3294 – 3303. https://doi.org/10.1016/j.trpro.2016.05.277

Katal, A., Dahiya, S., & Choudhury, T. (2022). Energy efficiency in cloud computing data centers: A survey on software technologies. *Cluster Computing*, 26, 1845–1875. https://doi.org/10.1007/s10586-022-03713-0

Katila, P., Pierce Colfer, C., De Jong, W., Galloway, G., Pacheco, P., & Winkel, G. (2019). *Sustainable development goals: Their impacts on forests and people*. Cambridge University Press.

Kaptein, M., & Duplinsky, S. (2013). Combining multiple influence strategies to increase consumer compliance. *International Journal of Internet Marketing and Advertising,* 8(1), 32 – 53. https://doi.org/10.1504/IJIMA.2013.056586

Kelders, S. M., Kok, R. N., Ossebaard, H. C., & Van Gemert-Pijnen, J. E. W. C. (2012). Persuasive system design does matter: A systematic review of adherence to web-based interventions. *Journal of Medical Internet Research*, 14(6), e152. https://doi.org/10.2196/jmir.2104

Kim, Y., Soyata, T., & Behnagh, R. (2018). Towards emotionally aware AI smart classroom: Current issues and directions for engineering and education. *IEEE Access*, 6, 5308–5331. https://doi.org/10.1109/ACCESS.2018.2791861

Kırdar, G., & Ardıç, S. (2020). A design proposal of integrated smart mobility application for travel behavior change towards sustainable mobility. *Civil Engineering and Architecture*, 8(5), 1095 - 1106. https://doi.org/10.13189/cea.2020.080536

Klein, M., Mogles, N., & Van Wissen, A. (2014). Intelligent mobile support for therapy adherence and behavior change. *Journal of Biomedical Informatics*, 51, 137-151. https://doi.org/10.1016/j.jbi.2014.05.005

Klotz, L., Potvin, G., Godwin, A., Cribbs, J., Hazari, Z., & Barclay, N. (2014). Sustainability as a route to broadening participation in engineering. *Journal of Engineering Education*, 103(1), 137-153. https://doi.org/10.1002/jee.20034

Kormos, E., & Julio, L. (2020). Student attitudes toward instructor assessment in higher education: Does the delivery method matter? *Education and Information Technologies*, 25, 4287–4296. https://doi.org/10.1007/s10639-020-10152-0

Kougias, K., & Efstathopoulos, J. (2020). The operational framework of the Greek educational system as an obstacle to the implementation of sustainable school. *Frontiers in Education*, 5, 142. https://doi.org/10.3389/feduc.2020.00142

Krajhanzl, J. (2010). Environmental and proenvironmental behavior. In E. Řehulka (Eds), *Health education: International experiences* (pp. 251–274). Masarykova Univerzita. Brno.

Kremer, D., Schlieder, C., Feulner, B., & Ohl, U. (2013). Spatial choices in an educational game. *Proceedings of the 5th International Conference on Games and Virtual Worlds for Serious Applications* (VS-GAMES 2013), 134–137. https://doi.org/10.1109/VS-GAMES.2013.6624243

Kukkonen, J., Kärkkäinen, S., & Keinonen, T. (2018). Examining the relationships between factors influencing environmental behaviour among university students. *Sustainability*, 10(11), 4294. https://doi.org/10.3390/su10114294

Kumar, A., Holuszko, M., & Espinosa, D. C. R. (2017). E-waste: An overview on generation, collection, legislation and recycling practices. *Resources, Conservation and Recycling*, 122, 32-42. https://doi.org/10.1016/j.resconrec.2017.01.018

Kumar, A. (2019). Exploring young adults' e-waste recycling behaviour using an extended theory of planned behaviour model: A cross-cultural study. *Resources, Conservation & Recycling Advances*, 141, 378-389. https://doi.org/10.1016/j.resconrec.2018.10.013

Kwet, M., & Prinsloo, P. (2020). The 'smart' classroom: A new frontier in the age of the smart university. *Teaching in Higher Education*, 25(4), 510-526. https://doi.org/10.1080/13562517.2020.1734922

Kyle, W. C. (2020). Expanding our views of science education to address sustainable development, empowerment, and social transformation. *Disciplinary and Interdisciplinary Science Education Research*, 2, 2. https://doi.org/10.1186/s43031-019-0018-5

Lai, C. H., Yang, J. C., Chen, F. C., Ho, C. W., & Chan, T. W. (2007). Affordances of mobile technologies for experiential learning: The interplay of technology and pedagogical practices. *Journal of Computer Assisted Learning*, 23(4), 326-337. https://doi.org/10.1111/j.1365-2729.2007.00237.x

Lam, W. W. Y., & Loo, B. P. Y. (2014). Determinants of children's independent mobility in Hong Kong. *Asian Transport Studies*, 3(2), 250-268.

Lambrechts, W. (2016). Possibilities and practices of competences for sustainable development in higher education. In W. Lambrechts, & J. Hindson (Eds.), *Research and innovation in education for sustainable development* (pp. 123-133). Austria: Environment and School Initiatives.

Lange, S., Pohl, J., & Santarius, T. (2020). Digitalization and energy consumption. Does ICT reduce energy demand? *Ecological Economics*, 176, 106760. https://doi.org/10.1016/j.ecolecon.2020.106760

Larsen, K., Buliung, R. N., & Faulkner, G. (2015). Assessing how the built and social environment relate to children's walking and independent mobility in the Greater Toronto and Hamilton Area. *Transportation Research Record: Journal of the Transportation Research Board*, 2513, 80–89. https://doi.org/10.3141/2513-10

Latorre-Cosculluela, C., Sierra-Sánchez, V., Rivera-Torres, P., & Liesa-Orús, M. (2023). ICT efficacy and response to different needs in university classrooms: Effects on attitudes and active behaviour towards technology. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-023-09357-2

Lazzarini, B., Perez-Foguet, A., & Boni, A. (2018). Key characteristics of academics promoting sustainable human development within engineering studies. *Journal of Cleaner Production*, 188, 237–252. https://doi.org/10.1016/j.jclepro.2018.03.270

Lee, M., & Louis, K. S. (2019). Mapping a strong school culture and linking it to sustainable school improvement. *Teaching and Teacher Education: An International Journal of Research and Studies*, 81(1), 84-96. https://doi.org/10.1016/j.tate.2019.02.001

Lee, U., Han, K., Cho, H., Chung, K. M., Hong, H., Lee, S. J., Noh, Y., Park, S., & Carroll, J. M. (2019). Intelligent positive computing with mobile, wearable, and IoT devices: Literature review and research directions. *Ad Hoc Networks*, 83, 8-24. https://doi.org/10.1016/j.adhoc.2018.08.021

Lengthorn, E. (2018). Science education and the UN sustainable development goals. *Education Science*, 274, 2–4.

Lertpratchya, A., Besley, J., Zwickle, A., Takahashi, B., & Whitley, C. (2017). Assessing the role of college as a sustainability communication channel. *International Journal of Sustainability in Higher Education*, 18(7), 1060-1075. https://doi.org/10.1108/IJSHE-09-2016-0172

Leung, K. Y. K., & Loo, B. P. Y. (2017). Association of children's mobility and wellbeing: A case study in Hong Kong. *Travel Behaviour and Society*, 9, 95-104. https://doi.org/10.1016/j.tbs.2017.07.004

Li, B., Kong, S. C., & Chen, G. (2015). Development and validation of the smart classroom inventory. *Smart Learning Environments,* 2(3). https://doi.org/10.1186/s40561-015-0012-0

Li, Y., & Voege, T. (2017). Mobility as a Service (MaaS): Challenges of implementation and policy required. *Journal of Transportation Technologies*, 7, 95-106. https://doi.org/10.4236/jtts.2017.72007

Lim, C. K., Haufiku, M. S., Tan, K. L., Farid Ahmed, M., & Ng, T. F. (2022). Systematic review of education sustainable development in higher education institutions. *Sustainability*, 14(20), 13241. https://doi.org/10.3390/su142013241

Lin, W. & Lee, M. (2018). Linking network learning capacity (NLC) to professional community and organizational learning. *Journal of Educational Administration*, 56(6), 620-642. https://doi.org/10.1108/JEA-10-2017-0150

Lin, Y. T., Huang, Y. M., & Cheng, S. C. (2010). An automatic group composition system for composing collaborative learning groups using enhanced particle swarm optimization. *Computers & Education*, 55(4), 1483–1493. https://doi.org/10.1016/j.compedu.2010.06.014

Liu, D., Huang, R., & Wosinski, M. (2017). Smart learning in classroom environment. In *Smart learning in smart cities, Lecture Notes in Educational Technology*. Springer

Liu, M., Horton, L., Olmanson, J., & Toprac, P. (2011). A study of learning and motivation in a new media enriched environment for middle school science. *Educational Technology Research and Development*, 59, 249–265. https://doi.org/10.1007/s11423-011-9192-7

Liu, X., Chen, Y., Yang, Y., Liu, B., Ma, C., Craig, G., & Gao, F. (2020). Understanding vocational accounting students' attitudes towards sustainable development. *Journal of Vocational Education and Training*, 72(2), 161-172. https://doi.org/10.1080/13636820.2020.1760333

Lucache, G., Turcanu, A., Lucache, D., & Nuca, I. (2017). Comparative study of the level of awareness of e-waste management in Romania and Republic of Moldova. *Proceedings of the International Conference on Electromechanical and Power Systems* (SIELMEN 2017), 431-436.

Lucas, H., Pinnington, S., & Cabeza, L. F. (2018). Education and training gaps in the renewable energy sector. *Solar Energy*, 173, 449–455. https://doi.org/10.1016/j.solener.2018.07.061

Lwoga, E. T., & Sangeda, R. Z. (2019). ICTs and development in developing countries: A systematic review of reviews. *The Electronic Journal of Information Systems in Developing Countries*, 85(1), e12060. https://doi.org/10.1002/isd2.12060

Machado, M. C., Hourneaux Junior, F., & Sobral, F. A. (2017). Sustainability in information technology: An analysis of the aspects considered in the model COBIT. *Journal of Information Systems and Technology Management,* 14(1), 88–110. https://doi.org/10.4301/S1807-17752017000100005

Mackett, R. L. (2013). Childrenˈs travel behaviour and its health implications. *Transport Policy,* 26, 66-72. https://doi.org/10.1016/j.tranpol.2012.01.002

MacLeod, J., Hao-Yang, H., Zhu, S., & Lee, Y. H. (2018). Understanding studentsˈ preferences towards the smart classroom learning environment: Development and validation of an instrument. *Computers & Education*, 122, 80–91. https://doi.org/10.1016/j.compedu.2018.03.015

Mahmoud, L., Gamal, M. E., & Zoghbor, W. (2020). Studentsˈ Assessment of electronic waste environmental management and sustainability at an Emirati federal institution. In A. N. Al-Masri, & Y. Al-Assaf (Eds), *Sustainable development and social responsibility*—Volume 2 (pp. 263-269). Springer.

Marques, C. G., & da Silva, V. G. (2017). E-waste in Portugal — A higher education-based study. Proceedings of the 12th Iberian Conference on Information Systems and Technologies (CISTI 2017), 1-6. https://doi.org/10.23919/CISTI.2017.7975793

Marouli, C. (2021). Sustainability education for the future? Challenges and implications for education and pedagogy in the 21st Century. *Sustainability*, 13(5), 2901. https://doi.org/10.3390/su13052901

Marzi, I., & Reimers, A. K. (2018). Childrenˈs independent mobility: Current knowledge, future directions, and public health implications. *International Journal of Environmental Research and Public Health*, 15(11), 2441. https://doi.org/10.3390/ijerph15112441

Masthoff, J., & Vassileva, J. (2015). Tutorial on personalization for behaviour change. *Proceedings of the 20th International Conference on Intelligent User Interfaces* (IUI '15), 439–442. https://doi.org/10.1145/2678025.2716264

Mathie, R. G. Wals, & A. E. J. (2022). Whole school approaches to sustainability: Exemplary practices from around the world, *Education & Learning Sciences*, Wageningen University. https://doi.org/10.18174/572267

Meneses, G. D., & Palacio, A. B. (2005). Recycling behavior: A multidimensional approach. *Environment and Behavior,* 37(6), 837-860. https://doi.org/10.1177/0013916505276742

Meurer, J., Lawo, D., Janßen, L., & Wulf, V. (2016). Designing mobility eco-feedback for elderly users. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA '16), 921-926. https://doi.org/10.1145/2851581.2851599

Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics*, 116, 108-121. https://doi.org/10.1016/j.ecolecon.2015.04.018

Miao, F., West, M., Hyo-Jeong So, S., & Toh, Y. (2017). *Supporting teachers with mobile technology: Lessons drawn from UNESCO projects in Mexico, Nigeria, Senegal and Pakistan*. UNESCO.

Online document Mid-Pacific ICT Center (2011). 2011 Environmental scan: Information and Communications Technologies (ICT) phase three educational program input. Retrieved June 23, 2023, from https://atecentral.net/r29677/2011_environmental_scan_information_and_communications_technologies_ict_phase_three_educational_program_input

Mishra, D., & Mishra, A. (2020). Sustainability inclusion in informatics curriculum development. *Sustainability*, 12(14), 5769. https://doi.org/10.3390/su12145769

Mogren, A. Gericke, N., & Scherp, H. A. (2018). Whole school approaches to education for sustainable development: A model that links to school improvement. *Environmental Education Research*, 25(4), 508– 531. https://doi.org/10.1080/13504622.2018.1455074

Mohamed Hashim, M., Tlemsani, I., & Duncan Matthews, R. (2022). A sustainable university: Digital transformation and beyond. *Education and Information Technologies*, 27, 8961–8996. https://doi.org/10.1007/s10639-022-10968-y

Montaño, D.E., & Kasprzyk, D. (2008). Theory of reasoned action, theory of planned behavior, and the integrated behavioral model. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (4th ed., pp. 67–96). Jossey-Bass.

Mougenot, B., & Doussoulin, J. P. (2023). A bibliometric analysis of the Global Reporting Initiative (GRI): Global trends in developed and developing countries. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-02974-y

Munson, S. A., & Consolvo, S. (2012). Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. *Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare* (PervasiveHealth 2012) and Workshops, 25-32. https://doi.org/10.4108/icst.pervasivehealth.2012.248691

Namusonga, S., & Carter, M. A. (2020). Reducing and recycling waste in Zambian schools: An exploratory study. *The Journal of Solid Waste Technology and Management*, 46(3), 342-349. https://doi.org/10.5276/JSWTM/2020.342

Novo, M., & Murga-Menoyo, M. (2015). The processes of integrating sustainability in higher education curricula: A theoretical-practical experience regarding key competences and their cross-curricular incorporation into degree courses. In W. L. Filho (Eds), *Transformative Approaches to Sustainable Development at Universities* (pp. 119-135). Springer.

Nowakowski, P. (2016). The influence of residents' behaviour on waste electrical and electronic equipment collection effectiveness. *Waste Management & Research*, 34(11), 1126-1135. https://doi.org/10.1177/0734242x16669997

Nowotny, J., Dodson, J., Fiechter, S., Gür, T. M., Kennedy, B., Macyk, W., Bak, T., Sigmund, W., Yamawaki, M., & Rahman, K. A. (2018). Towards global sustainability: Education on environmentally clean energy technologies. *Renewable and Sustainable Energy Reviews*, 81(2), 2541-2551. https://doi.org/10.1016/j.rser.2017.06.060

Ntona, E., Arabatzis, G., & Kyriakopoulos, G. L. (2015). Energy saving: Views and attitudes of students in secondary education. *Renewable and Sustainable Energy Reviews*, 46, 1-15. https://doi.org/10.1016/j.rser.2015.02.033

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd Edition). McGraw-Hill.

Nwagwu, W., & Okuneye, M. (2016). Awareness and attitudes of small-scale information technology business operators in Lagos, Nigeria toward e-waste hazards. *Journal of Global Information Technology Management*, 19(4), 267-282. https://doi.org/10.1080/1097198X.2016.1246934

Ogbuanya, T. C., & Nungse, N. I. (2021). Effectiveness of energy conservation awareness package on energy conservation behaviors of off-campus students in Nigerian universities. *Energy Exploration & Exploitation*, 39, 1415 – 1428. https://doi.org/10.1177/0144598720975133

Oinas-Kukkonen, H., & Harjumaa, M. (2008). A systematic framework for designing and evaluating persuasive systems. In H. Oinas-Kukkonen, P. Hasle, M. Harjumaa, K. Segerståhl, & P. Øhrstrøm (Eds.) *Persuasive Technology*. PERSUASIVE 2008. Lecture Notes in Computer Science (vol. 5033, pp. 164–176). Springer. https://doi.org/10.1007/978-3-540-68504-3_15

Okokpujie, I. P., Fayomi, O. S. I., & Oyedepo, S. O. (2019). The role of mechanical engineers in achieving sustainable development goals. *Procedia Manufacturing*, 35, 782-788. https://doi.org/10.1016/j.promfg.2019.06.023

Okoye, A., & Odoh, C. (2014). Assessment of the level of awareness of e-waste management and concern for the environment amongst the populace in Onitsha, Southeastern Nigeria. *Journal of Environmental Protection*, 5(2), 120-134. https://doi.org/10.4236/jep.2014.52016

Otto, S., & Pensini, P. (2017). Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. *Global Environmental Change*, 47, 88-94. https://doi.org/10.1016/j.gloenvcha.2017.09.009

Owens, T. L. (2017). Higher education in the sustainable development goals framework. *European Journal of Education*, 52(4), 414-420. https://doi.org/10.1111/ejed.12237

Online document Definition of mobility noun from the Oxford Advanced Learner's Dictionary. Retrieved August 7, 2023, from https://www.oxfordlearnersdictionaries.com/definition/english/mobility

Özkan, B., & Mishra, A. (2015). A curriculum on sustainable information communication technology. *Problems of Sustainable Development*, 10(2), 95–101.

Pacis, M., & Vanwynsberghe, R. (2020). Key sustainability competencies for education for sustainability: Creating a living, learning and adaptive tool for widespread use. *International Journal of Sustainability in Higher Education*, 21(3), pp. 575-592. https://doi.org/10.1108/IJSHE-12-2018-0234

Palau, R., & Mogas, J. (2019). Systematic literature review for a characterization of the smart learning environments. In A. M. Cruz, & A. I. Aguilar (Eds.), *Propuestas multidisciplinares de innovación e intervención educativa*, (pp. 55–71). Universidad Internacional de Valencia.

Papadakis, S., & Kalogiannakis, M. (2017). Mobile educational applications for children: What educators and parents need to know. *International Journal of Mobile Learning and Organisation*, 11(3), 256–277. https://doi.org/10.1504/IJMLO.2017.085338

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Educational Technology & Society*, 12(3), 150–162.

Paul, J. A., Baker, H. M., & Cochran, J. D. (2012). Effect of online social networking on student academic performance. *Computers in Human Behavior*, 28(6), 2117–2127. http://dx.doi.org/10.1016/j.chb.2012.06.016

Paul, P. K., Bhuimali, A., Aithal, P. S., Tiwary, K. S., & Sinha, R. R. (2020). Environmental informatics: Educational opportunities at bachelors level – international context and Indian potentialities. *International Journal of Applied Engineering and Management Letters*, 4(1), 243-256.

Pender, B., Currie, G., Delbosc, A., & Shiwakoti, N. (2014). Social Media Use during Unplanned Transit Network Disruptions: A Review of Literature. *Transport Reviews*, 34(4), 501–521. https://doi.org/10.1080/01441647.2014.915442

Perra, C. (2016). A Framework for the Development of Sustainable Urban Mobility Applications. *Proceedings of the 24th Telecommunications Forum* (TELFOR 2016), 1-4. https://doi.org/10.1109/TELFOR.2016.7818788

Philpott, C., & Oates, C. (2017). Professional learning communities as drivers of educational change: The case of learning rounds. *Journal of Educational Change*, 18, 209-234. https://doi.org/10.1007/s10833-016-9278-4

Piras, F., Sottile, E., Calli, D., & Meloni, I. (2018). Automatic data collection for detecting travel behavior: the IPET platform. *Procedia Computer Science*, 134, 421-426. https://doi.org/10.1016/j.procs.2018.07.189

Pishva, D., & Nishantha, G. G. D. (2008). Smart classrooms for distance education and their adoption to multiple classroom architecture. *Journal of Networks*, 3(5), 54–64. https://doi.org/10.4304/jnw.3.5.54-64

Pouezevara, S., Mekhael, S. & Darcy, N. (2014). Planning and evaluating ICT in education programs using the four dimensions of sustainability: A program evaluation from Egypt. *International Journal of Education and Development using ICT*, 10(2), 120-141

Prochaska, J. O., & DiClemente, C. C. (1982). Transtheoretical therapy: Toward a more integrative model of change. *Psychotherapy: Theory, Research & Practice*, 19(3), 276–288. https://doi.org/10.1037/h0088437

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, 14, 681–695. https://doi.org/10.1007/s11625-018-0627-5

Rada, E. C., Bresciani, C., Girelli, E., Ragazzi, M., Schiavon, M., & Torretta, V. (2016). Analysis and measures to improve waste management in schools. *Sustainability*, 8(9), 840. https://doi.org/10.3390/su8090840

Raghavan, B., & Pargman, D. (2017). Means and ends in human-computer interaction: Sustainability through disintermediation. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 786–796. https://doi.org/10.1145/3025453.3025542

Rahman, N. (2022). Existing green computing techniques: An insight. In: P. Agarwal, M. Mittal, J. Ahmed, & S. M. Idrees (Eds), *Smart technologies for energy and environmental sustainability* (pp. 87-95). Springer.

Ramzan, S., Liu, C., Munir, H., & Xu, Y. (2019). Assessing young consumers' awareness and participation in sustainable e-waste management practices: A survey study in Northwest China. *Environmental Science and Pollution Research*, 26, 20003-20013. https://doi.org/10.1007/s11356-019-05310-y

Ranganathan P. (2019). Understanding research study designs. *Indian journal of critical care medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine*, 23(4), 305–307. https://doi.org/10.5005/jp-journals-10071-23314

Rau, H., Goggins, G., & Fahy, F. (2018). From invisibility to impact: Recognising the scientific and societal relevance of interdisciplinary sustainability research. *Research Policy*, 47(1), 266-276. https://doi.org/10.1016/j.respol.2017.11.005

Reitberger, W., Ploderer, B., Obermair, C., & Tscheligi, M. (2007). The PerCues framework and its application for sustainable mobility. In Y. de Kort, W. IJsselsteijn, C. Midden, B. Eggen, & B. J. Fogg (Eds)*, Persuasive Technology*. PERSUASIVE 2007. Lecture Notes in Computer Science (vol. 4744, pp. 92–95). Springer. https://doi.org/10.1007/978-3-540-77006-0_11

Ren, X., Silpasuwanchai, C., & Cahill, J. (2019). Human-engaged computing: The future of human–computer interaction. *CCF Transactions on Pervasive Computing and Interaction*, 1, 47–68. https://doi.org/10.1007/s42486-019-00007-0

Richard, K. R. (2018). Level of awareness of energy measures of electricity users at universities in Kenya. *International Journal of Engineering and Computer Science*, 7(4), 23875-23882. https://ijecs.in/index.php/ijecs/article/view/4018

Rieckmann, M. (2018). Learning to transform the world: Key competencies. In A. Leicht, J. Heiss, & W. J. Byun (Eds), *Education for sustainable development. Issues and trends in education for sustainable development* (pp. 39–59). UNESCO.

Rodgers, M. D. (2021). Pathways to eliminate carbon emissions via renewable energy investments at higher education institutions. *The Electricity Journal*, 34(5), 106952. https://doi.org/10.1016/j.tej.2021.106952

Rodríguez, P., Nussbaum, M., & Dombrovskaia, L. (2012). ICT for education: A conceptual framework for the sustainable adoption of technology-enhanced learning environments in schools. *Technology, Pedagogy and Education*, 21(3), 291-315. https://doi.org/10.1080/1475939X.2012.720415

Rousta, K., Bolton, K., Lundin, M., & Dahlén, L. (2015). Quantitative assessment of distance to collection point and improved sorting information on source separation of household waste. *Waste Management*, 40, 22-30. https://doi.org/10.1016/j.wasman.2015.03.005

Ruchter, M., Klar, B., & Geiger, W. (2010). Comparing the effects of mobile computers and traditional approaches in environmental education, *Computers & Education*, 54(4), 1054-1067. https://doi.org/10.1016/j.compedu.2009.10.010

Ryan, A., & Tilbury, D. (2013). Uncharted waters: Voyages for education for sustainable development in the higher education curriculum. *Curriculum Journal*, 24(2), 272-294. https://doi.org/10.1080/09585176.2013.779287

Sadeghian, S., Wintersberger, P., Laschke, M., & Hassenzahl, M. (2022). Designing sustainable mobility: Understanding users' behavior. *Proceedings of the 14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (AutomotiveUI '22), 17–20. https://doi.org/10.1145/3543174.3546833

Saini, M. K., & Goel, N. (2019). How smart are smart classrooms? A review of smart classroom technologies. *ACM Computing Surveys*, 52(6), 1-28. https://doi.org/10.1145/3365757

Sammalisto, K., & Lindhqvist, T. (2008). Integration of sustainability in higher education: A study with international perspectives. *Innovative Higher Education*, 32, 221–233. https://doi.org/10.1007/s10755-007-9052-x

Samuel, M., & Lesley, S. (2007). Computing and sustainability. *Proceedings of the 20th Annual Conference of the National Advisory Committee on Computing Qualifications* (NACCQ 2007).

Sauvé, L. (2017). Education as life. In B. Jickling, & S. Sterling (Eds.), *Post-sustainability and environmental education: Remaking education for the future,* pp. 111–124. Macmillan.

Schoeppe, S., Duncan, M.J., Badland, H., Oliver, M., &Curtis, C. (2013). Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: A systematic review. *Journal of Science and Medicine in Sport*, 16(4), 312–319. https://doi.org/10.1016/j.jsams.2012.11.001

Schrammel, J., Prost, S., Mattheiss, E., Bothos, E., & Tscheligi, M. (2015). Using individual and collaborative challenges in behavior change support systems: Findings from a two-month field trial of a trip planner application. In T. MacTavish, & S. Basapur (Eds.), *Persuasive Technology*. PERSUASIVE 2015. Lecture Notes in Computer Science (vol. 9072, pp. 160–171). Springer. https://doi.org/10.1007/978-3-319-20306-5_15

Online document SDSN Australia, New Zealand & Pacific, (2017). *Getting started with the SDGs in universities*. Retrieved August 16, 2023, from https://resources.unsdsn.org/getting-started-with-the-sdgs-in-universities

Seralidou, E., & Douligeris, C. (2019). Learning with the AppInventor programming software through the use of structured educational scenarios in secondary education in Greece. *Education and Information Technologies*, 24, 2243–2281. https://doi.org/10.1007/s10639-019-09866-7

Seralidou, E., Douligeris, C. & Gralista, C. (2019). EduApp: A collaborative application for mobile devices to support the educational process in Greek secondary education. *Proceedings of the 10th IEEE Global Engineering Education Conference* (EDUCON 2019), 189-198. https://doi.org/10.1109/EDUCON.2019.8725175

Shi, Y., Xie, W., Xu, G., Shi, R., Chen, E., Mao, Y., & Liu, F. (2002). The smart classroom: Merging technologies for seamless tele-education. *Proceedings of the 4th International Conference on Multimodal Interfaces (ICMI 2002),* 429–434. IEEE CS Press.

Shyam, G. K., Manvi, S. S., & Bharti, P. (2017). Smart waste management using Internet-of-Things (IoT). *Proceedings of the 2nd International Conference on Computing and Communications Technologies* (ICCCT 2017), 199-203. https://doi.org/10.1109/ICCCT2.2017.7972276

Simon, B., Haghirian, P., & Schlegelmilch, B. B. (2003). Enriching global marketing education with virtual classrooms an effectiveness study. *Marketing Education Review*, 13(3), 27-39. https://doi.org/10.1080/10528008.2003.11488838

Sipos, Y., Battisti, B., & Grimm, K. (2008). Achieving transformative sustainability learning: Engaging head, hands and heart. *International Journal of Sustainability in Higher Education*, 9, 68–86. http://dx.doi.org/10.1108/14676370810842193

Siuhi, S., & Mwakalonge, J. (2016). Opportunities and challenges of smart mobile applications in transportation. *Journal of Traffic and Transportation Engineering*, 3(6), 582-592. https://doi.org/10.1016/j.jtte.2016.11.001

Skinner, B. F. (1953). *Science and human behavior*. Macmillan.

So, W. W. M., Lee, J. C. K., & Chow, C. F. (2019). Environmental sustainability and education for waste management. In W. W. M. So, C. F. Chow, & J. C. K. Lee, (Eds.), *Environmental Sustainability and Education for Waste Management* (pp. 1-11). Springer.

Söderberg, A., Winslott-Hiselius, L., & Adell, E. (2018). Promoting sustainable travel behaviour through the use of smartphone applications: A review and development of a conceptual model. *Travel Behaviour and Society*, 11, 52-61. https://doi.org/10.1016/j.tbs.2017.12.008

Soetrisno, F. N., & Delgado-Saborita, J. M. (2020). Chronic exposure to heavy metals from informal e-waste recycling plants and children's attention, executive function and academic performance. *Science of The Total Environment*, vol. 717, 2020. https://doi.org/10.1016/j.scitotenv.2020.137099

Online document SOS International (2021). *Students, sustainability and education*. Retrieved August 16, 2023, from https://sos.earth/wp-content/uploads/2021/02/SOS-International-Sustainability-in-Education-International-Survey-Report_FINAL.pdf

Steinfeld, J. I., & Mino, T. (2009). Education for sustainable development: The challenge of trans-disciplinarity. *Sustainability Science*, 4, 1-2. https://doi.org/10.1007/s11625-009-0072-6

Stibe, A., & Oinas-Kukkonen, H. (2014). Using social influence for motivating customers to generate and share feedback. In A. Spagnolli, L. Chittaro, & L. Gamberini (Eds.), *Persuasive Technology*. PERSUASIVE 2014. Lecture Notes in Computer Science (vol. 8462, pp. 224–235). Springer. https://doi.org/10.1007/978-3-319-07127-5_19

Stibe, A., & Larson, K. (2016). Persuasive cities for sustainable wellbeing: Quantified communities. In M. Younas, I. Awan, N. Kryvinska, C. Strauss, & D. Thanh (Eds.), *Mobile web and intelligent information systems*. MobiWIS 2016. Lecture Notes in Computer Science (vol. 9847, pp. 271–282). Springer. https://doi.org/10.1007/978-3-319-44215-0_22

Stough, T., Ceulemans, K., Lambrechts, W., & Cappuyns, V. (2018). Assessing sustainability in higher education curricula: A critical reflection on validity issues. *Journal of Cleaner Production*, 172, 4456–4466. https://doi.org/10.1016/j.jclepro.2017.02.017

Sunio, V., & Schmöcker, J. D. (2017). Can we promote sustainable travel behavior through mobile apps? Evaluation and review of evidence. *International Journal of Sustainable Transportation*, 11(8), 553-566. https://doi.org/10.1080/15568318.2017.1300716

Swaim, J. A., Maloni, M. J., Napshin, S. A., & Henley, A. B. (2014). Influences on student intention and behavior toward environmental sustainability. *Journal of Business Ethics*, 124(3), 465–484. http://www.jstor.org/stable/24033283

Tafesse, W. (2022). Social networking sites use and college students' academic performance: Testing for an inverted U-shaped relationship using automated mobile app usage data. *International Journal of Educational Technology in Higher Education*, 19, 16. https://doi.org/10.1186/s41239-022-00322-0

Taghikhah, F., Voinov, A., & Shukla, N. (2019). Extending the supply chain to address sustainability. *Journal of Cleaner Production*, 229, 652-666. https://doi.org/10.1016/j.jclepro.2019.05.051

Tang, W. Z., & Sillanpää, M. (2018). *Sustainable Environmental Engineering*. Wiley.

Teehan, T., & Kandlikar, M. (2013). Comparing embodied greenhouse gas emissions of modern computing and electronics products. *Environmental Science & Technology*, 47 (9), 3997-4003. https://doi.org/10.1021/es303012r

Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. *American Journal of Preventive Medicine and Public Health*, 28(3), 267–273. https://doi.org/10.1016/j.amepre.2004.12.003

Online document The CONNECT project, (September 2010). Sustainable mobility campaigns for young people. Retrieved August 16, 2023, from https://www.eltis.org/sites/default/files/trainingmaterials/connect_booklet.pdf

Tilbury, D., & Wortman, D. (2004). *Engaging people in sustainability, commission on education and communication*. IUCN, Gland, Switzerland and Cambridge, UK.

Tilbury, D. (2016). Student engagement and leadership in higher education for sustainability. In M. Barth, G. Michelsen, M. Rieckmann, & I. Thomas (Eds.), *Routledge Handbook of Higher Education for Sustainable Development* (pp. 241-260), Routledge.

Online document Tilbury, D., & Galvin, C. (2022). *A whole school approach to learning for environmental sustainability*. Retrieved September 19, 2023, from https://education.ec.europa.eu/sites/default/files/2022-02/input-paper-whole-school-approach-sustainability.pdf .

Tissenbaum, M., & Slotta, J. D. (2009). A new framework for smart classroom research: Co-designing curriculum, research and technology. *Proceedings of the 8th International Conference on Computer Supported Collaborative Learning* (CSCLˈ09), vol. 2. https://doi.dx.org/10.22318/cscl2009.2.91

Thøgersen, J. (2003). Monetary incentives and recycling: Behavioural and psychological reactions to a performance-dependent garbage fee. *Journal of Consumer Policy*, 26, 197–228. https://doi.org/10.1023/A:1023633320485

Tilbury, D. (2016). Student engagement and leadership in higher education for sustainability. In M. Barth, G. Michelsen, & I. T. Rieckmann (Eds), *Handbook of Higher Education for Sustainable Development* (pp. 241-260). Routledge.

Tindell, D. R., & Bohlander, R.W. (2012). The use and abuse of cell phones and text messaging in the classroom: A survey of college students. *College Teaching*, 60(1), 1-9. https://doi.org/10.1080/87567555.2011.604802

UNESCO (2005). *Guidelines and recommendations for reorienting teacher education to address sustainability*. UNESCO.

UNESCO (2012). *Education for sustainable development: Sourcebook. Education for sustainable development in action. Learning & Training Tools*. UNESCO.

Online document UNESCO, (2014). *UNESCO roadmap for implementing the global action programme on education for sustainable development*. Retrieved September 23, 2023, from https://unesdoc.unesco.org/home

UNESCO (2017). *Education for sustainable development goals learning objectives*. UNESCO.

UNESCO (2018). *Issues and trends in education for sustainable development*. UNESCO.

UNESCO (2020). *Education for sustainable development: A roadmap*. UNESCO.

Online document UN, (1987). *Report of the world commission on environment and development: Our common* future. Retrieved August 15, 2023, from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Online document UN, (2015). *Transforming our world: The 2030 agenda for sustainable development.* Retrieved August 15, 2023, from https://sdgs.un.org/2030agenda

Online document UN DESA, (2018). *2018 Revision of world urbanization prospects.* Retrieved August 15, 2023, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

Online document UNEP, (2022, January 28). *Annual report 2021.* Retrieved August 17, 2023, from https://www.unep.org/resources/annual-report-2021

Uskov, V. L., Bakken, J. P., Pandey, A. (2015). The ontology of next generation smart classrooms. In V. L., Uskov, R. Howlett, & L. Jain (Eds.), *Smart education and smart e-learning. Smart innovation, systems and technologies* (vol. 41). Springer.

Utama, Y. J., Ambariyanto, A., Zainuri, M., Darsono, D., Setyono, B., Widowati, & Putro, S. P. (2018). Sustainable development goals as the basis of university management towards global competitiveness. *Journal of Physics: Conference Series*, 1025(1). https://dx.doi.org/10.1088/1742-6596/1025/1/012094

Uzunboylu, H., Cavus, N., & Ercag, E. (2009). Using mobile learning to increase environmental awareness, *Computers & Education*, 52(2), 381-389. https://doi.org/10.1016/j.compedu.2008.09.008

Vahdat-Nejad, H., Ramazani, A., Mohammadi, T., & Mansoor, W. (2016). A survey on context-aware vehicular network applications. *Vehicular Communications*, 3, 43–57. https://doi.org/10.1016/j.vehcom.2016.01.002

Vakilinia, S. (2018). Energy efficient temporal load aware resource allocation in cloud computing data centers. *Journal of Cloud Computing*, 7(2). https://doi.org/10.1186/s13677-017-0103-2

Valls-Val, K., & Bovea, M. D. (2021). Carbon footprint in higher education institutions: A literature review and prospects for future research. *Clean Technologies and Environmental Policy*, 23, 2523–2542. https://doi.org/10.1007/s10098-021-02180-2

Van't Land, H., & Herzog, F. (2017). *Higher education paving the way to sustainable development: A global perspective*. International Association of Universities.

Venters, C. C., Capilla, R., Betz, S., Penzenstadler, B., Crick, T., Crouch, S., Nakagawa, E. Y., Becker, C., & Carrillo, C. (2018). Software sustainability: Research and practice from a software architecture viewpoint. *Journal of Systems and Software*, 138, 174-188. https://doi.org/10.1016/j.jss.2017.12.026

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view, *MIS Quarterly*, 27(3), 425–478. https://doi.org/10.2307/30036540

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology, *MIS Quarterly*, 36(1), 157–178. https://doi.org/10.2307/41410412

Verma, A., Singh, A., Lughofer, E., Cheng, X., & Abualsaud, K. (2021). Multilayered-quality education ecosystem (MQEE): An intelligent education modal for sustainable quality education. *Journal of Computing in Higher Education*, 33, 551–579. https://doi.org/10.1007/s12528-021-09291-1

Vlassenroot, V., Gillis, D., Bellens, R., & Gautama, S. (2015). The use of smartphone applications in the collection of travel behaviour data. *International Journal of Intelligent Transportation Systems Research*, 13(1), 17-27. https://doi.org/10.1007/s13177-013-0076-6

Voelkel, R. H., & Chrispeels, J. H. (2017). Understanding the link between professional learning communities and teacher collective efficacy. *School Effectiveness and School Improvement*, 28(4), 505-526. https://doi.org/10.1080/09243453.2017.1299015

Wadha, A., & Watkins, M. (2018). An investigation into domestic energy consumption behaviour and public awareness of renewable energy in Qatar. *Sustainable Cities and Society*, 41, 639-646. https://doi.org/10.1016/j.scs.2018.06.024

Wahyudin, D. (2018). Peace education curriculum in the context of Education Sustainable Development (ESD). *Journal of Sustainable Development Education and Research*, 2(1), 21-32. https://doi.org/10.17509/jsder.v2i1.12354

Wamsler, C. (2020). Education for sustainability: Fostering a more conscious society and transformation towards sustainability. *International Journal of Sustainability in Higher Education*, 21(1), 112-130. https://doi.org/10.1108/IJSHE-04-2019-0152

Wang, C., Qin, J., Qu, C., Ran, X., Liu, C., & Chen, B. (2021). A smart municipal waste management system based on deep-learning and Internet of Things. *Waste Management*, 135, 20-29. https://doi.org/10.1016/j.wasman.2021.08.028

Wang, H., & Wang, S. (2010). User acceptance of mobile Internet based on the unified theory of acceptance and use of technology: Investigating the determinants and gender differences, *Social Behavior & Personality: An International Journal*, 38(3), 415–426. https://doi.org/10.2224/sbp.2010.38.3.415

Wang, Y., Sommier, M., & Vasques, A. (2022). Sustainability education at higher education institutions: Pedagogies and students' competences. *International Journal of Sustainability in Higher Education*, 23(8), 174-193. https://doi.org/10.1108/IJSHE-11-2021-0465

Wang, Z., Guo, D., Wang, X., Zhang, B., & Wang, B. (2018). How does information publicity influence residents' behaviour intentions around e-waste recycling? *Resources, Conservation & Recycling Advances,* 133, 1-9. https://doi.org/10.1016/j.resconrec.2018.01.014

Warren, I., Meads, A., Whittaker, R., Dobson, R., & Ameratunga, S. (2018). Behavior change for youth drivers: Design and development of a smartphone-based app (BackPocketDriver). *JMIR Formative Research*, 2(2), e25. https://doi.org/10.2196/formative.9660

Waygood, E.O.D., & Kitamura, R. (2009). Children in a rail-based developed area of Japan: Travel patterns, independence and exercise. *Transportation Research Record: Journal of the Transportation Research Board*, 2125(1), 36–43. https://doi.org/10.3141/2125-05

Weiser, P., Bucher, D., Cellina, F., & De Luca, V. A. (2015). Taxonomy of motivational affordances for meaningful gamified and persuasive technologies. In *Proceedings of the EnviroInfo and ICT for Sustainability 2015*. https://doi.org/10.2991/ict4s-env-15.2015.31

Weiss, M., & Barth, M. (2019). Global research landscape of sustainability curricula implementation in higher education. *International Journal of Sustainability in Higher Education*, 20(4), 570-589. https://doi.org/10.1108/IJSHE-10-2018-0190

Welch, T. F., & Widita, A. (2019). Big data in public transportation: A review of sources and methods. *Transport Reviews*, 39(6), 795-818. https://doi.org/10.1080/01441647.2019.1616849

Weng, F., Yang, R. J., Ho, H. J. & Su, H. M. (2018). A TAM-based study of the attitude towards use intention of multimedia among school teachers. *Applied System Innovation*, 1(3), 36. https://doi.org/10.3390/asi1030036

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6, 203–218. https://doi.org/10.1007/s11625-011-0132-6

Wissinger, J. E., Visa, A., Saha, B. B., Matlin, S. A., Mahaffy, P. G., Kümmerer, K., & Cornell, S. (2021). Integrating sustainability into learning in chemistry. *Journal of Chemical Education*, 98(4), 1061-1063. https://doi.org/10.1021/acs.jchemed.1c00284

Wunsch, M., Stibe, A., Millonig, A., Seer, S., Dai, C., Schechtner, K., & Chin R. C. C. (2015). What makes you bike? Exploring persuasive strategies to encourage low-energy mobility. In T. MacTavish, & S. Basapur (Eds.), *Persuasive Technology*. PERSUASIVE 2015. Lecture Notes in Computer Science (vol. 9072, pp. 53–64). Springer. https://doi.org/10.1007/978-3-319-20306-5_5

Yadav, R., & Pathak, G. S. (2016). Young consumersˈ intention towards buying green products in a developing nation: Extending the theory of planned behavior. *Journal of Cleaner Production*, 135, 732-739. https://doi.org/10.1016/j.jclepro.2016.06.120

Yushkova, E., & Feng, Y. (2017). What explains the intention to bring mobile phones for recycling? A study on university students in China and Germany. *International Economics and Economic Policy*, 14(3), 501-516. https://doi.org/10.1007/s10368-017-0383-5

Žalėnienė, I., & Pereira, P. (2021). Higher education for sustainability: A global perspective. *Geography and Sustainability*, 2(2), 99-106. https://doi.org/10.1016/j.geosus.2021.05.001

Zanellato, G., & Tiron-Tudor, A. (2021). Toward a sustainable university: Babes-Bolyai University goes green. *Administrative Sciences*, 11(4), 133. https://doi.org/10.3390/admsci11040133

Zeng, X., Yang, C., Chiang, J. F., & Li, J. (2017). Innovating e-waste management: From macroscopic to microscopic scales. *Science of the Total Environment*, 575, 1–5. https://doi.org/10.1016/j.scitotenv.2016.09.078

Zhang, L., Qu, J., Sheng, H., Yang, J., Wu, H., & Yuan, Z. (2019). Urban mining potentials of university: In-use and hibernating stocks of personal electronics and studentsˈ disposal behaviors. *Resources, Conservation and Recycling*, 143, 210-217. https://doi.org/10.1016/j.resconrec.2019.01.007

Zhang, X., Shinozuka, M., Tanaka, Y., Kanamori, Y., & Masui, T. (2022). How ICT can contribute to realize a sustainable society in the future: A CGE approach. *Environment, Development and Sustainability*, 24, 5614–5640. https://doi.org/10.1007/s10668-021-01674-9

Zhao, J., & Baird, T. (2014). Nudgingˈ active travel: A framework for behavioral interventions using mobile technology. *Proceedings of the Transportation Research Board 93rd Annual Meeting*. https://trid.trb.org/view/1286022

Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments*, 3(4). https://doi.org/10.1186/s40561-016-0026-2

Ziemba, E. (2019). The contribution of ICT adoption to the sustainable information society. Journal of *Computer Information Systems*, 59(2), 116-126. https://doi.org/10.1080/08874417.2017.1312635

Appendix A – The research Outputs of the PhD Thesis

Book chapter

[1] Angelaki, M. E., Karvounidis, T., & Douligeris, C. (2022). Towards a smart classroom enabled sustainability education: A conceptual model. In M.E. Auer, & T. Tsiatsos (Eds.), *New realities, mobile systems and applications*. IMCL 2021. Lecture Notes in Networks and Systems (vol. 411, pp. 497–509). Springer. https://doi.org/10.1007/978-3-030-96296-8_45

Publications in peer-reviewed scientific journals indexed by Web of Science Master Journal List by Clarivate

[1] Angelaki M. E., Karvounidis, T., & Douligeris, C. (2020). Pupils' perceptions and suggestions for the improvement of distance education in Greece. *International Journal Of Education And Information Technologies*, 14, 205-213. https://doi.org/10.46300/9109.2020.14.22

[2] Angelaki M. E., Karvounidis, T., & Douligeris, C. (2021). ESTA: Educating adolescents in sustainable travel urban behavior through mobile applications using motivational features. *Computation,* 9(2), 15. https://doi.org/10.3390/computation9020015

[3] Angelaki, M. E., Karvounidis, T., & Douligeris, C. (2023). Applying a persuasive framework for adopting a sustainable mobile travelling attitude. *International Journal of Mobile Communications*, 22(4), 476–510. https://doi.org/10.1504/IJMC.2023.10046510

[4] Angelaki M. E., Bersimis F., Karvounidis T., & Douligeris C. (2024). Exploring the awareness outcomes of educating ICT students on the environmental implications of e-waste recycling and energy consumption in data centers. *IEEE Transactions on Education,* 67(1), 143 – 152. https://doi.org/10.1109/TE.2023.3330913

[5] Angelaki, M. E., Bersimis, F., Karvounidis, T., & Douligeris, C. (2024). Towards more sustainable higher education institutions: Implementing the sustainable development goals and embedding sustainability into the information and computer technology curricula. *Education and Information Technologies*, 29, 5079–5113. https://doi.org/10.1007/s10639-023-12025-8

Publications in peer-reviewed proceedings of international conferences

[1] Angelaki, M. E., Karvounidis, T., & Douligeris, C. (2020). A Theoretical persuasive framework for supporting and evolving an individual's sustainable mobile traveling attitude. *Proceedings of the 11th International Conference on Information, Intelligence, Systems and Applications* (IISA 2020), 1-4. https://doi.org/10.1109/IISA50023.2020.9284408

[2] Angelaki M. E., Karvounidis T., & Douligeris, C. (2020). Educating adolescents in sustainable travel urban behavior through mobile applications using motivational features. *Proceedings of the 5th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference* (SEEDA-CECNSM 2020), 1-6. https://doi.org/10.1109/SEEDA-CECNSM49515.2020.9221777

[3] Angelaki M. E., Karvounidis T., & Douligeris, C. (2020). Mobile applications and projects for sustainable urban public transportation: A selective review. *Proceedings of the 24th Pan-Hellenic Conference on Informatics* (PCI 2020), 156–161. https://doi.org/10.1145/3437120.3437297

[4] Angelaki M. E., Karvounidis T., & Douligeris, C. (2022). Exploring pupils' knowledge and awareness of e-waste recycling in Greece. *Proceedings of the 7th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference* (SEEDA-CECNSM 2022), 1-7. https://doi.org/10.1109/SEEDA-CECNSM57760.2022.9932919

[5] Angelaki M. E., Karvounidis T., & Douligeris, C. (2023). Sustainability-oriented schools in Greece: Analyzing pupils' opinions and perceptions about sustainability and redesign computer science curricula towards green informatics. *Proceedings of the 14th IEEE Global Engineering Education Conference* (EDUCON 2023), 1-8. https://doi.org/10.1109/EDUCON54358.2023.10125238

Appendix B – Secondary Education: Questionnaire for the Use of Smartphones and Mobile Transit Applications

A. Demographics information

A.1. Gender: ☐ Boy ☐ Girl

A.2. Age: ……………………………………….

B. Daily travel habits

B.1. How many routes do you conduct per day? (The route from a point A to a point B and back from B to A are two routes)

☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ More than 6

B.2. How many minutes does your daily commute take in total (to and from) to	
school	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
foreign languages classes	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
tutorial centers	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
sports	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
arts (music, dance, …)	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
interest/hobbies	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
outdoor play	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20
visiting friends	☐ <5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ >20

B.3. What is your primary transport mode?

☐ Metro/Tram
☐ Walking/Cycling
☐ Bus
☐ Car/Taxi
☐ Motorcycle/Scooter
☐ Other (please note)

C. Use of smartphones and mobile applications

C.1. Do you have (please tick all that apply)

☐ A smartphone
☐ A tablet
☐ A personal computer or laptop
☐ None of the above

C.2. If you have a mobile/tablet, what kind of applications do you use the most? (please tick up to three)

☐ Gaming
☐ Sport/Health/Fitness
☐ Travelling and maps
☐ Social networking
☐ Entertainment (Music, Dance, etc.)
☐ Searching Tools
☐ Messaging
☐ Weather Forecasting
☐ News
☐ Other (please note)

C.3. Would you use a mobile application that would help you adopt a friendlier and more environmentally sustainable behavior in your daily routes?

- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

C.4. What features would you like a mobile transit application to have in order to use it every day? (please tick all that apply)

- ☐ Suggest travel options to other users
- ☐ Share/post real-time information about traffic, disruptive events and transport choices
- ☐ Set reminders/Get notifications about a scheduled trip
- ☐ Give feedback on travel options provided
- ☐ Collect points/Get rewards, i.e., free public transportation tickets
- ☐ Learn more on the topic of sustainability with relevant information, calories burned, carbon footprint calculation, etc.
- ☐ Set a Journey planner
- ☐ Share/post your itineraries with other users
- ☐ Play Eco-Games
- ☐ Other (please note)

C.5. Are you interested in or prepared to change your travel behavior just for the sake of the environment?

- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

C.6. Do you intend to use a mobile transit application in order to obtain a more sustainable travel behavior?

- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

C.7. How concerned are you about protecting your privacy and personal data when using a mobile application?

- ☐ High
- ☐ Moderate
- ☐ Low
- ☐ None

C.8. What are your primary concerns with the use of a mobile application concerning personal data and privacy? (please tick all that apply)

- ☐ The application must be hack-proof
- ☐ The personal data needs to be protected when stored through effective encryption
- ☐ The users must be able to choose which data they want to share with others or with third-party services
- ☐ The mobile application must collect only those data that are strictly necessary to perform the lawful functionalities as identified and planned
- ☐ Other (please note)

Appendix C Secondary Education: Evaluation Questionnaire of the Six Simulation Screens of a Mobile Transit Application Named ESTA

A. Demographics information

A.1. Gender:	☐ Boy	☐ Girl

A.2. Age: ………………………………………

B. The ESTA Welcome Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
B.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.3. What other features would you like to see in an upcoming redesign? Please specify	

C. The ESTA Home Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
C.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.3. What other features would you like to see in an upcoming redesign? Please specify	

D. The ESTA My Preferences Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
D.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.3. What other features would you like to see in an upcoming redesign? Please specify	

E. The ESTA My EcoGoals Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
E.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.3. What other features would you like to see in an upcoming redesign? Please specify	

F. The ESTA Plan a Trip Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
F.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.3. What other features would you like to see in an upcoming redesign? Please specify	

G. The ESTA My Past Trips Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
G.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
G.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
G.3. What other features would you like to see in an upcoming redesign? Please specify	

H. Overall evaluation of the ESTA simulation Screens

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
H.1. I can use ESTA without written instructions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.2. I think that I would use ESTA frequently	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.3. I am highly motivated to use ESTA	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.4. The content that appeared in ESTA is appropriate for a pupil	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.5. ESTA's use is relevant to the pupils' needs for the adoption of sustainable travel behavior	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.6. I found ESTA easy to use	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.7. I can use ESTA without written instructions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.8. ESTA has functionality that is easy to understand	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.9. ESTA works the way I would want it to work	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

H.10. Would you recommend ESTA to a friend?

- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

H.11. If you intend to use ESTA upon its implementation, please write the reasons:

Appendix D – Privacy Policy for the Epma_App

Privacy Policy

Last updated: 03 September 2023

This Privacy Policy describes Our policies and procedures on the collection, use and disclosure of Your information when You use the Service and tells You about Your privacy rights and how the law protects You. We use Your Personal data to provide and improve the Service. By using the Service, You agree to the collection and use of information in accordance with this Privacy Policy.

Interpretation and Definitions

Interpretation

The words of which the initial letter is capitalized have meanings defined under the following conditions. The following definitions shall have the same meaning regardless of whether they appear singular or plural.

Definitions

For the purposes of this Privacy Policy:

- **Account** means a unique account created for You to access our Service or parts of our Service.
- **Affiliate** means an entity that controls, is controlled by or is under common control with a party, where "control" means ownership of 50% or more of the shares, equity interest or other securities entitled to vote for the election of directors or other managing authority.
- **Application** means the software program provided by the Company downloaded by You on any electronic device, named Epma_App.
- **Company** (referred to as either "the Company", "We", "Us", or "Our" in this Agreement) refers to Epma_App.
- **Country** refers to Greece.
- **Device** means any device that can access the Service, such as a computer, a cellphone or a digital tablet.
- **Personal Data** is any information that relates to an identified or identifiable individual.
- **Service** refers to the Application.
- **Service Provider** means any natural or legal person who processes the data on behalf of the Company. It refers to third-party companies or individuals employed by the Company to facilitate the Service, to provide the Service on behalf of the Company, to perform services related to the Service or to assist the Company in analyzing how the Service is used.
- **Third-party Social Media Service** refers to any website or any social network website through which a User can log in or create an account to use the Service.
- **Usage Data** refers to data collected automatically, either generated by the use of the Service or from the Service infrastructure itself (for example, the duration of a page visit).
- **You** means the individual accessing or using the Service, or the Company, or other legal entity on behalf of which such individual is accessing or using the Service, as applicable.

Collecting and Using Your Personal Data

Types of Data Collected

Personal Data

While using Our Service, We may ask You to provide Us with certain personally identifiable information that can be used to contact or identify You. Personally identifiable information may include, but is not limited to:

- Email address
- First name and last name
- Usage Data

Usage Data

Usage Data is collected automatically when using the Service.

Usage Data may include information such as Your Device's Internet Protocol address (e.g., I.P. address), browser type, browser version, the pages of our Service that You visit, the time and date of Your visit, the time spent on those pages, unique device identifiers and other diagnostic data.

When You access the Service by or through a mobile device, We may collect certain information automatically, including, but not limited to, the type of mobile device You use, Your mobile device unique I.D., the I.P. address of Your mobile device, Your mobile operating system, the type of mobile Internet browser You use, unique device identifiers and other diagnostic data.

We may also collect information that Your browser sends whenever You visit our Service or when You access the Service by or through a mobile device.

Information from Third-Party Social Media Services

The Company allows You to create an account and log in to use the Service through the following Third-party Social Media Services:

- Google
- Facebook
- Twitter

If You decide to register through or otherwise grant us access to a Third-Party Social Media Service, We may collect Personal data that is already associated with Your Third-Party Social Media Service's account, such as Your name, Your email address, Your activities or Your contact list associated with that account.

You may also have the option of sharing additional information with the Company through Your Third-Party Social Media Service's account. If You choose to provide such information and Personal Data, during registration or otherwise, You are giving the Company permission to use, share, and store it in a manner consistent with this Privacy Policy.

Information Collected while Using the Application

While using Our Application, in order to provide features of Our Application, We may collect, with Your prior permission:

- Information regarding your location
- Pictures and other information from your device's camera and photo library

We use this information to provide features of Our Service, to improve and customize Our Service. The information may be uploaded to the Company's servers and/or a Service Provider's server, or it may be simply stored on Your device.

You can enable or disable access to this information at any time, through Your Device settings.

Use of Your Personal Data

The Company may use Personal Data for the following purposes:

- **To provide and maintain our Service**, including to monitor the usage of our Service.
- **To manage Your Account**: to manage Your registration as a user of the Service. The Personal Data You provide can give You access to different functionalities of the Service that are available to You as a registered user.
- **For the performance of a contract:** the development, compliance and undertaking of the purchase contract for the products, items or services You have purchased or of any other contract with Us through the Service.
- **To contact You**: To contact You by email, telephone calls, SMS, or other equivalent forms of electronic communication, such as a mobile application's push notifications regarding updates or informative communications related to the functionalities, products or contracted services, including the security updates, when necessary or reasonable for their implementation.
- **To provide You** with news, special offers and general information about other goods, services and events which we offer that are similar to those that you have already purchased or enquired about unless You have opted not to receive such information.
- **To manage Your requests**: To attend and manage Your requests to Us.
- **For business transfers**: We may use Your information to evaluate or conduct a merger, divestiture, restructuring, reorganization, dissolution, or other sale or transfer of some or all of Our assets, whether as a going concern or as part of bankruptcy, liquidation, or similar proceeding, in which Personal Data held by Us about our Service users is among the assets transferred.
- **For other purposes**: We may use Your information for other purposes, such as data analysis, identifying usage trends, determining the effectiveness of our promotional campaigns and to evaluate and improve our Service, products, services, marketing and your experience.

We may share Your personal information in the following situations:

- **With Service Providers**: We may share Your personal information with Service Providers to monitor and analyze the use of our Service, to contact You.
- **For business transfers**: We may share or transfer Your personal information in connection with, or during negotiations of, any merger, sale of Company assets, financing, or acquisition of all or a portion of Our business to another company.
- **With Affiliates**: We may share Your information with Our affiliates, in which case we will require those affiliates to honor this Privacy Policy. Affiliates include Our parent company and any other subsidiaries, joint venture partners or other companies that We control or that are under common control with Us.

- **With business partners**: We may share Your information with Our business partners to offer You certain products, services or promotions.
- **With other users**: When You share personal information or otherwise interact in the public areas with other users, such information may be viewed by all users and may be publicly distributed outside. If You interact with other users or register through a Third-Party Social Media Service, Your contacts on the Third-Party Social Media Service may see Your name, profile, pictures and description of Your activity. Similarly, other users will be able to view descriptions of Your activity, communicate with You and view Your profile.
- **With Your consent**: We may disclose Your personal information for any other purpose with Your consent.

Retention of Your Personal Data

The Company will retain Your Personal Data only for as long as is necessary for the purposes set out in this Privacy Policy. We will retain and use Your Personal Data to the extent necessary to comply with our legal obligations (for example, if we are required to retain your data to comply with applicable laws), resolve disputes, and enforce our legal agreements and policies.

The Company will also retain Usage Data for internal analysis purposes. Usage Data is generally retained for a shorter period of time, except when this data is used to strengthen the security or to improve the functionality of Our Service, or We are legally obligated to retain this data for longer time periods.

Transfer of Your Personal Data

Your information, including Personal Data, is processed at the Company's operating offices and in any other places where the parties involved in the processing are located. It means that this information may be transferred to — and maintained on — computers located outside of Your state, province, country or other governmental jurisdiction where the data protection laws may differ than those from Your jurisdiction.

Your consent to this Privacy Policy followed by Your submission of such information represents Your agreement to that transfer.

The Company will take all steps reasonably necessary to ensure that Your data is treated securely and in accordance with this Privacy Policy and no transfer of Your Personal Data will take place to an organization or a country unless there are adequate controls in place including the security of Your data and other personal information.

Disclosure of Your Personal Data

Business Transactions

If the Company is involved in a merger, acquisition or asset sale, Your Personal Data may be transferred. We will provide notice before Your Personal Data is transferred and becomes subject to a different Privacy Policy.

Law enforcement

Under certain circumstances, the Company may be required to disclose Your Personal Data if required to do so by law or in response to valid requests by public authorities (e.g., a court or a government agency).

Other legal requirements

The Company may disclose Your Personal Data in the good faith belief that such action is necessary to:

- Comply with a legal obligation
- Protect and defend the rights or property of the Company
- Prevent or investigate possible wrongdoing in connection with the Service
- Protect the personal safety of Users of the Service or the public
- Protect against legal liability

Security of Your Personal Data

The security of Your Personal Data is important to Us, but remember that no method of transmission over the Internet, or method of electronic storage is 100% secure. While We strive to use commercially acceptable means to protect Your Personal Data, We cannot guarantee its absolute security.

Children's Privacy

Our Service does not address anyone under the age of 13. We do not knowingly collect personally identifiable information from anyone under the age of 13. If You are a parent or guardian and You are aware that Your child has provided Us with Personal Data, please contact Us. If We become aware that We have collected Personal Data from anyone under the age of 13 without verification of parental consent, We take steps to remove that information from Our servers.

If We need to rely on consent as a legal basis for processing Your information and Your country requires consent from a parent, We may require Your parent's consent before We collect and use that information.

Links to Other Websites

Our Service may contain links to other websites that are not operated by Us. If You click on a third-party link, You will be directed to that third party's site. We strongly advise You to review the Privacy Policy of every site You visit.

We have no control over and assume no responsibility for the content, privacy policies or practices of any third-party sites or services.

Changes to this Privacy Policy

We may update Our Privacy Policy from time to time. We will notify You of any changes by posting the new Privacy Policy on this page.

We will let You know via email and/or a prominent notice on Our Service, prior to the change becoming effective and update the "Last updated" date at the top of this Privacy Policy.

You are advised to review this Privacy Policy periodically for any changes. Changes to this Privacy Policy are effective when they are posted on this page.

Contact Us

If you have any questions about this Privacy Policy, You can contact us:

By email: office@Epma_App.com

Appendix E – Higher Education: Evaluation Questionnaire of the Seven Simulation Screens of a Mobile Transit Application Named Epma_App

A. Demographics information

A.1. Gender: ☐ Men ☐ Women

A.2. What is your age group?
- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65 and over

A.3. What is the highest degree or level of education you have completed?
- ☐ High School
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Ph.D. or higher

A.4. What is your current employment status? (please tick all that apply)
- ☐ Employed Full-Time
- ☐ Employed Part-Time
- ☐ Self-employed
- ☐ Seeking opportunities
- ☐ Student

B. Daily travel habits

B.1. How many routes do you conduct per day? (The route from a point A to a point B and back from B to A are two routes)
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ More than 6

B.2. How many minutes does your daily commute take in total (to and from) to	
work-education	☐ <10 ☐ 10-15 ☐ 15-20 ☐ 20-30 ☐ >30
pick up - drop off	☐ <10 ☐ 10-15 ☐ 15-20 ☐ 20-30 ☐ >30
leisure/entertainment	☐ <10 ☐ 10-15 ☐ 15-20 ☐ 20-30 ☐ >30
shopping	☐ <10 ☐ 10-15 ☐ 15-20 ☐ 20-30 ☐ >30

B.3. What is your primary transport mode to/from?	
work-education	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
pick up - drop off	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
Leisure/entertainment	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
shopping	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other

B.4. If your answer is Other in Question B.3., please specify

B.5. How many are your daily intermodal trips? (combination of different means of transport)
- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ More than 4

B.6. In the case of an intermodal trip, which different means of transportation do you use? (please tick all that apply)	
work-education	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
pick up - drop off	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
Leisure/entertainment	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other
shopping	☐ Metro/Tram ☐ Walking/Cycling ☐ Bus ☐ Car/Taxi ☐ Motorcycle/Scooter ☐Other

B.7. If the car is used as the primary means of transport, what would be the main reason for the reduction in its use? (please tick up to three answers)
- ☐ Avoidance of traffic congestion
- ☐ A limited car parking area
- ☐ An extensive public transport system
- ☐ Environmental protection
- ☐ Wish for physical activity
- ☐ Real-time transport information on the smartphone
- ☐ Saving time
- ☐ Low cost of public transport modes - Saving money
- ☐ A well-organized bike-car-scooter sharing system in the city center
- ☐ Social reasons
- ☐ Avoidance of tolls
- ☐ Other (please note)

C. Use of smartphones and mobile applications

C.1. Do you have (please tick all that apply)
- ☐ A smartphone
- ☐ A tablet
- ☐ A personal computer or laptop
- ☐ None of the above

C.2. If you have a mobile or tablet, what kind of applications do you use the most? (please tick up to three)
- ☐ Gaming
- ☐ Sport/Health/Fitness
- ☐ Travelling and maps
- ☐ Social networking
- ☐ Entertainment (Music, Dance, etc.)
- ☐ Searching Tools
- ☐ Messaging
- ☐ Weather Forecasting
- ☐ News
- ☐ Other (please note)

C.3. Would you use a mobile or tablet application that would help you adopt a friendlier and more environmentally sustainable behavior in your daily routes?
- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

C.4. What features would you like a mobile transit application to have in order to use it daily? (please tick all that apply)
- ☐ Set an accurate journey planner
- ☐ Integrated e-ticket payment by combining all the available options, including all the transport modes
- ☐ Share/post-real-time information about traffic, disruptive events and transport choices
- ☐ Ticket price information for public transport, taxis, tolls, and car parking
- ☐ Real-time notifications about parking (availability, pay-by-phone options, alerts on remaining parking time, and reminders about where the user parked her vehicle)
- ☐ Compare trip costs for all alternative routes and show daily travel costs
- ☐ Set reminders or get notifications about a scheduled trip
- ☐ Collect points or get rewards (e.g., free public transportation tickets, free/cheaper parking for people who carpool to work)
- ☐ Learn more on environmental sustainability with relevant information, carbon footprint calculation, etc.
- ☐ Give feedback on travel options provided
- ☐ Suggest travel options to other users
- ☐ Share with other users relevant information about mobility and updates on the traffic situation
- ☐ Play eco-Games
- ☐ Other (please note)

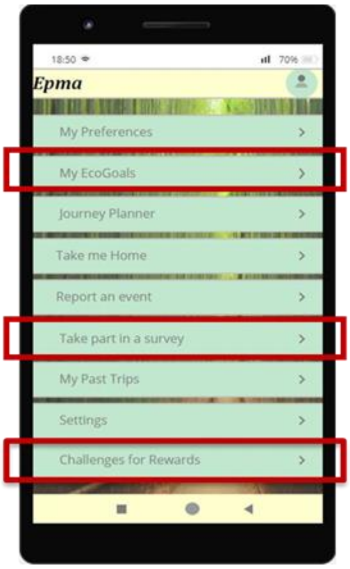
C.5. Are you interested in or prepared to change your travel behavior just for the sake of the environment?
- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

C.6. Would you like the application to reward you every time you choose "green" travel options with
- ☐ nothing
- ☐ playing eco games and getting free perks
- ☐ free transport tickets
- ☐ free software installations
- ☐ free admission to cinemas, theaters, sports, games, etc.
- ☐ free mobile data, phone calls, sms

C.7. How concerned are you about protecting your privacy and personal data when using a mobile application?
- ☐ High
- ☐ Moderate
- ☐ Low
- ☐ None

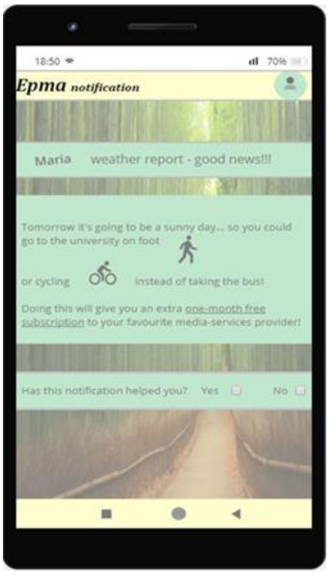
C.8. What are your primary concerns with the use of a mobile application concerning personal data and privacy? (please tick all that apply)
- ☐ The application must be hack-proof
- ☐ The personal data needs to be protected when stored through effective encryption
- ☐ The users must be able to choose which data they want to share with others or with third-party services
- ☐ The mobile application must collect only those data that are strictly necessary to perform the lawful functionalities as identified and planned
- ☐ The application must delete all the data generated after signing out
- ☐ The application should ask for access to the camera, the contacts, or the photos of the user
- ☐ Other (please note)

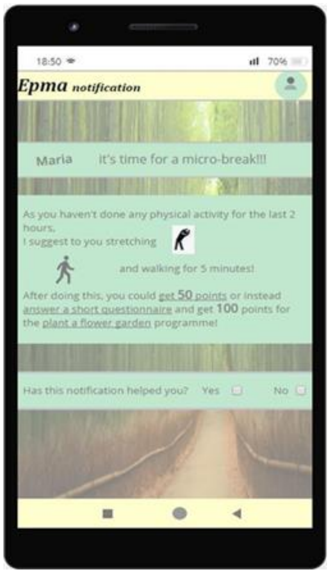
Assessment of the Epma_App Screens and suggestions



D. The Epma_App Home Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
D.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.3. What other features would you like to see in an upcoming redesign? Please specify	



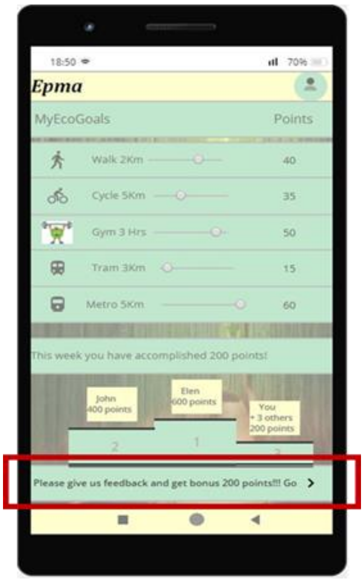


E. The Epma_App Notification Screens

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
E.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.3. What other features would you like to see in an upcoming redesign? Please specify	

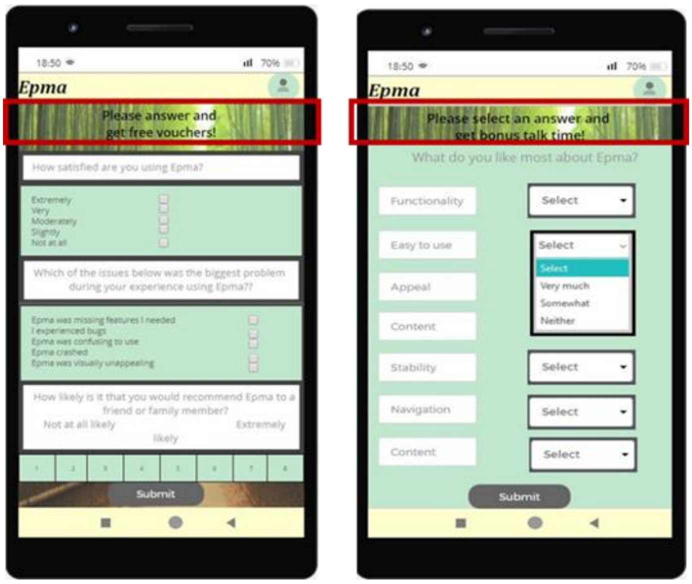
F. The Epma_App Progress Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
F.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.3. What other features would you like to see in an upcoming redesign? Please specify	



G. The Epma_App My EcoGoals Screen

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
G.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
G.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
G.3. What other features would you like to see in an upcoming redesign? Please specify	



H. The Epma_App Collecting data Screens

(Rate your agreement with each feature, from 1 strongly disagree to 5 strongly agree)	
Feature	**Low agreement High agreement**
H.1. User-friendly application design	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.2. Position of on-screen messages	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
H.3. What other features would you like to see in an upcoming redesign? Please specify	

I. Effort expectancy of the Epma_App use

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
I.1. I found Epma_App easy to use	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I.2. Epma_App was not unnecessarily complex	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I.3. I can use Epma_App without written instructions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I.4. Epma_App works the way I would want it to work	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I.5. The language used in Epma_App is easily understood	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I.6. The prompts for input/post are effective in making you want to contribute	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

J. Performance expectancy of the Epma_App use

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
J.1. The different screens of the Epma_App are cohesive in look and feel	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
J.2. Epma_App has clearly marked way-finding buttons (exit, back, next page, etc.)	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
J.3. Epma_App has functionality that is easy to understand	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
J.4. Epma_App does everything I would expect it to do	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
J.5. The use of the Epma_App is relevant to the user needs for the adoption of sustainable travel behavior	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
J.6. Using Epma_App was an enjoyable experience	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

K. Motivation for the Epma_App use

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement** **High agreement**
K.1. I am motivated to use Epma_App in order to discover more healthy and sustainable options in my daily journeys	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
K.2. I am motivated to use Epma_App in order to get rewards	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
K.3. I am motivated to use Epma_App in order to be informed of environmental actions in the city	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

L. Intention for the Epma_App use

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement** **High agreement**
L.1. I think that I would use Epma_App frequently	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
L.2. I would recommend Epma_App to a friend	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
L.3. I am expecting the final Epma_App implementation in order to test it	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

M. Would you recommend Epma_App to a friend?
- ☐ Yes
- ☐ No
- ☐ Maybe/I do not know

Appendix F – Secondary Education: Questionnaire for the Concept of Sustainability and its Integration into the ICT Curricula

A. Demographics information

A.1. Gender:	☐ Boy ☐ Girl

A.2. Age: ………………………………………

B. Knowledge and perceptions about sustainability and green informatics

B.1. I think that sustainability is best described as (please tick all that apply)
- ☐ Development of technology for a better world
- ☐ Development of technology with less resource consumption
- ☐ **E**nsuring that our current society can be maintained in the future
- ☐ **E**nsuring that all life forms as we know them can be maintained in the long term
- ☐ Ensuring sustainable prosperity for all people on earth

B.2. I think that green informatics is best described as (please tick all that apply)
- ☐ Development of efficient computing systems for energy-saving
- ☐ Reusing computing systems in a way that is effective and efficient and, at the same time, limits the environmental impacts
- ☐ Development of environmentally friendly technologies like virtual energy management (virtualization), recycling, telecommuting
- ☐ Development of innovative products, tools and services that contribute to the protection and restoration of the natural environment

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)

Statement	Low agreement High agreement
B.3. I know the concept of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.4. I know the concept of green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.5. It is the first course that deals with sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.6. I am not interested in learning more about sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.7. I am not interested in learning more about green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

C. Awareness of the sustainable development goals and the use of clean energy

C.1. Concerning the Sustainable Development Goals (SDGs)
- ☐ I have never heard of SDGs
- ☐ I have heard, but I do not know what exactly SDGs are
- ☐ I have heard, and I do know what exactly SDGs are

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)

Statement	Low agreement High agreement
C.2. I would be willing to use digital services exclusively from IT companies whose energy for their operation comes from 100% renewable energy sources	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.3. I would be willing to visit websites that are more energy efficient, e.g., sustainable websites	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.4. I am not interested in supporting an organization that is active in the use of clean energy, e.g., wind, solar	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

D. Intention to engage in sustainability and green informatics

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
D.1. I believe that it is appropriate to include content related to green informatics in school lessons	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.2. I intend to deal with green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.3. I would be willing to improve the world around me by using environmentally friendly methods	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.4. I would be willing to learn more about sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.5. I would be willing to learn about green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

E. Expectations for embedding sustainability into the ICT curricula

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
I believe that	
E.1. the school should actively promote sustainability in the school community	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.2. sustainability should be integrated into ICT curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.3. the school should engage in various ways with the SDGs, sustainability and green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.4. the school should provide opportunities for pupils to take part in sustainability actions related to the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

F. The contribution of education to environmental awareness

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
I believe that my school helps me to learn how	
F.1. I can have a positive environmental impact on the world around me	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.2. I make changes in my own lifestyle to help the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.3. ICT can contribute to have a positive environmental impact on the world around me	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
F.4. ICT can help the environment, e.g., energy savings, greater efficiency of systems, reduction of greenhouse gas emissions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

G. Note the ways or actions in which you would like the school to engage with sustainability and green informatics

G.1. Creating a poster about green informatics in order to use for a school campaign or a competition where pupils may win a prize reward	☐
G.2. Implementing a sustainability theme week that will include presentations, educational visits, panel discussions or workshops	☐
G.3. Invitating and discussing with graduates of the school already working in fields of green informatics	☐
G.4. Organizing an art exhibition at school with works by pupils (photos, paintings, etc.) related to the sustainable development goals	☐
G.5. Organizing a sustainability day at school with different activities related to the sustainable development goals (e.g., e-waste recycling workshops)	☐
G.6. Other (please note)	

Appendix G – Secondary Education: Questionnaire for the E-Waste Management and the Intention for E-Waste Recycling

A. Demographics information

A.1. Gender: ☐ Boy ☐ Girl

A.2. Age: ……………………………………….

A.3. Do you have (please tick all that apply)
- ☐ A smartphone
- ☐ A tablet
- ☐ A personal computer or laptop
- ☐ None of the above

A.4. How many IT devices (mobile phone, tablet, computer or laptop) have you owned in total in the last three (3) years?
- ☐ None
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ More than 5

B. Perceptions about sustainability - Integrating sustainability into education

B.1. Concerning the Sustainable Development Goals (SDGs)
- ☐ I have never heard of SDGs
- ☐ I have heard, but I do not know what exactly SDGs are
- ☐ I have heard, and I do know what exactly SDGs are

B.2. Is this your first sustainability course?
- ☐ Yes
- ☐ No

B.3. If the answer to the previous question is «No», which grade has encouraged you the most to think and act in ways that help the environment and other people more?
- ☐ Primary
- ☐ Lower secondary (Gymnasium)
- ☐ Upper secondary (Lyceum)

B.4. When you want to find out more information about environmental issues (i.e., global warming, etc.) that affect your local community and people around the world, the primary source is
- ☐ Family
- ☐ Friends
- ☐ Books
- ☐ Teachers-educators
- ☐ Social networks
- ☐ Internet

B.5. What do you think best describes sustainability?
- ☐ Development of technology for a better world
- ☐ Development of technology with less resource consumption
- ☐ Ensuring that our current society can be maintained in the future
- ☐ Ensuring that all life forms as we know them can be maintained in the long term
- ☐ Ensuring sustainable prosperity for all people on earth

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
B.6. I have understood the concept of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.7. I understand how sustainability can help the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.8. I have been motivated to get involved with sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.9. I want to help to improve the world around me by using environmentally friendly techniques	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.10. I want to know more about sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.11. School helps me learn how to make changes in my own lifestyle to help the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.12. School helps me learn how I can have a positive environmental impact on the world around me	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.13. The school make efforts to reduce its negative environmental impact on the environment and society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.14. Sustainability must be actively integrated into all school subjects	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
B.15. The school should actively integrate and promote sustainability in the school community	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

C. Knowledge, perceptions and attitudes about e-waste recycling

C.1. Concerning the e-waste
- ☐ I have never heard of e-waste
- ☐ I have heard, but I do not know what exactly e-waste are
- ☐ I have heard, and I do know what exactly e-waste are

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
C.2. I have already implemented or have begun e-waste recycling	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.3. People should be rewarded every time they recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.4. E-waste recycling is an easy process	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.5. E-waste recycling has environmental benefits	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.6. E-waste recycling is a responsible practice	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
I am aware of	
C.7. the government regulations or policy for e-waste management in Greece	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.8. the existence of toxic/hazardous materials in electronic IT products	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.9. the impacts of e-waste on public health, the environment and natural resources	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
C.10. which electronic IT products can be recycled	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

D. Intention to engage in e-waste recycling and management

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)	
Statement	**Low agreement High agreement**
D.1. I intend to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.2. I will make an extra effort to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.3. It is a mistake for me not to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.4. It comes easily for me to find information regarding e-waste recycling	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
D.5. The school should organize activities for e-waste management and recycling	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

E. Awareness of e-waste recycling

E.1. Indicate how to dispose of IT products that have completed their life cycle or that have been damaged

- ☐ Dump them in designated e-waste collection points
- ☐ Deliver these products to a store and purchase a new one
- ☐ Give to another person or sell them
- ☐ Keep them at home
- ☐ Dispose of them in the sea or a river

(Rate your agreement with each statement, from 1 strongly disagree to 5 strongly agree)

Statement	**Low agreement High agreement**
E-waste recycling	
E.2. works reciprocally for the society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.3. is a new business opportunity/challenge	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.4. promotes the right to repair and reuse an electrical IT device	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.5. supports the Sustainability of the planet	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
E.6. reduces the level of e-waste generated by the community today	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Appendix H – Higher Education: Questionnaires for Embedding Sustainability into the ICT Curricula

First Questionnaire – Pre-test

A. Demographics information

A.1. Gender:	☐ Men ☐ Women

A.2. Age: ………………………………………	**A.3.** Semester: ………………………………………

A.4. Place of residence:	……………………………………………………

B. Knowledge about sustainability, SDGs, e-waste recycling and energy consumption in DCs

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
B.1. This is the first educational unit I will attend regarding sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.2. Concerning the Sustainable Development Goals (SDGs)	
B.2.1. I have never heard of SDGs	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.2.2. I have heard, but I do not know what exactly SDGs are	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.2.3. I have heard, and I do know what exactly SDGs are	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.3. Concerning the e-waste	
B.3.1. I have never heard of e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.3.2. I have heard, but I do not know what exactly e-waste are	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.3.3. I have heard, and I do know what exactly e-waste are	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.4. Concerning the energy consumption in Data Centers (DCs)	
B.4.1. I have never heard of this	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.4.2. I have heard, but I do not know what exactly is	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.4.3. I have heard, and I do know what exactly is	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5. When you want to find out more information about environmental issues (i.e., global warming, etc.) that affect your local community and people around the world, the primary source is	
B.5.1. Family	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5.2. Friends	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5.3. Books	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5.4. Teachers-educators	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5.5. Social networks	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.5.6. Internet	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.6. Concerning your time in education so far, which grade has encouraged you the most to think and act in ways that help the environment and other people more	
B.6.1. Primary	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.6.2. Secondary	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
B.6.3. Tertiary	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

C. Knowledge about sustainability issues and the environmental impact of the ICT studies

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
C.1. I know the concept of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.2. I know how green informatics can be applied to other fields of science	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.3. The subject of my studies has no potential impact on the environmental pillar of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.4. The subject of my studies has no potential impact on the social pillar of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.5. I am interested in the environmental impact of my work as a future IT professional	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6. I think that sustainability is best described as:	
C.6.1. Development of technology for a better world	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.2. Development of technology with less resource consumption	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.3. Ensuring that our current society can be maintained in the future	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.4. Ensuring that all life forms as we know them can be maintained in the long term	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.5. Ensuring sustainable prosperity for all people on earth	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7. I think that green informatics is best described as:	
C.7.1. Development of efficient computing systems for energy-saving	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.2. Reusing computing systems in a way that is effective and efficient and, at the same time, limits the environmental impacts	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.3. Development of environmentally friendly technologies like virtual energy management (virtualization), recycling, telecommuting	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.4. Development of innovative products, tools and services that contribute to the protection and restoration of the natural environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

D. Perceptions regarding the contribution of university education to environmental awareness and the expectations of the students about the inclusion of sustainability into the ICT curricula

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
D.1. The university provides opportunities for students to participate in actions to limit the negative effects it brings on the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.2. The university should organize informational activities regarding the sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.3. My studies do not help me learn how to make a positive environmental impact on the world around me	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.4. The university should actively promote sustainability in the university curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.5. I believe that sustainability should be integrated into all university subjects	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.6. The study of e-waste management should be included in the curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.7. The study of energy consumption in DCs should be included in the curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

E. Intention to engage in sustainability and green informatics

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
E.1. I want to be involved in green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.2. I would like to help improve the world around me by using environmentally friendly techniques	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.3. I want to learn more about sustainability and green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.4. I am interested in green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

G. Knowledge and intention to engage in e-waste recycling and management

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
G.1. I am aware of the implications of e-waste recycling on natural resources and the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.2. I am aware of the implications of e-waste recycling on human health	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.3. I know the Greek policy or regulations on the management of e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.4. I am aware of the existence of toxic/hazardous materials in IT electronic products	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.5. The electronic IT products that have reached end-of-life are considered e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.6. The damaged IT electronic products are considered e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.7. I intend to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.8. I am interested in recycling e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

I. Knowledge and awareness of the students about renewable energy usage in DCs

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
The adoption of renewable energy sources	
I.1. reduces the level of greenhouse gas emissions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.2. is profitable	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.3. is not dangerous for health and the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.4. supports the sustainability of the planet	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.5. is beneficial to society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.6. creates jobs and benefits local communities	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Second Questionnaire – Post-test

A. Demographics information

A.1. Gender:	☐ Men ☐ Women

A.2. Age: ……………………………………….	**A.3.** Semester: ……………………………………….

A.4. Place of residence:	……………………………………………………….

C. Knowledge about sustainability issues and the environmental impact of the ICT studies

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
C.1. I know the concept of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.2. I know how green informatics can be applied to other fields of science	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.3. The subject of my studies has no potential impact on the environmental pillar of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.4. The subject of my studies has no potential impact on the social pillar of sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.5. I am interested in the environmental impact of my work as a future IT professional	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6. I think that sustainability is best described as:	
C.6.1. Development of technology for a better world	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.2. Development of technology with less resource consumption	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.3. Ensuring that our current society can be maintained in the future	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.4. Ensuring that all life forms as we know them can be maintained in the long term	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.6.5. Ensuring sustainable prosperity for all people on earth	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7. I think that green informatics is best described as:	
C.7.1. Development of efficient computing systems for energy-saving	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.2. Reusing computing systems in a way that is effective and efficient and, at the same time, limits the environmental impacts	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.3. Development of environmentally friendly technologies like virtual energy management (virtualization), recycling, telecommuting	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
C.7.4. Development of innovative products, tools and services that contribute to the protection and restoration of the natural environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

D. Perceptions regarding the contribution of university education to environmental awareness and the expectations of the students about the inclusion of sustainability into the ICT curricula

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
D.1. The university provides opportunities for students to participate in actions to limit the negative effects it brings on the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.2. The university should organize informational activities regarding the sustainability	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.3. My studies do not help me learn how to make a positive environmental impact on the world around me	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.4. The university should actively promote sustainability in the university curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.5. I believe that sustainability should be integrated into all university subjects	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.6. The study of e-waste management should be included in the curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
D.7. The study of energy consumption in DCs should be included in the curricula	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

E. Intention to engage in sustainability and green informatics

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
E.1. I want to be involved in green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.2. I would like to help improve the world around me by using environmentally friendly techniques	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.3. I want to learn more about sustainability and green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
E.4. I am interested in green informatics	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

F. Provision of rewards to engage in sustainability and e-waste recycling

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
F.1. Supporting sustainability is nice to be rewarded, e.g., vouchers for every electronic device I recycle	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
F.2. E-waste recycling should reward the person who implements it	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

G. Knowledge and intention to engage in e-waste recycling and management

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
G.1. I am aware of the implications of e-waste recycling on natural resources and the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.2. I am aware of the implications of e-waste recycling on human health	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.3. I know the Greek policy or regulations on the management of e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.4. I am aware of the existence of toxic/hazardous materials in IT electronic products	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.5. The electronic IT products that have reached end-of-life are considered e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.6. The damaged IT electronic products are considered e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.7. I intend to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
G.8. I am interested in recycling e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

H. Perceptions, attitudes and awareness of the students about e-waste recycling and management

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
H.1. Recycling reduces the level of e-waste generated by society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.2. E-waste recycling is beneficial for the environment	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.3. E-waste recycling works in a rewarding way for the society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.4. If I wanted to, I would have no problem managing to recycle e-waste	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.5. I have already implemented e-waste recycling	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.6. People should be rewarded for e-waste recycling	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.7. E-waste recycling offers good quality products to others at affordable	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
H.8. E-waste recycling is profitable	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

I. Knowledge and awareness of the students about renewable energy usage in DCs

(Rate your agreement with each statement, from 1 strongly disagree to 7 strongly agree)	
Statement	**Low agreement High agreement**
The adoption of renewable energy sources	
I.1. reduces the level of greenhouse gas emissions	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
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I.5. is beneficial to society	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
I.6. creates jobs and benefits local communities	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

J. Note the ways or actions in which you would like the university to engage with the SDGs, sustainability and green informatics – Creating a Sustainable University Network (SUN)

J.1. SDGs poster creation, which can be used for a campaign on campus or a competition where students can win a prize	☐
J.2. Creation of a website with content about the actions that foreign HEIs around the world are already taking about sustainability in ICT education	☐
J.3. Implementation of theme semester, including talks, video screenings, excursions, panel discussions or workshops	☐
J.4. Invitation and discussion with alums from the HEIs who are working on the SD	☐
J.5. SDGs art exhibition presenting photographs, paintings, or sculptures that involve the SDGs	☐
J.6. Lecture series or documentary about the importance and necessity of SDGs adoption	☐
J.7. SDGs day with different activities related to the SDGs (e.g., workshops on e-waste recycling or sustainable food)	☐
J.8. Other (please note)	