

THE FOOTPRINT OF ARTIFICIAL INTELLIGENCE: ADVANCED TECHNOLOGY OR A SUSTAINABLE FUTURE?

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INTRODUCTION

While users having ChatGPT draw a picture or simply say "thank you" may seem like ordinary, simple actions at first glance, such digital interactions create significant energy consumption each time and have serious impacts on environmental sustainability (Crawford, 2024; Sellman, 2024). Training, developing, and running artificial intelligence (AI) models require enormous amounts of electricity, and the impact is twofold: carbon emissions on one side and the heavy water use needed to cool data centers on the other. Indeed, one study reported that approximately 5.4 million liters of water were consumed during the training of GPT-3, one of the large language models (LLMs) (Li et al., 2025). This clearly demonstrates that data centers require significant water resources for their processing operations. On the other hand, only 2.5% of the water on Earth consists of freshwater sources, and since a large portion of this is stored in glaciers or underground, the amount of directly usable drinking water is quite limited (UNESCO, 2020). While people's access to water is limited on a global scale, the uninformed use of technologies such as AI, which require high energy and water consumption, poses a serious threat to sustainability.

With the increasing use of ChatGPT, one of the most popular tools of recent times, AI-based technologies have become more prevalent in everyday life (Lo, 2023; Rahman & Watanobe, 2023). A review of the literature reveals that the unconscious use of AI-based models and technologies could pose a significant threat to a sustainable future. Users' unconscious consumption of technology brings with it concerns about the future of the environment. Every user must

be a conscious consumer when using these technologies for our future. In this case, a conceptual framework is needed to understand and make visible the environmental impacts of AI use.

The concept of *footprint*, developed to measure the impact of human activities on nature, has long been used to conceptualize this relationship. Galli et al. (2012) expanded this framework by proposing the *Footprint Family* approach. This approach consists of three fundamental concepts: the ecological footprint, the carbon footprint, and the water footprint. The authors argue that these concepts must be considered together and suggest thinking of these three concepts as a *family*.

However, users of these technologies are often unaware of the environmental consequences of their individual actions. This lack of awareness makes not only consumption but also responsibility invisible. At this point, some questions become inevitable. To what extent are individuals using generative artificial intelligence (GenAI) aware of the effects they may have in the future? Have we ever considered the true cost of a composition written by ChatGPT, an image created by Midjourney, a video produced through Runway, or a voice cloned by ElevenLabs and similar GenAI tools? Each time we click the “*try again*” button, it is not only the algorithms that are strained, but in a quiet way, the planet itself. So, who will take responsibility for these invisible traces? Perhaps the real question is this: while benefiting from these technologies, are we genuinely aware of the footprint we leave behind?

Purpose of the Chapter

The aim of this chapter is to re-evaluate the Footprint Family approach proposed by Galli et al. (2012) in light of the environmental realities of the digital age. By examining the environmental impacts of widespread technology use, it argues that, in addition to traditional footprint types, the new generation of footprints born of the digital age must also be defined and included in this family. In this context, the chapter explains the emergence and development of the footprint concept in the context of sustainability and then covers the concepts of ecological footprint, carbon footprint, water footprint, technological footprint, digital and artificial footprint. After all, this book chapter invites us to reconsider the Footprint Family approach proposed by Galli et al. (2012).

Environmental Sustainability and Sustainable Development

Environment

When examining the literature, the concept of environment is defined in its broadest sense as the entirety of natural, artificial, social, and cultural conditions necessary for living beings to sustain their lives (ÇŞİDB, 2022; Sevil & Dimişli, 1999). The Ministry of Environment, Urbanization, and Climate Change of the Republic of Turkey defines the environment as the external environment with which living beings interact and maintain relationships throughout their lives (ÇŞİDB, 2022). This definition shows that the environment has not only physical but also social and cultural dimensions. Palmer (1998), considers the

environment as a system that should be evaluated together with the social, cultural and biophysical structures of the individual and emphasizes that environmental education should be taught to individuals within this integrity (e.g. **Figure 1**).

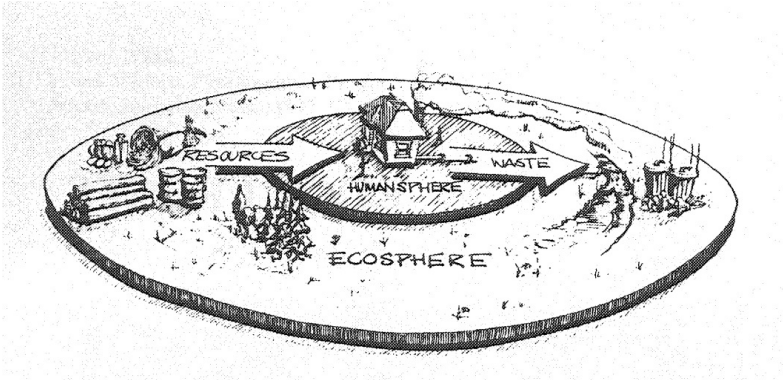


Figure 1. *Ecological Footprint Model*

Explanatory note. Adapted from *Our Ecological Footprint: Reducing Human Impact on the Earth* (Rees & Wackernagel, 1996). © New Society Publishers.

Today, environmental problems are becoming not only an ecological but also a socio-economic crisis. It is observed that the basis of these problems is the destruction of nature by human hands, unconscious consumption of natural resources and insensitivity to the environment. Erten (2004) defines this situation as a result of human beings' ruthless use of nature for their own interests. And he especially emphasizes that industrialization increases environmental destruction. In the same study, it is said that environmental problems such as air, water and soil pollution are effective on a global scale and threaten the right to life of all living things.

It is seen that academic studies in the field of environmental education in Turkey generally focus on environmental attitudes, behaviors, knowledge levels and environmental problems (Bahar & Kiras, 2017). This trend reveals that environmental education is being handled with increasing interest, but it also shows that the content for early age groups is limited.

On the other hand, studies that environmental education should be supported not only at the cognitive level but also in affective and visual ways draw attention. For example, it is emphasized that film and animation-based content is effective in raising environmental awareness in students, and the integration of such materials into curriculum is recommended (Duran, 2019).

Taken together, these findings highlight the need to broaden the scope of environmental education both thematically and pedagogically. There is a growing call for programs that go beyond transferring knowledge to also nurture emotional awareness and adopt multidimensional, age-appropriate learning approaches.

Sustainable Development

When definitions and educational perspectives on the environment are examined together, it becomes clear that this field must now be addressed within the framework of sustainable development. Today's environmental problems affect not only ecosystems but also people's daily lives and the economic structures of societies. For this reason, environmental policies should move beyond the simple protection of nature and adopt a broader, more holistic understanding that supports social transformation.

Sustainable development is commonly described as meeting present needs without limiting the ability of future generations to meet theirs (WCED, 1987). This principle seeks to balance environmental, economic and social priorities. It also argues that progress should be assessed not only through economic growth but by considering ecological stability and social justice. Palmer (1998), points out that one of the key goals of environmental education is to cultivate responsibility toward the environment and to develop sustainable living skills. He further emphasizes that education plays an important role in achieving this balance and must be an integral part of the sustainability process.

Recent studies emphasize that environmental education plays a key role in raising awareness of the goals of sustainable development. Bulut and Özer (2024) discuss sustainability through the idea of an environmental footprint, highlighting the link between individual consumption habits and broader social transformation. Drawing on ecological modernization theory, they suggest that environmental education should be viewed as a multidimensional process that promotes behavioral change rather than only offering cognitive knowledge.

When all these studies are evaluated together, it is understood that sustainable development goals should be supported not only on the economic or political level, but also through educational processes. In this context, it is envisaged that sustainability-based programs included in the education system will enable students to develop a sense of responsibility towards nature, question consumption habits, and grow up as individuals who will contribute to social change.

Environmental Footprint and the Concept of Footprint

Environmental Footprint

When the literature is examined, the importance of the effect of individual behaviors on the environment is emphasized in environmental education studies (Carson, 1962, as cited in Hynes, 1989; Sheehan, 2008). In this context, environmental footprint can be defined as the measurement of the natural resource consumption and environmental damage caused by individuals or societies. According to Keleş and Aydoğdu (2010), the ecological footprint is the sum of the production areas needed by the individual depending on their consumption habits and the biologically productive areas required for the wastes generated in this consumption process to be balanced by natural systems. In the same study, it is emphasized that the ecological footprint is not only a

technical concept but also an effective educational tool. They further argue that this concept should not be viewed only as a technical calculation but also as a valuable educational instrument that helps children develop sustainability awareness and behavioral sensitivity.

Sheehan (2008), similarly, observes that environmental education can foster meaningful changes in behavior, but such transformation becomes more lasting when individuals can connect their own actions with environmental consequences. Through this connection, the notion of the environmental footprint turns from a numerical indicator into a tool for reflection and behavioral change.

Carson's *Silent Spring* (Hynes, 1989) also shows how human activities intertwine with specific ecological threats such as chemical pollution. Her work illustrates that the environmental footprint is not limited to present-day consumption habits; it also invites questioning of the historical relationship between humans and nature.

Taken together, these studies suggest that the concept of the environmental footprint should be approached from a holistic perspective—one that extends beyond the cognitive focus of environmental education to include the values, attitudes and behaviors that shape everyday life. Designing programs around this concept, not only through content but through experiences that encourage behavioral and attitudinal transformation, represents a necessary step toward educating individuals for a sustainable future.

Footprint

Understanding the environmental impact of human consumption and achieving sustainability goals has become increasingly important today. In this context, several concepts have been developed to measure environmental impacts. One of the most used concepts is the footprint (e.g. **Figure 2**). First introduced in the 1990s in the context of sustainability, this concept has been used specifically to express ecological impacts in concrete terms (Rees and Wackernagel, 1996).

The concept of ecological footprint was originally used to express the physical impact of an object on nature or the amount of land it occupies. However, over time, this definition has expanded and begun to address human-induced environmental pressures more extensively (Hoekstra & Wiedmann, 2014). Ecological footprint was first developed and defined in the literature by *Mathis Wackernagel and William Rees at the University of British Columbia in 1990* (Global Footprint Network, 2023).

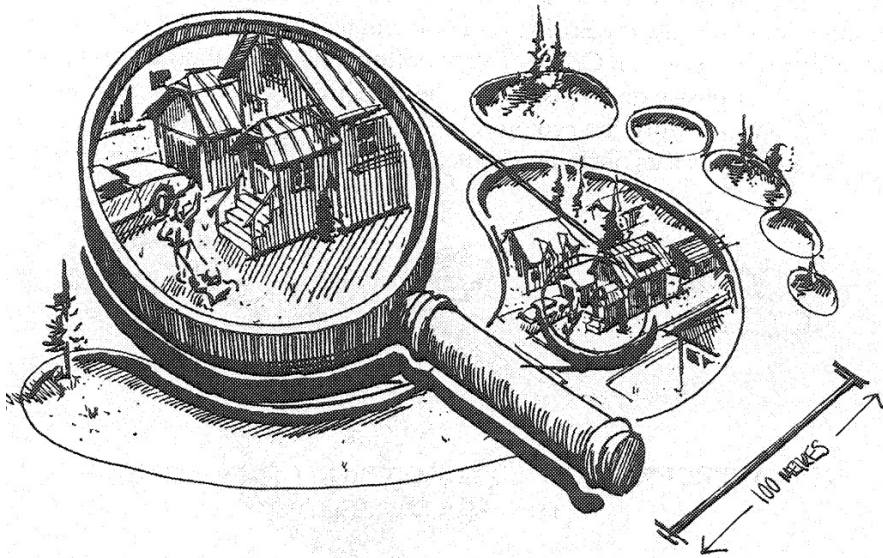


Figure 2. *Footprint*

Explanatory note. Adapted from *Our Ecological Footprint: Reducing Human Impact on the Earth* (Rees & Wackernagel, 1996). © New Society Publishers.

Today, the footprint concept is considered a multifaceted assessment tool that includes not only ecological impacts but also social and economic dimensions (Čuček et al., 2012). Due to its broad scope, this concept has been adopted by the media, civil society organizations, and the business world, leading to its well-known use (Galli et al., 2012). However, there are some differences in the literature regarding the definition and calculation methods of the footprint. The concept represents both environmental pressure and resource consumption, which has led to the emergence of different approaches (Fang et al., 2016).

This chapter of the book aims to examine the concept of footprint from both traditional and innovative perspectives. It will focus particularly on the new dimensions that AI and digitalization have added to this concept. Furthermore, the concept of footprint will be analyzed through a multidimensional and comprehensive approach, covering both ecological and technological types of footprints.

Galli et al. (2012) introduced the concept of *Footprint Family* to address the effects of human activities in a multidimensional way in the context of environmental sustainability (e.g. **Figure 3**). This approach advocates for the combined evaluation of ecological, carbon and water footprints, allowing for a more overall analysis of environmental impacts.

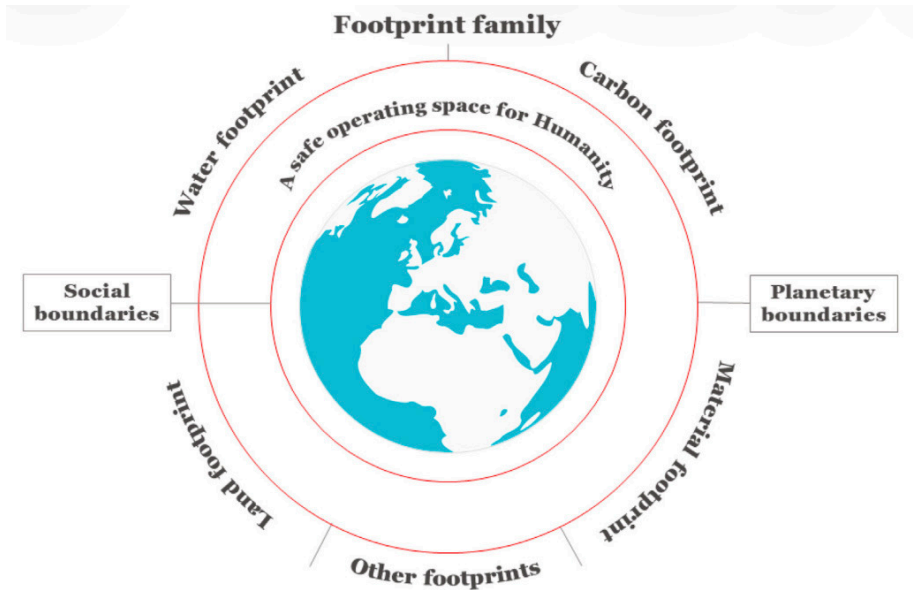


Figure 3. *Footprint Family*

Explanatory note. Adapted from What is a footprint? A conceptual analysis of environmental footprint indicators, Matušík & Kočí (2021).

Based on the Footprint Family approach, this image reveals that human activities should take place in a safe space without exceeding the carrying capacity of the planet and in a way that meets basic socio-economic needs (Raworth, 2017). While there are different types of footprint concepts in the literature (agricultural footprint, fashion footprint, etc.), this book chapter will focus on the ecological, carbon, and water footprint concepts addressed by Galli et al. (2012) within the framework of the Footprint Family.

Footprint Family

Ecological Footprint

First developed by Rees and Wackernagel (1996), the concept of the ecological footprint is defined as the amount of biologically productive land and water area, measured in hectares, required to regenerate the resources consumed and absorb the waste produced by a given population or individual. In other words, the ecological footprint is a calculation tool that allows us to measure and recognize the extent to which we own nature and how much of it we use, both globally and nationally (Keleş et al., 2008).

Akilli et al. (2008) states that the concept of ecological footprint is based on the idea of sustainability, which aims to preserve the environment for future generations. Durkaya (2022) defines ecological footprint as a measure of how sustainably people use natural resources. The ecological footprint is a sustainability indicator that expresses the impact of human resource consumption and waste production on nature's capacity for renewal (Global Footprint Network, 2023; WWF, 2020). When these definitions are considered together,

the ecological footprint is a measure that helps us understand environmental impacts at both the individual and societal levels (e.g. **Figure 4**).

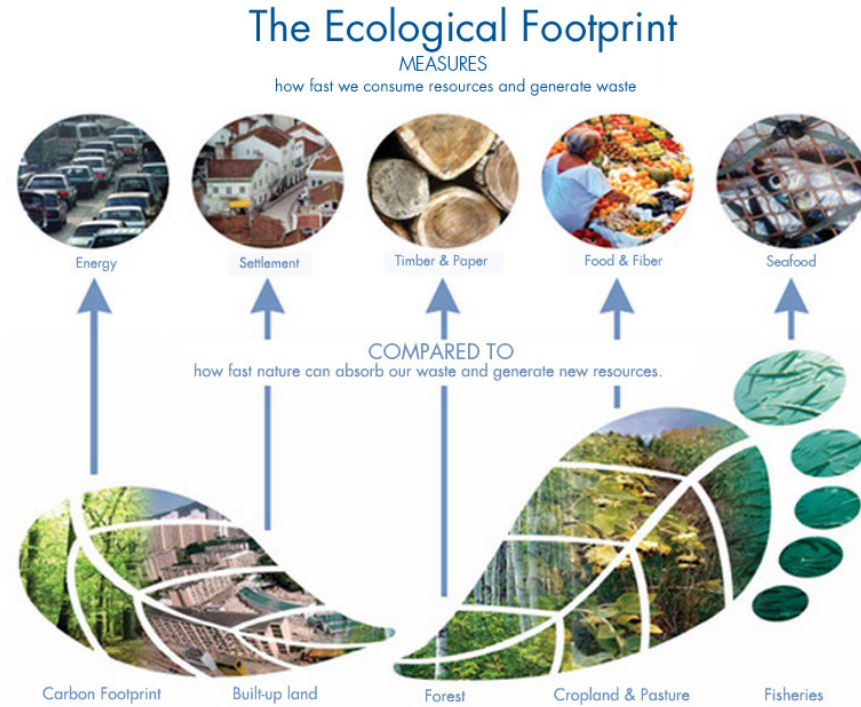


Figure 4. Ecological Footprint

Explanatory note. Adapted from Global Footprint Network
(<https://www.footprintnetwork.org/our-work/ecological-footprint/>).

The concept of ecological footprint has also been addressed in the context of the global sustainable development goals. Recent studies have shown that humanity's demands on the biosphere have begun to exceed the resources provided by nature. This situation is explained by the concept of impact inequality, which emphasizes that the services provided by nature are not being used efficiently enough, especially within consumption-oriented economic models (Dasgupta et al., 2023).

Cordero et al. (2020) have shown that climate change-based education has a significant reducing effect on individuals' lifetime carbon footprint. In the research, it is emphasized that environmental education is not only limited to increasing the level of knowledge but also contributes to long-term behavioral transformations. Ecological footprint is not only theoretical, but also a behavioral transformation tool that can be shaped by education. As a matter of fact, the study conducted by Cordero et al. shows that this transformation is possible by showing that carbon footprints decrease in the long term if individuals are educated.

Carbon Footprint

Wiedmann and Minx (2008) define carbon footprint as "the measurement of the total carbon dioxide emissions directly and indirectly caused by an activity or accumulated over the life cycle of a product". Similarly, the Center for Sustainable Systems (n.d.) defines carbon footprint as "*total greenhouse gas emissions caused directly and indirectly by an individual, organization, activity, or product.*" Accordingly, carbon footprint has become a widely used indicator in environmental and climate change policies, allowing quantitative calculation of climate impacts in tons of carbon dioxide equivalent (Peters, 2010, p. 1325).

When the literature is examined, this concept in Turkey is not only an environmental indicator but also turns into an important learning tool that supports individual awareness and behavior change in educational environments. As a matter of fact, academic studies carried out in recent years show that practices for carbon footprint are integrated into the education system. For example, Kurt and Çavuş-Güngören (2020) examined the carbon footprint knowledge levels and sustainability attitudes of secondary school students and revealed that awareness development varies according to grade level.

Studies comparing the effects of formal and distance education processes on carbon footprint provide meaningful data for the development of environmentally conscious education models (Güçül & Kılınc, 2022). It has been observed that environmental education practices implemented at the primary education level increase students' awareness of their carbon footprint. All these findings demonstrate that the carbon footprint has important potential in the context of education to increase environmental literacy, develop sustainable attitudes, and cultivate active individuals in the fight against climate change (Weidema et al., 2008).

Water Footprint

The literature reveals that integrating environmental footprint concepts into education is becoming increasingly important in terms of understanding environmental issues and updating sustainable living skills (Galli et al., 2012; Hoekstra & Wiedmann, 2014; Matušík & Kočí, 2021). In this context, the water footprint is discussed in educational environments as an important concept that supports both individual awareness and behavioral transformation. Matušík and Kočí (2021) define water footprint as an environmental pressure indicator measured as the sum of blue, green, and gray water volumes used throughout the production chain and emphasize that this indicator has the potential to assess environmental impacts holistically. Because of this, water footprint offers a functional learning area not only for natural resource management but also for transforming individual consumption habits through education.

Various studies conducted in Turkey show that this concept is directly related to education. For example, a study conducted by Akbaş and Sünbül (2022) found that most middle school students could not define the concept of water footprint scientifically, generally providing superficial explanations

such as “water pollution” or “wasting water”. This situation reveals that environmental concepts are not sufficiently included in teaching programs.

Scale-based applications developed to address this deficiency aim to raise awareness at different levels of education and encourage behavioral change. The Water Consumption Behavior Scale, developed by Çankaya and Filik İşçen (2014), was designed to assess the individual water usage habits of science teacher candidates and has been supported by validity and reliability analyses. Similarly, the Water Attitude Scale developed by Karslı and Tunca Güçlü (2023) is a reliable tool that assesses primary school students' attitudes toward water in three sub-dimensions and can serve as a basis for educational interventions. In addition, the Water Literacy Scale developed by Aytaç (2023) has been added to the literature as a unique tool that can comprehensively measure students' water knowledge, behavior and attitudes.

These studies show that it is not enough to teach environmental concepts such as water footprint only as content and that multifaceted teaching processes targeting the cognitive, affective and operational dimensions of learners are needed. The common feature of these scales should be to focus on individual attitudes and behaviors rather than conceptual knowledge.

In conclusion, these studies show that the reflection of environmental concepts on education should be structured not only at the cognitive but also at the attitudinal and behavioral level. As in the example of the water footprint, it is thought that social transformation that will support environmental sustainability will be possible through the systematic and practical transfer of these concepts into educational environments.

New Generation Footprints

This section discusses the concepts of *technology footprint*, *digital footprint*, and *artificial intelligence footprint*, which we believe that new members of the Footprint Family. In short, the technology footprint refers to the amount of energy consumption, carbon emissions, and waste that occur from the production to the use of technological tools. Digital footprint refers to the data traces left by individuals on the internet and is related to privacy, security and ethical issues. The artificial intelligence footprint shows the energy consumed and the resulting carbon emissions during the design, training and operation of AI systems.

Technology Footprint

With the widespread adoption of technology in daily life, the environmental impacts of digital tools have also become more pronounced. The technological footprint includes the environmental impacts caused directly or indirectly by individuals, organizations, or societies through digital tools, hardware, and technology-based organizations, such as energy consumption, carbon emissions, and electronic waste production (e.g. **Figure 5**). This concept encompasses not only physical production and consumption processes but also the envi-

ronmental burdens arising during data processing, automation systems and digital infrastructures (Dam et al., 2024; Gupta et al., 2021).

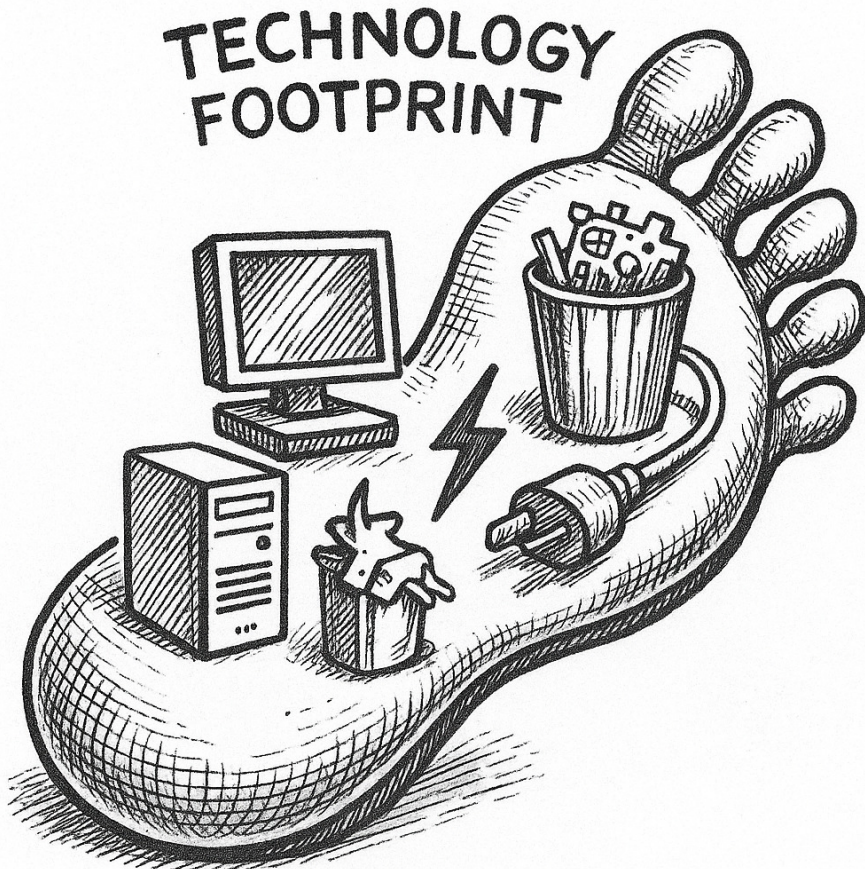


Figure 5. Technology Footprint

Explanatory note. This figure was created by the authors using ChatGPT (OpenAI), 2025.

Studies show that technological innovations can have a long-term effect of reducing the ecological footprint. For example, it has been found that technological innovations have long-term effects of reducing the ecological footprint in the E-7 countries, which consist of Brazil, China, India, Indonesia, Mexico, Russia, and Turkey. The study emphasizes that technological progress must be supported by renewable energy use and green innovation strategies to contribute to environmental sustainability. Furthermore, it has been observed that there is a unidirectional causality relationship between technological innovation and ecological footprint and that this effect becomes more pronounced in the long term (Dam et al., 2024).

The association of technological footprint with education has been supported in recent years by approaches such as computational sustainability (Gomes et al., 2019) and green computing in education (Murugesan, 2008).

These frameworks highlight aspects such as low carbon emission targets, data saving strategies and eco-friendly digital tool selection for the sustainable use of educational technologies. For example, the annual carbon emissions of desktop computers are on average 50% higher than those of laptops (Strubell et al., 2020).

In Gupta et al. (2021), it was revealed that the environmental impacts of information technology are not limited to energy consumption during the usage phase. The study highlights that the production stages of technological devices and infrastructure also contribute significantly to the total carbon footprint. The environmental impact of data centers was examined in detail, noting that major technology companies such as Facebook and Google have taken significant steps to reduce their daily operational emissions by switching to renewable energy. However, despite this transformation, it was also stated that approximately 80% of emissions still originate from production-based processes such as server production, manufacturing of integrated circuits, data center construction and cooling systems. For example, it is stated that a mobile device or server must be used continuously for at least three years to balance the carbon emissions from production in an environmental sense.

These findings show that the technological footprint is not limited to the usage process but also creates environmental impacts throughout the entire life cycle of technological products, from their design to production, from the use of individuals to the process after that. Especially when the invisibility of carbon emissions from the production stage and production loads that are not visible in environmental sustainability analyses are ignored, incomplete or misleading results may occur. Therefore, energy consumption-oriented solutions alone are not enough but a holistic evaluation covering the entire life cycle of products is required. To analyze the environmental impacts of technological devices more accurately, it is important to report production processes transparently and include these impacts in decision-making processes (Dam et al., 2024; Gupta et al., 2021).

It is important for students to realize their environmental impact while using technological tools to develop sustainable digital habits. To gain this awareness, the following practices can be included in educational environments:

- Providing information about energy consumption helps students recognize the invisible environmental costs.
- Discussing the environmental impact of hardware choices fosters conscious device usage habits.
- Activities focused on electronic waste increase students' awareness of recycling and technology ethics.
- Calculating the school's technological footprint encourages students to question their consumption habits.
- Discussion and project-based applications develop the ability to evaluate technology critically and responsibly.

- These approaches support students in becoming not only users of technology but also conscious individuals who question its environmental and ethical consequences.

Digital Footprint

With the acceleration of digitalization, the traces left by individuals in online environments have become an important research topic both technologically and sociologically. Digital footprint refers to the data traces formed because of individuals' interactions in digital environments and these traces shape the virtual identity of the individual; It is directly related to many critical issues such as data security, privacy, surveillance and ethical responsibility (McDermot, 2018; Zuboff, 2019). Digital footprints: It is obtained from various digital environments such as social media platforms (Facebook, Twitter), learning management systems (e.g. Moodle) and online learning environments (e.g. MOOCs) and allows for the systematic monitoring of individuals' online behaviors (Buitrago-Ropero et al., 2020).

The academic use of the concept was first used by Bailey and Caidi (2005) when discussing the privacy implications of smart card-based systems. In this context, the term has its origins in the study of surveillance and privacy. Witte (2006), emphasizing that social lives in digitalizing societies increasingly leave digital traces, drew attention to the importance of the concept of digital footprint in the social sciences (Schrenk, 2022).

In the early uses of the concept of digital footprint, some terminological variations are observed. According to Kligiené (2012), this concept was first expressed by Negroponte (1995) as “slug trail” and later defined by Tim O'Reilly as “data exhaust.” This concept refers to the traces left behind because of actions taken in the digital environment. A digital footprint is the trace left behind by individuals after their actions in the digital environment. All actions performed via television, mobile phones, the internet, and other digital devices contribute to these footprints. Moreover, digital footprints are not limited to individuals but also apply similarly to companies and institutions (Kligiené, 2012).

In the literature, the digital footprint is generally examined under two main headings. These active and passive digital footprints (Buitrago-Ropero et al., 2020; Kligiené, 2012; McDermot, 2018; Schrenk, 2022). These two basic classifications reveal how digital traces are shaped according to user awareness (e.g. **Table 1**).

Table 1. Comparison of Active and Passive Digital Footprints

Feature	Active Digital Footprint	Passive Digital Footprint
Definition	Digital traces intentionally created by the user.	Digital traces collected without the user's awareness.
User Awareness	Conscious: the user is aware and produces content deliberately.	Unconscious: data are collected automatically in the background.
Examples	Social media posts, blogs, comments.	IP addresses, cookies, browsing history.
Collection Method	Through direct user actions.	Automatically by systems and algorithms.
Use in Education	Digital citizenship education, content creation activities.	Learning analytics, behavioral tracking.
Ethical Concern	Responsibility for sharing, digital identity management.	Privacy violation, surveillance capitalism.

Explanatory note. Adapted from Schrenk (2022), Kligienė (2012), McDermot (2018), & Buitrago-Ropero et al. (2020).

- **Active Digital Footprint:** These are traces left by the user consciously. Social media posts, blog articles, and online comments fall into this category. These traces are usually created to reach a specific audience and directly reflect the individual's digital identity.

- **Passive Digital Footprint:** These are the traces created by the user without realizing it. Examples of this category include IP addresses, cookies, and browsing data collected in the background. This type of data is usually recorded automatically by systems and used to analyze user behavior.

Digital footprints are considered an important tool in education for tracking students' learning processes and predicting their success. In a study conducted by Shafiq et al. (2025), it was found that online interaction data obtained through Moodle was positively correlated with academic success. It was found that students who logged into the platform on weekends and at night had a 10% increase in their success scores. This finding provides strong evidence of how digital footprints can be used to evaluate student participation and academic success in education.

Digital footprints can be considered a two-way tool in educational settings:

1) Teaching Tool: Educators can use digital footprints to analyze students' digital behavior. User data obtained through the Learning Management System can be effective in predicting academic success (Shafiq et al., 2025).

2) Critical Awareness Tool: By learning what digital footprints are and how they are managed, students can develop critical 21st-century skills such as digital citizenship, data literacy, and digital ethics. In this context, teaching digital footprints is essential for students to protect their online privacy and become ethical individuals in the digital world (Livingstone and Third, 2017).

In the context of the digital economy, which Zuboff (2019) defines as "surveillance capitalism", digital footprints are not only an issue of individual

privacy but are also entangled with multi-layered ethical issues such as global data exploitation, algorithmic biases, and digital inequalities. Therefore, digital footprint education should be approached as an interdisciplinary field of education that encompasses themes such as information ethics, cultural awareness, and responsible technology use (Emejulu & McGregor, 2016).

Finally, a recent study examining the environmental impacts of digital technologies has shown that elements such as digital infrastructure and industrial automation can reduce carbon emissions at the city level. This impact is felt positively not only at the local level but also in neighboring regions, demonstrating that digitalization can make indirect contributions to environmental sustainability (Shen et al., 2023).

Artificial Intelligence Footprint

Recently, the use of AI has risen steeply, particularly through GenAI applications. While users may not realize it, these technologies are making significant impacts on environmental sustainability. The high processing power and data requirement of GenAI increase energy consumption, which causes carbon emissions. Therefore, each user unwittingly creates an environmental *artificial intelligence footprint* while using GenAI applications (e.g. **Figure 6**). However, most users are unaware of the environmental impact of GenAI.

Current research reveals that these models consume high amounts of energy in their training and release processes, and significantly consume environmental resources such as water. In the literature, the effects of GenAI on the environment are discussed with several examples, and suggestions are presented to lower these effects. The concept of artificial intelligence footprint can be defined as the totality of carbon emissions, energy consumption, data processing load and ethical-interactive consequences arising from the use and development of AI-based technologies.

The study by Strubell et al. (2020) is an important piece of research that draws attention to the environmental impacts of AI models. The study found that the carbon emissions generated during the training of LLMs such as BERT and GPT-2 are quite high and that this process requires a significant amount of energy consumption. This finding demonstrates that the efficiency and productivity offered by AI systems come at an invisible environmental cost. Therefore, the development of AI technologies must consider not only accuracy and processing power but also energy efficiency and environmental responsibility.

GenAI models place important pressure on environmental sustainability, particularly due to their high computational power and large data requirements. A study conducted by Ding et al. (2025) examined 369 GenAI models developed between 2018 and 2024 and found that the energy consumption and carbon emissions of these models are particularly high in countries with high carbon intensity. According to the research results, China and the US account for 99% of productive AI-related emissions. Carbon emissions were calculated at 6.76–8.98 million tons in China and 3.66–8.72 million tons in the

US. In low-carbon intensity countries such as Sweden, these values are seen to be quite low. Furthermore, while the finance and healthcare sectors account for the highest energy consumption related to AI, the education sector poses a more limited burden in this regard.

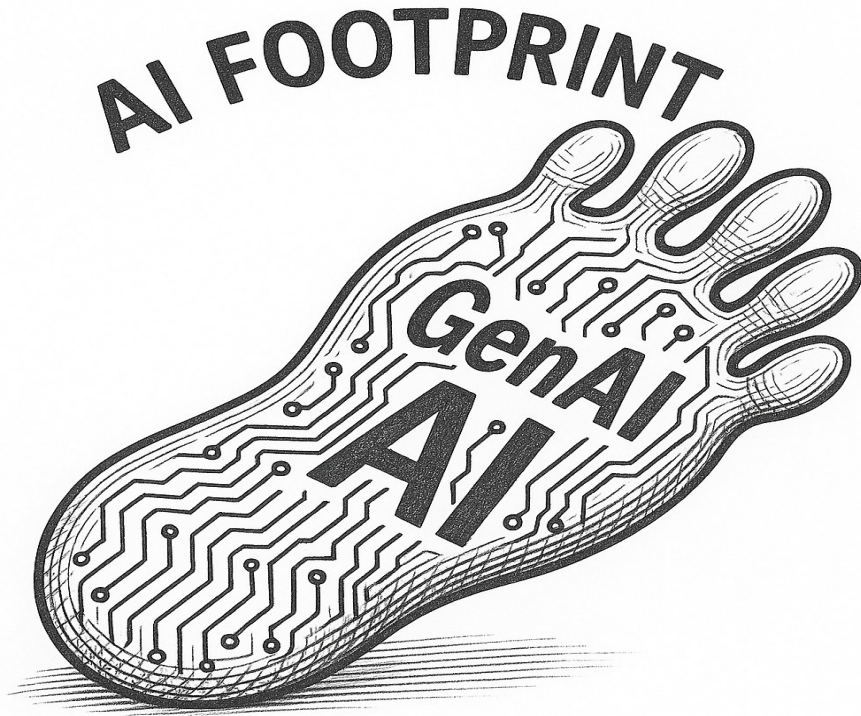


Figure 6. Artificial Intelligence Footprint

Explanatory note. This figure was created by the authors using ChatGPT (OpenAI), 2025.

The environmental impacts of AI models are generally assessed through their carbon footprint. However, some studies also examine the effects of AI on water consumption. Water consumption arising during the training processes of AI applications, especially LLMs (e.g., GPT-3), presents a significant problem. In this context, a study found that about 5.4 million liters of water were consumed during the training of the GPT-3 model. This consumption stems from the cooling processes of data centers, and it has been observed that more water is required, especially during hot periods. The research results show that AI systems create sustainability problems not only in terms of carbon footprint but also in terms of water footprint. It is recommended that data centers be relocated to cooler regions and that renewable energy sources be used (Li et al., 2025).

Also, the environmental sustainability impacts of AI technologies have become an important research topic in recent years, particularly in the context of the energy consumption of large-scale models. It has been noted that AI models generate a major carbon footprint both in operational processes

and through hardware-related factors. Research indicates that LLMs pose a high risk in terms of operational carbon footprint (Wu et al., 2022). In this context, it is emphasized that energy efficiency strategies need to be developed to reduce the environmental impact of AI models. Approaches such as model optimization and the use of low-energy hardware have the potential to significantly reduce carbon emissions. Furthermore, encouraging the use of renewable energy sources increases the sustainability level of AI applications.

The Green AI approach offers a comprehensive perspective aimed at minimizing the environmental impact of AI systems. This approach advocates for the development of AI models with a focus on environmental sustainability and promotes the adoption of green computing strategies to reduce energy consumption. Green AI is not just a technological preference but also a holistic and strategic approach that supports long-term environmental well-being. Ensuring that AI systems developed within this framework consider criteria such as energy efficiency and resource utilization is a fundamental requirement for sustainable digital transformation (Mitu and Mitu, 2024; Wang et al., 2024).

In contrast, the Red AI approach, commonly encountered in the field of AI, aims to maximize model accuracy while ignoring the major environmental and computational costs incurred in achieving this success. The development of LLMs, which involves using millions of parameters and training on massive datasets, often results in only very small increases in accuracy. For example, it is common for increasing a model's accuracy by 1% to require thousands of times more processing power and energy consumption. This situation leads to significant carbon emissions and energy consumption, while also creating barriers to access for low-resource research groups. Red AI inclines to prioritize computational power in this race, often at the expense of environmental sustainability, ethical concerns and principles of equitable access (Schwartz et al., 2020).

To reduce the environmental impacts of AI technologies, countries must develop long-term plans, integrate these technologies into their development strategies and express policies united with sustainability goals. Particularly in industrialized countries, it is crucial to direct AI applications in a manner that supports the energy transition. In this context, a study conducted in China compared 30 regions and found that AI usage meaningfully reduced the ecological footprint per capita in eastern and central regions, thanks to advanced technological infrastructure and environmentally friendly applications. In contrast, it was determined that a similar effect could not be achieved in Western regions due to infrastructure deficiencies and limited applications. The findings show that not only technology investments but also comprehensive strategies sensitive to regional conditions are necessary (Wang et al., 2024).

The fast-increasing use of AI and GenAI models also raises major problems in terms of environmental sustainability. A review of the literature reveals that AI applications requiring high processing power, particularly LLMs, have environmental impacts in terms of both carbon emissions and water consumption. In this context, the unconscious use of AI and GenAI models poses an even

greater threat to our future. Some studies in the literature reveal that this environmental impact is closely related to model architecture. Sparse models consume much less energy than intensive models because they only run the necessary processing steps and can therefore significantly reduce carbon emissions (Patterson et al., 2021).

Therefore, it is crucial to increase users' awareness of the AI footprint they create when using AI models. To reduce the environmental impact of AI models, a Green AI approach needs to be adopted and individuals need to be made aware of this issue. It is very important for our future that not only the manufacturers and developers of these models, but also the users, take responsibility for making AI models more sustainable. It plays an important role for individuals to understand the concept of artificial intelligence footprint and use these models consciously, while also reducing environmental impacts. In this context, it is necessary to increase the awareness of individuals and society and it will affect the more conscious and sustainable use of AI models by individuals.

While the use of AI tools in education supports learning processes, students should also question the invisible effects of these technologies. AI footprint awareness in education can be developed in individuals by:

- Energy awareness should be instilled: The processing load and carbon footprints of tools such as ChatGPT and Midjourney can be explained.
- Data ethics education should be provided: Discussions should be held with students based on questions such as "Where did this system get my data?"
- Ethical usage protocols should be developed: It should be determined how, for what purpose, and within what limits AI systems will be used in schools.

Conclusion

Artificial intelligence (AI) and generative artificial intelligence (GenAI) models are rapidly developing and becoming an indispensable part of daily life. AI and GenAI tools/models make it easier to think, write and produce. It saves users' time, speeds up work and maybe even makes its users more productive individuals. However, behind these conveniences, there are often invisible environmental effects. Every new content, every output, every line of data consumes energy, consumes water and emits carbon. In other words, these systems, where users get help, shape our future on the one hand and consume it on the other. It is no longer only important what we do and how fast, but also what trace we leave behind. Because every technological convenience leaves a mark on the future. So, how aware are we of this impact on the future?

When raising the next generation, it is essential to discuss this concept within educational programs and to raise our children, who are our future, with this awareness. Especially today, when rapidly developing technologies such as the Internet of Things have become part of everyday life, children and young people must be raised not only to use these tools but also to question

their effects and think in terms of sustainability. This awareness begins at an early age. When teaching our children about technology, we must also teach them about its footprint.

As Galli et al. (2012) have demonstrated, the concepts of carbon, water, and ecological footprints should not be considered independently but rather addressed holistically under the term "*footprint family*". In this study, we argue that new generation footprints, such as the digital footprint and artificial intelligence footprint, which have expanded this conceptual structure due to the impact of the digital age, should also be included in this family. When the literature is examined, we argue that the concept of footprint family has evolved with digitalization and in this context, new generation footprint types should be included in this structure.

The footprint of technology transforms not only the environment but also the individual. Sustainability has now become a multi-layered concept that includes not only environmental but also ethical, digital, social and pedagogical dimensions. Today's technological tools have multiple intertwined effects in areas such as energy use, data security, privacy and ethical responsibility.

Every trace we leave in digital environments affects not only today but also tomorrow. For this reason, it is important to not only understand how we use technology but also to be aware of and question its impacts. Educational environments are one of the most powerful grounds for this awareness to develop. Children and young people are not just consumers of information, but also carriers of data, energy and ethical decisions. Therefore, footprint awareness should be the cornerstone not only of science classes but also of digital citizenship, environmental ethics and social responsibility education.

The *footprint family* has now expanded. And recognizing, promoting and questioning this expanding structure is one of the most basic responsibilities of today. Because today's technological tools interact not only with environmental but also with multi-layered areas such as data security, energy use, ethical responsibility and privacy. Therefore, sustainability is no longer just an environmental issue but has become a multidimensional conceptual framework that requires an interdisciplinary perspective. In educational environments, this awareness should be gained from an early age and even users should learn that there may be a footprint behind every click, every algorithm, every line of code.

Today's technological tools interact not only with the environment but also with many other sub-dimensions such as data security, energy use, ethical responsibility and privacy. Therefore, sustainability is no longer just an environmental issue but a conceptual framework that needs to be addressed with a multidimensional and interdisciplinary approach. For this reason, increasing the awareness of individuals and society, especially the younger generation about digital and AI footprints has become a fundamental necessity for more ethical, conscious and sustainable use of technology.

AI systems are growing and developing day by day and are now becoming an integral part of daily life. With these systems, production accelerates, processes become easier and time saving becomes inevitable. However, behind every ease there is an invisible trace. Because every convenience provided by AI systems has an impact on the environment, society and the future. This mark has become not only today's responsibility but also tomorrow's responsibility. For this reason, when using technology, it is necessary not only to benefit from it but also to be aware of the traces we leave behind. Every user, every institution and every educator should be able to recognize, understand and question the trace left behind by technology. Because the sustainability of the future is possible not only by producing technology but also by recognizing its footprint.

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