sustainability

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# Assessing Education for Sustainable Development in Engineering Study Programs: A Case of AI Ecosystem Creation

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**Abstract:** The issue of sustainability in education has never been more important for the future of our environment, and strategies to develop the skills needed by younger generations to meet this significant global challenge should be developed across all curricula. There is much focus on the topic of sustainability in business, finance, climate, health, water and education; however, there are some challenges when sustainability needs to be integrated into engineering or fundamental study programs (SPs). In the latter, sustainability is more often emphasized and implemented through its general principles or separate modules in social sciences and project activities. There are a number of questions and challenges in how to highlight sustainability aspects and evaluation metrics due to the specifics of the engineering study field. For evaluating the sustainability level in engineering studies, a hierarchical methodology employing the SAMR (Substitution, Augmentation, Modification, Redefinition) model is proposed, taking a technological university in Lithuania as the case study. As a more concrete example, the first and second cycle SPs titled 'Artificial Intelligence' are described and analyzed in all relevant perspectives of sustainability. The study proposes five tangible criteria that must be emphasized in the learning process in order to ensure the development of sustainability goals in IT/AI study programs.

**Keywords:** sustainability; high education; engineering study programs; Artificial Intelligence

**Citation:** Paulauskaite-Tarasseviciene, A.; Lagzdinyte-Budnike, I.; Gaiziuniene, L.; Sukacke, V.; Daniuseviciute-Brazaite, L. Assessing Education for Sustainable Development in Engineering Study Programs: A Case of AI Ecosystem Creation. *Sustainability* **2022**, *14*, 1702. https://doi.org/10.3390/su14031702

Academic Editor: Barbara Motyl

Received: 13 December 2021
Accepted: 28 January 2022
Published: 1 February 2022



## 1. Introduction

In general, Education for Sustainable Development (ESD) provides and develops the knowledge, skills, values and worldview needed by members of society to act in a way that contributes to more sustainable lifestyles and for tackling the global challenges we face, including climate change, environmental degradation, consumerism, etc. Looking purely from a teaching perspective, ESD is an educational approach with the aim to raise awareness and knowledge of sustainability issues, to develop critical thinking and reflection, and to develop innovation and solutions for a more sustainable way of life. ESD is geared towards our future, with a focus on protecting the environment and building green and eco solutions employing our knowledge, experience, science and innovative technologies [1]. Such education is fostered by a broad understanding of education and learning, as it aims to help people understand the importance of collaboration, where synergy between economic, social, ethical and engineering approaches is essential.

The changes brought about by the ideology of sustainability are already visible in many areas such as business, industry, the public sector, and the behavior of certain members of society [2–4]. Therefore, higher education needs to react to these needs and changes as well, in order to educate sustainability-conscious graduates [5]. 'Cheaper, faster, and more'—these are the aspirations of the last century. Nevertheless, the purpose of business is no longer just to make a profit. It must be responsible, non-corrupt, reliable, open, as well as friendly to employees and to society in general, and, of course, to the environment. Future engineers are expected to be able to handle complexity and ongoing changes in the workplace, which relate not only to product and technology development but also to social change [6]. This means that the component of sustainability must be integrated into classical theory, knowledge, projects and final theses already in the study programs in order to prepare the professionals of the new generation. For example, in the study programs of energy engineering, in addition to basic and essential knowledge, information about the transformation of energy systems, conventional and renewable energy sources or how to supply energy at the lowest environmental and social costs must be provided as well. In design technologies, it is fundamentally important to teach how to combine creativity with knowledge of sustainability in order to design ecologically and ethically produced products and materials. In study programs in architecture and constructions, the main focus is on sustainable architectural design and BIM (building information modelling) decisions, etc.

The issue of sustainability in education has never been more important for the future of our environment, and strategies to develop the skills needed by the younger generation to meet this significant global challenge should be discussed, planned and developed in all study programs. The most commonly developed sustainability competencies and relevant knowledge specific to sustainability topics (e.g., water, renewable energy, and the carbon cycle) come from the natural and social sciences and the humanities [7]. Specific learning objectives include forward-, values-, and strategic-thinking, networking, and transdisciplinary competencies, etc. [8]. Despite the rather clear purpose, there are some challenges when the sustainability paradigm needs to be integrated into computer science, mathematics, physics or other fundamental study programs or modules. Currently, in the study programs of IT and computer science most of the modules are related to the development of professional competencies in the field, as they include knowledge of computer science, mathematics, IT systems design, and other relevant essentials [9]. Such study programs and their content are not directly related to sustainability, therefore, sustainability is more often emphasized and implemented through the above-mentioned competencies promoting the perception of sustainability, including separate social and humanitarian modules or project activities and final thesis or by providing recommendations for improvements [10–12]. Understanding the concept and importance of sustainability is the first step if educational institutions want to train future IT engineers to incorporate sustainability into the software development lifecycle [10] and be able to create innovative solutions achieving the targets of the UN's Sustainable Development Goals (SDGs). There are, however, a number of questions and challenges in how to properly integrate sustainability theory into engineering study programs [9].

To address these existing issues, the present paper provides a description and analysis of a case where sustainability is implemented into the curricula across different study programs at a technical university in Lithuania. To provide a more specific example and to showcase a success story, the paper focuses on the study programs called 'Artificial Intelligence', which are taught on the undergraduate and graduate levels. In doing so, the authors also describe and propose a novel methodology which can be used to evaluate the sustainability level of the engineering studies in the early stages of its integration.

*Study Programmes for Sustainability Development at Different Universities Around the World*

In terms of all sustainability-oriented study programs, the majority of existing undergraduate (or bachelor's, BSc) and graduate programs (or master's, MSc) focus on the fields of economics, social sciences and general sustainability, which often provide an understanding of the global sustainability goal in order to become the sustainability leaders of tomorrow. As can be found in the statistics on study programs, study programs with such titles as 'Sustainable Management', 'Sustainability', 'Sustainability Development', 'Global Sustainability', 'Sustainability Environments' or 'Sustainable Design Project' are the most common (see Figure 1). It can be seen that most programs focus on sustainable economics, with 33% in the BSc and 36% in MSc programs. Study programs in the field of sustainable environment are in the second place for both study cycles, 26% in BSc and 30% for MSc (Figure 1). In addition, BSc study programs are more focused on the direction in which management paradigms will be developed, while MSs studies do not necessarily focus on the development of general principles of sustainability or the specific needs of the market or region (21% of all SPs on sustainability).

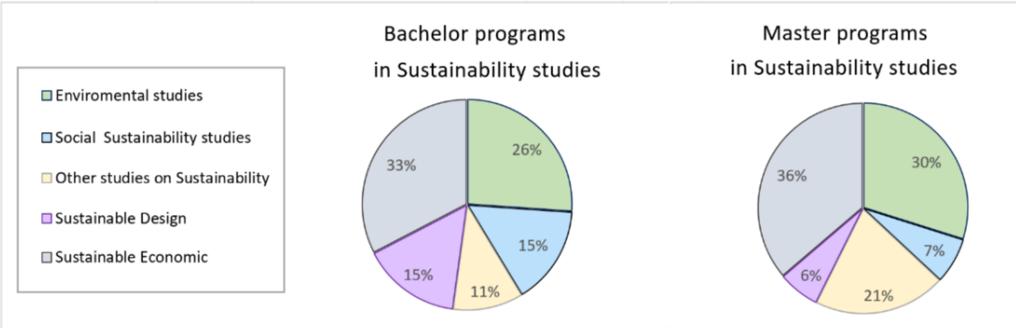


**Figure 1.** Frequency of study programs in the field of sustainability 2021 (statistics generated from data provided at https://www.masterstudies.com (accessed on 20 November 2021)).

Based on the objectives of the sustainability-focused study programs and the modules (as well as their content) included, various skills and competences can be noticed. The most common ones across the different study programs are the ability to develop collaborative solutions based on ecological and socio-economic sustainability, analytical and critical thinking, understanding of the SDGs' implementation pathways, global awareness, strengthened leadership and communication skills of a multidisciplinary research team. In general, the existing study programs could be divided into five main groups, which are further subdivided into the following subgroups:

1. *Environmental sustainability* in general mostly provides the fundamentals for climate, water, and life protection. Study programs (SPs) in this area focus on the changing climate, natural resource depletion, and increased demands on our food, water, and energy resources as well as on the transition to a more sustainable environment and society. Some of the SPs are interdisciplinary, with a wide range of specific objectives (e.g., 'Strategic Earth resources', 'Climate and society'", 'Global energy and climate policy'); however, the majority of such SPs are focused on one of the following five areas:
    - *Agriculture and Food* is the largest group in the category of environmental study programs. It covers the fundamentals of sustainable agriculture that enables students to acquire solid competencies on alternative agriculture, reinforcing their capacity for critical reflection on the sustainability issues of agricultural systems and the creation of new solutions. In general, students develop knowledge about digital agriculture technologies, alternative agriculture, principles of sustainable agriculture, smart farm management, advanced machinery for precision farming, and assessment methods of food quality and safety.
    - *Land and Soil* management programs basically focus on two themes, namely, soil science or land resource engineering. Therefore, sustainable land and soil management, landscape ecology, plant nutrition, plant health, global soil threats, and ecosystem services are the key topics.
    - *Resource management* SPs seek to educate a new generation of professionals with a holistic understanding of advanced technologies for resource management, who are familiar with the concepts of sustainability and have innovative think-

ing to increase the economic importance of the sector. The main focus is on renewable energy sources, natural resources management, global food and water challenges, causes and consequences of environmental change, environmental law, ethics and public policies, and global sustainable features, etc.

- *Climate and Environment* SPs aim to train students to tackle global environmental and sustainability challenges, providing an understanding of different ecosystems and giving guidance toward their sustainable use. It has been noted that some of the most practical MSc programs are destination-based or context-based, because they are held at the campus in the specific countries or islands (e.g., climate change in the Arctic ecosystems and societies in Iceland). Either way, the main topics are about climate-based decisions, ecosystem analysis, materials for pollution control, and advanced climate modelling techniques, etc.
- *Disaster management* SPs offer interdisciplinary comprehension and skills that meet the needs of modern emergency management and disaster response. SDGs address the global challenges, including those related to poverty and inequality, climate and environmental degradation, prosperity, peace and justice. Students learn about disaster preparedness and planning methodologies, disaster response, recovery and risk managements, the importance of geo-information in disaster situations, shelter and settlements in disasters and so on.

2. *Sustainable Design* SPs are trans-disciplinary, collaborative design programs in which students can obtain problem-solving skills to develop market-driven solutions and become leaders in sustainable design. The most common SPs in this field have such titles as ‘Sustainable Design’, ‘Sustainable Urban Design’, and ‘Sustainable Architecture’. To summarize, sustainable design education can be divided into four more specific fields:
    - *Art sustainability* SPs give opportunities to develop a range of skills that will allow students to go through all of the stages linked to ethical art (e.g., fashion, furniture, vehicles, etc.), including trends, research on eco-innovation, eco material and fabric selection, merchandising plan, product eco-design, sustainability prototype development and production procedures.
    - *Urbanism* SPs are oriented to educating a new generation of urban practitioners to deal with the enormous environmental, cultural, socio-economic and governance challenges that result from the dynamic urban transformation around the world.
    - *Sustainable architecture* SPs aim to provide greater understanding of sustainability issues in the built environment, because architecture design plays a very important role in environmental impact.
    - *Global design* SPs develop broad interdisciplinary education on various SDGs. In general, the curriculum integrates the natural sciences, technology, economics, policy, ethics, and other areas; however, students can undertake a focused study on topics such as alternative energy, pollution, conservation, public policy and law, healthy living, and sustainability management in business and industry.
3. *Social Sustainability* SPs teach for the development of long-term solutions to local and global challenges by understanding the connections between social equity, environmental and economic well-being. Such programs seek to help students think across disciplines, through explorations of concepts, case studies, and projects in the framework of social sustainability. The purpose of such SPs is to develop skills for sustainability design, assessment, communication, conflict resolution, advocacy, policy and to provide the skills required to develop new approaches to a more sustainable world. There are two main types of SPs in this group:

- *Infrastructure planning* SPs teach how to design innovative policy solutions for more sustainable living through the analysis of urban (regional) planning strategies, infrastructure-related challenges and governance approaches for complicated situations.
- *Inequalities and justice* SPs provide skills to become an expert in the field of social inequality from different scientific perspectives (e.g., a study program of 'Languages and Social Justice'). In addition, such programs provide essential critical, analytical, methodological skills, as well as the ability to provide valuable insights into the causes and consequences of social inequality, to identify the ways in which social policy can reduce them.

4. *Sustainable Economics* SPs aim to develop key transdisciplinary skills in management and sustainability. They provide the understanding of how strong the connection is between business, society, and the environment. Why long-term improvements in the economic performance of companies and countries can only be achieved if people are protected, their dignity is enhanced, social welfare is enhanced, natural resources are managed efficiently, and the global environment is protected.
    - *Sustainable business* SPs operate at the intersection of engineering, management and economics. The programs teach about sustainability challenges, and the technological and other options that businesses can use to work in a more environmentally and socially friendly manner. Moreover, students will learn about sustainability innovations, life cycle assessment, ecoefficiency production, sustainability reporting and how to help business in their journey toward making societies more sustainable (e.g., 'Global Sustainable Business Management, and 'International Business Sustainable Finance').
    - *Sustainability Management and Development* SPs provide the skills to explore how sustainability is changing all levels of management and teach students to analyze organizational problems in their environmental context and to produce economic, ecological, and socially responsible solutions. Such programs aim to educate students to identify the threats and risks as well as the opportunities related to activities at a global level. After graduating from such SPs, students are able to maximize and monitor the development of green products and services in order to create sustainable value for their organization (e.g., a study program called 'Responsible Management and Sustainable Economic Development').
5. *Other studies on Sustainability* are oriented to a very specific area, problem or sector. At the same time there exist SPs that develop general skills for enhancing a sustainable ecosystem, such as sustainability principles, global goals, our environment and its future, and so on. The SPs in this category can be classified into the following:
    - *Sustainable systems* SPs try to balance between sustainable Natural Sciences and sustainable Humanities. These SPs teach how to translate social and ecological theories and technological innovations into effective sustainable development policies and practices. They also focus on how to use resilience thinking as an approach to managing socio-ecological systems and to help people solve real-world problems (e.g., SPs called 'Sustainable Digital Life' and 'Sustainable Food Systems').
    - *Energy efficiency* SPs aim to provide knowledge of the various energy technologies and respect for the environment necessary to address energy and environmental sustainability issues (e.g., SPs such as 'Sustainable Transportation and Electrical Power Systems'). These SPs teach students to carry out research and practical activities related to renewable energy, energy saving and efficiency, focusing on the sustainability of the industrial and construction sectors. Students get training in resource assessment, technology knowledge, and monitoring, etc.

- *Sustainable Chemistry* SPs have curricula that teach how to understand and apply chemistry in the context of sustainability, from the molecular level to global product flows, sustainability assessment, and alternative models for chemicals (e.g., SPs such as 'Sustainable Chemistry'). Another focus is on the creation of new chemical processes that are environmentally friendly, thus reducing the consumption of energy and raw material (e.g., SPs such as 'Chemistry of Sustainable Processes and Materials')
- *Education* SPs increase the knowledge about learning processes with a focus on different learning modes and methods to foster skills in sustainability education. Such SPs teach to design and implement sustainable solutions in a variety of settings, including schools, non-profit organizations, land, etc. Study programs like 'Pedagogy and Teaching for Sustainability' and 'Outdoor and Sustainability Education' are only a few examples in the field.
- *Miscellaneous* SPs include programs on sustainable digital life, marketing and leadership, politics, aviation and aerospace, tourism management or region-specific programs, for example, 'Island and Sustainability', 'Renewable Energy in the Marine Environment', 'North Sea Energy Law', and 'Island: Climate Change and the Arctic'.

Figure 2 summarizes the key competencies that, as was reported in this section earlier, are developed in sustainability-focused SPs. These competencies are really valuable because they foster sustainable thinking, emphasize the problem itself, and ultimately it is hoped that sustainable ideas can be applied by the student in his or her professional career. There are some doubts as to whether this is enough. In all study programs, it is emphasized that it is fundamentally important to provide as much as possible interdisciplinary knowledge on sustainability because novel and valuable sustainable solutions require the competencies of representatives of different fields. One might argue that in reality, the SPs that include the so-called sustainability buzzwords in the title and priorities of SDGs in their descriptions may not give the expected study outcomes and this is especially true because such sustainability-enhancing ideas and practices often require innovative technologies, automation, or artificial intelligence (AI) solutions.

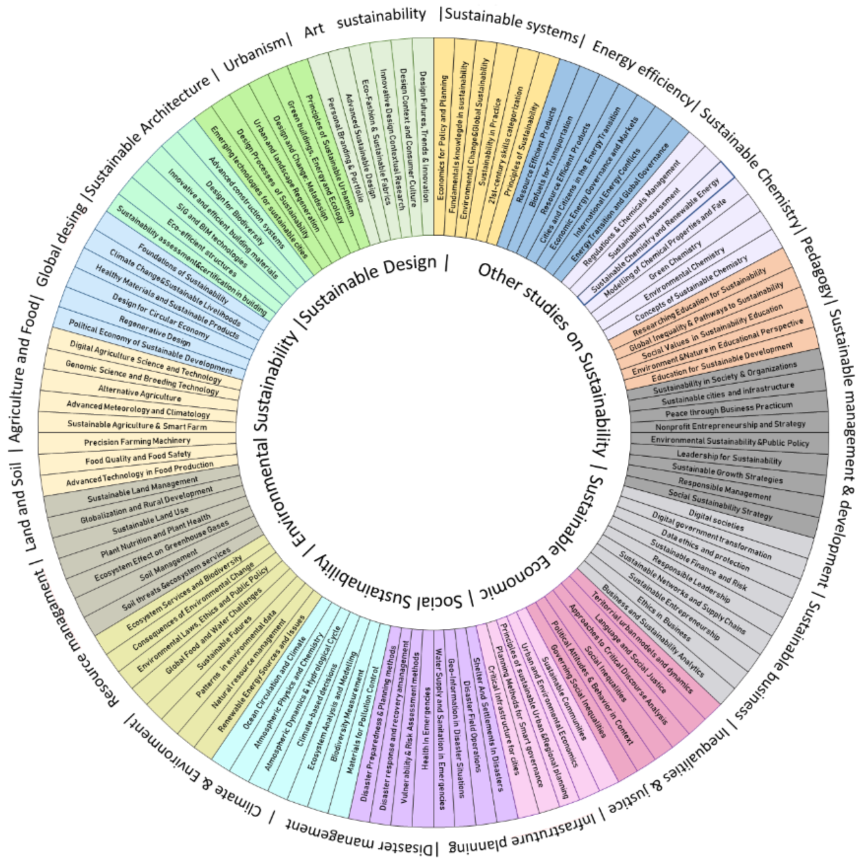


**Figure 2.** Key competencies developed in sustainability study programs over 2021 (created by authors based on https://www.masterstudies.com (accessed on 20 November 2021)).

It is important to note that there are almost no SPs related to the development of sustainability in computer science, mathematics or physics. Such a phenomenon may have a reasonable explanation (priority to more technical skills, rigorous classical theory, etc.), but it does not mean that these study programs must be left outside the ideology of sustainability. There are a number of ways and methodologies to emphasize sustainability within certain curriculum modules, but this requires a creative approach, the support of curriculum leaders, and the involvement of teachers in mentoring students in the right direction to show where sustainability can be promoted and strengthened. This means that not only the student, but also the administration, the teacher, and certain aspects of the theory being taught, goals and solutions have to be changed accordingly. At present, some topics or goals of sustainability theory are noticeable across different institutions in project activities, sometimes for the purposes of final theses, but nothing more. This indicates that when assessing the integration of sustainability into studies and looking for ways to strengthen it, we need to examine not only the modules declaring the features of sustainability in their title, but also to analyze in detail the whole study process with its elements, covering both topics and activities, as well as the study and assessment methods, resources, and other important elements of the study process.

## 2. An Overview of the Study Area

The benefits of ESD are visible to a wide range of stakeholders. Overcoming the sharp separation between the disciplines in higher education and emphasizing interdisciplinary approaches places people in a better position to restore meaningfulness and to face today's challenges [13–15]. Universities hold the responsibility for creating learning opportunities in order to wisely shape people's perspectives and their relationships with diverse ecosystems so that life on our planet is possible. The key problem is that despite the strategies and goals of various societies and communities, the integration of ESD in higher education still faces some challenges [16–20]. These cover aspects in different levels of the study process, from the lack of support for faculty training, efficient teaching materials and incorporation of sustainability in the instruments for quality assessment of degree programs [21], to issues of engineering schools or universities only including the question of sustainability in their curricula to a considerably limited extent [22]. When it comes to engineering education for sustainable development, there is no clear consensus on the definition or the list of desired competencies, skills, or learning outcomes [23]. In many cases, the focus in the curricula of the universities is still on providing engineers with the knowledge to solve technological problems without considering the social and environmental impact of their work [24,25].

Nowadays, research is related to setting the number of study modules that appear in engineering study programs related to sustainability [23,26,27], the benefits of sustainability in an engineering curriculum [28,29] and emerging challenges in engineering education [16]. Research studies reveal that the main advantage is that the integration of sustainability into curriculum design, implementation, and evaluation inspires greater social responsibility in engineering students' decision-making processes. It helps to create smarter solutions focused on society, its development, and well-being. It can be seen from the research results that sustainability is implemented in study programs at different levels and to a varying extent. Therefore, the problem is that only individual topics appear in the study programs, which do not help to develop all the necessary competencies; however, there is a lack of research to assess the implementation of sustainability and the systematic nature of the sustainability implementation process. In addition, the accounts of implementation success stories are scarce, especially when it comes to providing clear metrics that can be used to assess students and the overall implementation of sustainability in such study areas as IT.

ESD should be holistically integrated across all students' learning pathways. In the research [30] it has been noted that few faculty members give adequate attention to the transfer of sustainability concepts to students during teaching the principles of engineering design, while the majority of them focus on physical foundations and mathematical approaches in the content and learning outcomes. Sustainability concepts must be embedded in the student culture and not imposed by force as a necessary design standard so that students understand the need for its practice in their daily lives as well as in their professional thinking style.

Research also focuses on how sustainability is implemented in terms of content that includes the integration of the SDGs [31,32]. SDGs are also known as the Global Goals, which were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. Different study disciplines focus on areas relevant to them, albeit they sometimes lack a holistic approach. Research results [33] indicate strong signs of SDG 4 (quality education) at the School of Education and the School of Social Sciences as well as SDG 3 (good-health and well-being) at the School of Health Sciences. It is very important that sustainability topics are integrated into engineering studies as much as possible, since this shapes sustainability-related values.

Approaches to sustainable higher education may vary as well as the criteria used to assess how effectively sustainability is integrated. Scholarly work indicates such criteria as progress [34,35] or spectrum [36] of students' or teachers' ESD competencies [37,38] and these are assessed most commonly; however, it is recommended that the institution implements and assesses the following practices on the path to sustainability: (1) institution's mission and purpose for the sustainability problem; (2) the inclusion of the concept of sustainability in all academic disciplines; (3) whether students learn about institutional values and practices for the development of a sustainable ecosystem; (4) institutional support for activities that emphasize sustainability; and (5) collaboration forming partnerships at a national and international level to enhance sustainability [32].

In order to shape students' correct understanding of sustainability, its concepts should be integrated with the topics covered, course learning outcomes, study objects, and the assessment approach [30]. Authors in the paper [39] highlight the importance of teachers being able to adapt the constantly changing content, approach, and examples of education. Each study subject (module) has its own essential content, which is constantly updated with innovations [40]. Usually, each innovative study method has certain activities, tasks, and actions that must be flexible in relation to the study subjects, i.e., it must be adapted to them. Modification of tasks, activities, and tests are necessary depending on the learning outcomes and the emergence of new relevant topics. They should be adapted according to the selected tasks and according to the groups of students. To be more specific, it may be suggested that the most significant components to be adapted by teachers in the constantly changing teaching/learning process are subject content, activities, and the assessment process [41]. It is important to model the essential activities so that they correspond to the learning outcomes. The evaluation system must also be adapted according to what activities were organized and what content was taught as well as what it was intended to do or achieve. Therefore, it is important not only to include sustainability themes, topics, and components, but to also identify the appropriate tasks, examples, and activities, or perhaps even new study methods and how to assess the success of their implementation. In many cases, the inclusion of ESD also changes the assessment methods and learning outcomes.

As mentioned in several studies indicated previously, it is relevant to explore a holistic view of how the sustainability dimension is integrated into studies. In this case, it might be suggested that it is important to study the path of sustainability implementation. It might be done by assessing such quantitative and qualitative metrics as whether and how the sustainability-related topics change in the modules, what competencies are developed, whether and how the number of sustainability topics in both modules and final projects is increasing, how much time is spent on sustainability education, and whether sustainability is developed in parallel in all engineering studies.

It is important to reveal not only what (sustainability dimension) should be implemented, but also how ESD should be implemented. Different higher education institutions, study programs, and teachers accept and implement the dimension of sustainability in different ways, at different scales and speeds. That is, some make a decision about innovation immediately, while others fluctuate for a long time and the implementation of sustainability can be recognized at different levels. In some SPs only one study module which has a sustainability dimension can be integrated, whereas in others sustainability can be developed through several competencies. Furthermore, there may be SPs in which sustainability can cover the entire scope of the study program and although there are many studies that analyze the extent to which sustainability issues have emerged in studies, emphasizing that they are growing, the main problem is that sustainability education, including such important aspects as its assessment, is unsystematic [26,42].

It is especially noticeable in the cases where the ideas of sustainability in higher education are implemented in a fragmented way and are often not even reflected in the titles of the programs or modules. As a result, there is no way to identify and systematically strengthen the level of integration of the sustainability aspects. The authors believe that their proposed methodology could fill this gap and suggest a way to identify sustainability-related study elements in various contexts (e.g., certain module topics, activities, events, project work, teaching methods, etc.) and to show how to strengthen and develop them in a more systematic way until these elements become part of the core ESD competencies.

## 3. Methods

The present paper is based on the case study design. This case study is qualitative and aims to provide an in-depth description and analysis of a particular example (case) that is focused on the assessment of education for sustainable development in the Artificial Intelligence (AI) study area.

In the previous section, it was stated that the integration of sustainability into SPs can be detected by trying to identify its features at a more detailed level than the module title. That is, it can be done by analyzing the topics of the module, the study results, the aim of the module, and the defended final projects; however, these are not enough to provide a more in-depth holistic assessment. Therefore, the authors of this publication suggest a way to determine whether a program has the characteristics of sustainability with the help of more detailed metrics. It is suggested to build on the SAMR (Substitution Augmentation Modification Redefinition) model presented by [43] and to show how the levels in this model relate to more detailed sustainability assessment metrics.

The SAMR model describes different degrees of technology integration that enable change in education from barely switching from something traditional to digital towards completely transforming learning. The model allows to visualize the consistent process of using and integrating particular technology into a subject [44,45]. There are successful examples of SAMR combinations with other methodologies, for example, with the Technological Pedagogical Content Knowledge model (TPACK) [46–48] that essentially explains how teachers make pedagogically informed decisions on how to teach specific content with the help of the most suitable technology.

With regard to sustainability, the SAMR model is like a framework that can be used to evaluate how significantly the approach of sustainability development has influenced the whole process of learning, including the activities, infrastructure of the study methods, learning outcomes, etc. The SAMR model is based on Bloom's taxonomy and it shows that there are four levels of impact on the teaching/learning process. They are focused on specific cognitive goals at each stage, which, if one takes ESD as an example, are the following: (1) at the first stage, substitution, ESD allows for replacing existing topics and part of the resources (for example, recommended literature, etc.); (2) at the stage of augmentation, thematic/topics, resources, and activities are replaced by improving the functions they performed; (3) at the stage of modification, new sustainability thematic/topics allow for significantly modifying learning activities, and also allows for formulating new learning aim(s), objectives, and adding new study and assessment methods—here, the number of activities can be expanded, which sometimes is highly important when seeking to understand specific complicated learning elements; and (4) at the stage of redefinition, ESD completely replaces previous activities at the same time by transforming the teaching and learning process as well; thus, new activities, which have not existed before, emerge. These levels can help assess the depth in which ESD is embedded in SPs and modules (see Table 1).

**Table 1.** SAMR model for evaluation of sustainability integration level (model, adapted to fit ESD by authors).

| Curriculum Elements | Levels of Education for Sustainable Development Integration | | | |
|---|---|---|---|---|
| | Substitution (1) | Augmentation (2) | Modification (3) | Redefinition (4) |
| *Purpose* | | | | changes |
| *Learning outcomes* | | | might change | changes |
| *Study methods* | | | changes | changes |
| *Assessment methods* | | | changes | changes |
| *Infrastructure/resources* | changes | changes | changes | changes |
| *Activities* | | changes | changes | changes |
| *Topics* | changes | changes | changes | changes |
| *Final projects* | | changes | changes | changes |

The hierarchical scheme presented in Figure 3 describes how the SAMR model can be applied to identify and assess sustainability integration in a field of study, study program, or module. The unique value of the proposed method is that sustainability implementation, its impact on learning processes and potential for improvement are analyzed by assessing different elements of each study field, study program or study module. This makes it possible to identify the signs of sustainability in the early stages of its integration or in cases where aspects of sustainability are not highlighted in the title of the study program or module, even though they are implemented in the study process itself.

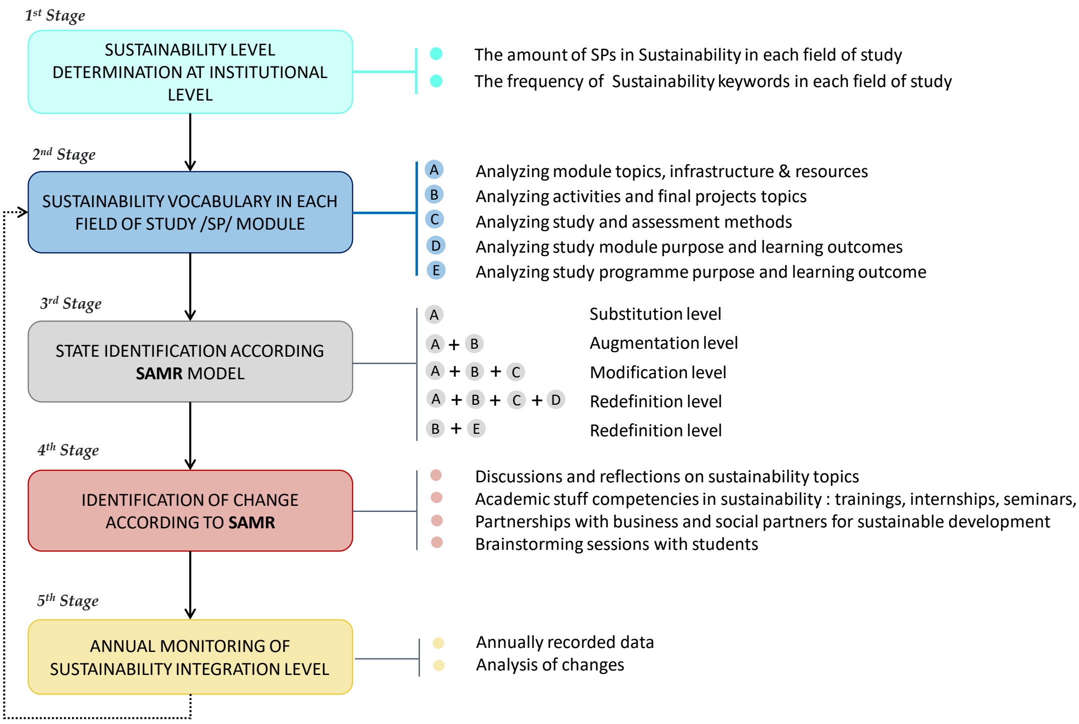


**Figure 3.** Hierarchical scheme of the proposed methodology implemented in the Artificial Intelligence study programs.

Parts of the proposed methodology (Figure 3) were developed and implemented by integrating the ideology of sustainability in 'Artificial Intelligence' study programs that are taught to BSc and MSc students at a technological university in Lithuania. The achieved results are discussed in the next section of the paper. This section further describes the proposed assessment methodology that consists of several stages, which are elaborated upon below.

In stage 1, it is proposed to identify: (A) the number of SPs that declare sustainability aspects in their name; (B) the number of fields of study where signs of sustainability are found, although such field is not mentioned in the title of the SP.

In case A, it is recommended to perform the analysis by searching for signs of sustainability in the titles of the study programs. In such study programs, sustainability issues are usually implemented systematically through the results of the study program, study modules and their elements (topics, study, assessment methods, etc.). Therefore, such programs can be assigned to the highest level of the SAMR model (Redefinition). It shows that the integration of sustainability aspects into the study process is high, and the impact of sustainability ideology on the study process is significant compared to what the SP or its parts might have looked like prior.

In case B, it is recommended to perform the analysis by examining the titles, annotations, goals and topics of the study modules according to the glossary of words in the field of sustainability. The obtained results of the analysis allow to identify the study fields that contain SPs that implement sustainability ideas at a certain level, although their title does not reflect this. Such programs usually require more detailed analysis to identify a more accurate level of sustainability implementation.

Stage 2 is implemented when a more detailed analysis of sustainability integration is required in a specific field of study or study program (most relevant in case B). The aim of the analysis is to search for the keywords indicating sustainability in different elements of the module, as well as to form a glossary from them. The analysis should include examining such elements of the modules as the topics, the literature recommended for reading (Group A), the practical tasks, the bachelor's and master's theses prepared and defended (Group B), the study and assessment methods (Group C), the aim of the study modules and the competencies developed (Group D), and, finally, the aim of the study program itself as well as the competencies developed (Group E).

The aim of Stage 3 is to link the dictionaries identified in the different groups to a specific level of the SAMR model. The established level shows how deep the sustainability aspects are integrated in the analyzed field of study/study program. The proposed methodology suggests which groups to associate with what level. For example, if the glossary is found only in the topics of the modules (A- > 1 association), we consider that sustainability is integrated at the lowest level. This means that the ideas of sustainability do not have a significant impact on the learning process, but potentially broadens the learners' horizons. If the glossary is found not only in the topics taught, but also in the descriptions of the competencies developed in the studies, in the competence evaluation criteria, and in the final projects (A + B + C + D association), we consider that sustainability topics are integrated at the highest level. This means that the ideas of sustainability have a significant impact on the learning process, although this is not reflected in the title of the module.

In Stage 4, it is recommended to initiate actions that could enhance the implementation of sustainability ideas in the study process. Actions should conform the degree of sustainability integration identified in Stage 3. Practical experience shows that such a principle would allow to initiate the changes needed in an individual situation more constructively and effectively. The methods used can vary widely and are discussed in a number of studies on sustainability issues [49–55]. These may include open discussions, training, traineeships for teaching staff, integration of different pedagogical approaches, participation in memberships and networks promoting sustainability, developing and applying sustainability related competence frameworks and many other activities at local, faculty or institutional levels.

In Stage 5, it is recommended to implement the monitoring and strengthening of the integration of sustainability aspects into the study process. It is recommended to evaluate the changes annually by repeating the steps described in Stages 2–4 of the proposed methodology.

## 4. Results

The proposed sustainability level assessment methodology was piloted and adapted to the assessment of implementing sustainability at a technological university in Lithuania, Kaunas University of Technology (KTU) to be more specific. The university is one of the largest technological universities in the Baltics. KTU offers studies in 42 study fields such as mathematics, informatics, physical sciences, engineering, technologies, health, social and educational sciences, humanities, arts, business, and public management. The university provides study programs of the first, second, and third study cycles. A total of 96 study programs were available for admission in the academic year 2020–2021, out of which 42 were BSc SPs, 53 MSc SPs, and 1 study program of integrated studies. Of these, 43 SPs were delivered in the English language.

### *4.1. First Stage: Determining the Implementation of Sustainability at the Institutional Level*

#### 4.1.1. The Number of SPs Including Sustainability in Their Title

KTU has six engineering faculties which were involved in the content analysis of the SPs:

- Faculty of Civil Engineering and Architecture (FCEA),
- Faculty of Informatics (IF),
- Faculty of Chemical Technology (FCT),
- Faculty of Electrical and Electronics Engineering (FEEE),
- Faculty of Mathematics and Natural Sciences, (FMNS),
- Faculty of Mechanical Engineering and Design (FMED).

There were no undergraduate programs with the word 'sustainability', 'eco', or 'green' in the title. The master's degree programs are presented in Table 2, which shows that only two SPs declared sustainable development in the field in their official title, namely, 'Sustainable and Energy Efficient Buildings' and 'Sustainable Management and Production' (Table 2).

**Table 2.** Master's degree study programs in the field of engineering.

| FCEA | IF | FMED | FCT | FEEE | FMNS |
|---|---|---|---|---|---|
| Architecture | Artificial Intelligence | Mechatronics | Industrial Biotechnology | Electronics Engineering | Applied Mathematics |
| Construction Management | Software Engineering | Mechanical Engineering | Applied Chemistry | Biomedical Engineering | Business Big Data Analytics |
| Sustainable and Energy Efficient Buildings | Information and Information Technologies Security | Sustainable Management and Production | Food Technology and Innovation | Electrical Power Engineering | Medical Physics |
| Structural and Building Products Engineering | Information Technologies of Distance Education | Textile Engineering and Finishing | Food Science and Safety | Energy Technologies and Economics | |
| | Information Systems Engineering | Industrial Engineering and Management | Medicinal Chemistry | Control Technologies | |
| | | Aeronautical Engineering | Environmental Engineering | | |
| | | | Chemical Engineering | | |

#### 4.1.2. Content Analysis of the SPs

For deeper content analysis of the SPs, quantitative data were collected on the institutional level, by searching for the SPs and specific courses that focus on or at least to some extent implement sustainability. The authors of the paper made a special query to retrieve the details on the aforementioned relevant programs and courses based on certain keywords that relate to sustainability (see Table 3). The list was piloted and validated by consulting teachers and educational managers who were involved in various sustainability-related courses, projects, etc. In terms of linguistics, the target language (i.e., Lithuanian) is a synthetical language with a lot of possible variation in the word forms, thus the search terms were surrounded by a special syntax that allowed for tracing and retrieving all the possible forms of the relevant search terms (the translation into English in Table 3 contains the full word form).

**Table 3.** Query search terms in Lithuanian and their translation into the English language.

| Search Term in Target Language (Lithuanian) | Translation into English |
| --- | --- |
| '%klimat% kait%' | Climate change |
| '%tvaru%' | Sustainable |
| '%gerovė%', '%gerove%' | Welfare |
| '%švar% energij%' | Clean energy |
| '%atsaking% vartojim%' | Responsible consumption |
| '%ekologi%' | Ecology |
| '%žalio%' | Green |
| '%atsinaujinan%' | Renewable |
| '%žiedin%' | Circular |
| '%darn%' | Sustainable |
| '%aplink% draugišk%' | Environmentally friendly |
| '%žal% finans%' | Green finance |
| '%etik%' | Ethics |

Sustainability keywords were used to evaluate the sustainability level by analyzing the descriptions and thematics/topics of the modules. The analysis showed that the sustainability aspect was addressed in a number of fields of study, although this was not reflected in the titles of the field, SPs or the study modules. After assessing all 39 of KTU's study fields at the lowest level (less than 1%), we had studies from the Faculty of Social Sciences, Arts and Humanities: in Education (0.61%), Physics (0.65%), and Philosophy (0.79%). A slightly higher result was found in Translation and Linguistics studies−1.02 %, followed by Communication, Political Sciences and Music (Figure 4).

More attention to sustainability issues was paid in such study fields as 'Environmental Engineering', 'Food Technology and Innovation', and 'Renewable Energy Engineering' (Figure 4). It should be noted, however, that sustainability integration was rather fragmented in all study areas, and there were only a few signs of a systematic approach.

On the other hand, analyzing the situation in the last four years, it was noticed that sustainability keywords were mentioned in the descriptions of modules in 2021 twice as often as in 2018. This shows the positive dynamics of the integration of sustainability issues into studies. In addition, it was observed that the topic of sustainability was more relevant in master's level studies than in bachelor's studies.


**Figure 4.** Top-20 levels of sustainability implementation according to the module descriptions of KTU's engineering study scientific fields.

During the validation of the 2nd–5th stages of the proposed methodology, two—1st and 2nd cycle study programs for 'Artificial Intelligence', that belong to the fields of Computer Science and Informatics Engineering, were selected for a more detailed analysis of the sustainability integration issues.

### *4.2. Second, Third and Fifth Stages: Sustainability Evaluation and Monitoring According to the SAMR Model*

To determine the level of sustainability integration according to the SAMR model, the following material was analyzed:

(i) bachelor's and master's theses prepared and defended in the last semester of both study programs.
(ii) elements of the 1st and 2nd cycle study program modules such as annotation, aim of the module, topics taught, declared practical activities and tasks, need for resources (including recommended literature, technical and software resources required for practical work), study and assessment methods, developed competencies, competencies connections with study and assessment methods.

During the implementation of the 2nd stage of the proposed methodology, the words indicating sustainability aspects were searched for in the above-mentioned elements and their glossaries were compiled.

During the implementation of the 3rd stage of the proposed methodology, the appropriate level of the SAMR model was assigned to each of the examined modules. The assignment was made according to the group of module elements in which the glossaries of words indicating sustainability aspects were formed.

During the implementation of the 4th stage of the proposed methodology, depending on which level of the SAMR model the module was assigned, certain actions were initiated that would enable the transformation of the module in the direction of sustainability in the future.

All three steps of the methodology were carried out annually since 2018 (5th stage of the proposed methodology), analyzing the change in study modules amount at the appropriate level of the SAMR model. The goal is to have at least 50% of the modules to be at level 3 or level 4 of the SAMR model by the end of 2022. This would mean that the impact of sustainability on the learning process had become systematic and significant.

#### 4.2.1. Analysis of Integrating Sustainability Issues in Final BSc and MSc Projects

Although the number of final theses in the field of artificial intelligence dealing with sustainability issues is increasing, the term 'sustainability' itself was not common in 2018 and only recently, starting in 2021, began to appear directly in the titles of theses (Figure 5). In the summer of 2021, only one bachelor's thesis had been prepared and defended with the word 'sustainability' included in the title (i.e., "*Two-Dimensional Graphic Animation. Social Advertising: Sustainable Living*"). It was observed that instead of 'sustainable,', such phrases as explainable AI, trustworthy, reusable, circular economy, healthy living, and green house had become more prevalent in the titles starting from 2020. It should be noted that sometimes the title of the thesis did not include any sustainability keywords, but the issues addressed in the work were related to sustainability and often met the objectives of the SDGs (e.g., "*Creation of PET Bottles Sorting Model Using Random Forests*").

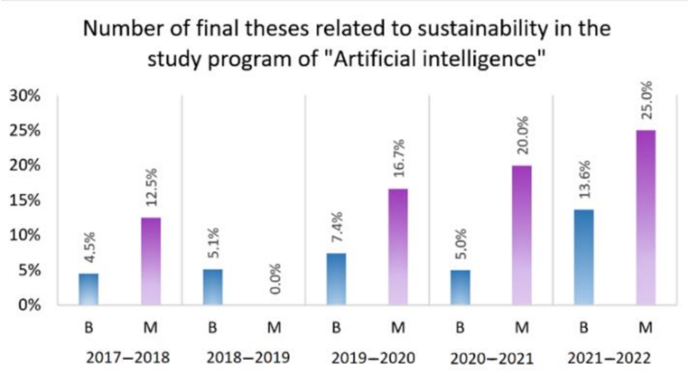


**Figure 5.** Bachelor's and master's theses, which cover the issues of artificial intelligence and sustainability at the Faculty of Informatics (KTU).

The analysis of the 2018–2021 BSc and MSc theses showed that the sustainability aspect is becoming more and more important when designing and implementing IT solutions. After assessing the period of almost five years, it was clear that the number of MSc theses involving sustainability had increased two times (and now stands at 25%). The result for the MSc theses was an increase of almost three times, albeit there is still plenty of space for improvements from this perspective.

#### 4.2.2. Analysis of Issues Related to Sustainability Integration into Modules of SPs

Table 4 presents the results of the application of the SAMR model in the evaluation of AI study programs in the context of sustainability development. It can be observed that there were significant changes in the evaluation of the study modules in 2018 and 2021. The most basic level of bringing sustainability into the modules had been observed in a few modules during 2018. The need for cloud computing, data analysis and machine learning infrastructure had been identified, resulting in the acquisition of access to cloud services. Later, in 2020–2021, local platforms oriented to AI-solutions were created, reducing the need to acquire additional resources for the calculation of AI objectives. In addition, in 2021, there was a higher demand for such infrastructure (six modules), and open access databases, which contain the data sets necessary for the training of AI models.

**Table 4.** SAMR model for KTU I-II cycle SPs 'Artificial Intelligence'.

| Curriculum Elements | Levels of Education for Sustainable Development Integration | | | |
|---|---|---|---|---|
| | Substitution | Augmentation | Modification | Redefinition |
| | Quantitative Comparison 2018/2021 (Number of Modules) | | | |
| *Purpose* | | | | 0/3 |
| *Learning outcomes* | | | | 0/3 |
| *Study methods* | | | 2/5 | 0/3 |
| *Assessment methods* | | | 0/4 | 0/3 |
| *Infrastructure/resources* | 2/6 | 3/4 | 1/4 | 0/3 |
| *Activities* | | 2/4 | 2/5 | 0/3 |
| *Topics* | 3/6 | 2/4 | 2/5 | 0/3 |
| *Final projects* | | 2/8 | 2/5 | 0/3 |

In terms of activities, changes were observed since 2018, and those activities were associated with a final thesis, research or engineering projects, dissemination of results during conferences, or participation in relevant seminars, etc. If in 2018 some of such activities were included more as recommendations, then in 2021 such activities were mandatory in certain modules or had a clear added value in assessing students' results. Comparing these two elements (activities and infrastructure) in the augmentation level, there was no such significant difference during the few years; however, sustainable elements (requirements and goals) are increasing every year, and in 2021, eight modules had highlighted SDG purposes in the final projects. This situation was observed at the modification level as well. In general, looking at the changes in the final project horizontally, one can see that in three years it had grown significantly, from 4 modules to 16. Meanwhile, the assessment methods were more difficult to modify because there was no common way to accurately assess the sustainability of the IT/AI subjects. Assessing the sustainability component by evaluating the accuracy and correctness of a program or IT program code is a new and rather unusual practice. During 2021, four modules provided sustainability assessment criteria within the framework of their subject theory at the modification level and three modules on the redefinition level.

Since only a 3-year period was considered, it is not surprising that more modules were still in the augmentation stage rather than in the modification or redefinition stages. At the level of redefinition, three modules (i.e., 'AI ecosystems', 'Intelligent Assistive Systems Technologies', and 'Final Practice') were identified. Since 2021, these modules have included completely new topics, activities, and learning outcomes. Through the developed IT solutions, the purpose of these modules is to create a sustainable AI ecosystem in line with the SDGs, the guidelines of AI ethics, and the direction of green transformation. Assessing the dynamics over all four levels, we can conclude that 2/3 of all program modules had started or completed the transformation towards sustainability.

The proposed approach of how the progress of redefinition level could be identified and assessed within modules of an AI study program, considering the specifics of the AI research area, ML algorithms, infrastructure, data, and developed solutions are provided in the next section.

### *4.3. Fourth Stage: The Proposed Pathway to Redefinition for Sustainability Transformation in AI Study Programs*

In this section, we provide valuable insights after the annual monitoring of sustainability integration level, hence proposing a pathway to the SAMR level of redefinition. In order to define the most relevant aspects of sustainability in AI study programs, different AI modules, their learning outcomes, and outputs (e.g., created systems, models, algorithms, etc.) with their purpose and potential market, infrastructure used, and the relationship of all these components to sustainability approach were analyzed. During the 3-

year period there were many discussions with the teaching staff, students, business representatives, and other stakeholders as well as seminars and trainings to raise awareness of sustainability issues. To summarize our observations and analysis results, the five most tangible criteria are proposed to ensure the goal of sustainability, which must be included in promoting the understanding of the SDGs in IT/AI study programs (Figure 6).

**Output sustainability level**. The sustainability component, which defines the level of sustainability that should be added to all standard AI system outputs. Probably the most common output of AI systems is accuracy (i.e., classification, prediction, and recognition), which could be supplemented by a sustainability component denoting a certain verbal (categorical) estimate of the sustainability level of the output. This means that we can identify, for example, consumer consumption patterns (e.g., utilities, shopping, etc.) and provide sustainability assessment according to certain features such as wasteful, high consumerism, malicious, rational, or eco-friendly, etc. These levels can be both very general and case-specific, most often discussed in brainstorming sessions, and workshops with students and business representatives; however, providing the right level of sustainability alone will not be of much use if there is no proposal for how to be more sustainable. For example, when customers intend to purchase goods (e.g., food products) online in glass and plastic packaging, sustainability-based AI solutions might offer similar goods in eco-friendly packaging. Or by watching illegal video or audio content, it is possible to provide a sustainability-based AI system that will not only inform the user about the legality of the content, but also offer different options for downloading or viewing the legal content.

**HPC optimization**. Deep learning algorithms require intensive training and significant computing power to speed up training cycles. High performance computing (HPC) significantly reduces the cost of learning time and at the same time enables the use of large amounts of data. By default, these are image processing technology solutions incorporating various CNN architectures, which are the most efficient in terms of accuracy of results, but expensive in terms of HPC because the learning processes take days or weeks. Due to ahigh-energy consumption, it is very important to create less HPC-oriented AI solutions and to make the users of HPC clusters aware of the cost of their computations. Students must be taught to calculate the balance between solution accuracy and solution development costs including HPC resources and to choose the most efficient solution. Achieving the highest possible accuracy, simply because it is in principle possible (regardless of survey hours, electricity, equipment costs, etc.) is not always necessary.

**SDGs-based research**. When working with MSc research, state-of-the-art proposed solutions are always the main focus, especially during the presentation and defense of a thesis. Until now, it has usually been a modified algorithm, a new scope, a hybrid model or improved technological solution aimed at proposing a new, modernizing solution or improving an existing solution, by optimizing certain processes, and finding a cheaper technological solution. All of these goals are important, but more recently, sustainability, environmental friendliness (e.g., ecological goods, solutions, etc.), and ethical aspects of the solution have also been emphasized. This means that it should be indicated how the proposed decision fulfils the objectives of the SDGs with ethical recommendations for the development of AI that are taken into account, etc.

**Open data**. In terms of solution innovation, the principle of 'sharing is caring' has recently been promoted, and students are encouraged to share their software code as well as collected data that can be highly valued for other research, in compliance with all legal, commercial, and ethical requirements. Students need to be clear about which parts of a programming code (e.g., ML algorithm) will be published for other research purposes and link to the newly created open datasets (e.g., Kaggle and GitHub). Finally, in the preparation of both BSc and MSc theses, students are taught to disseminate their research results (whatever they might be) at international scientific conferences. Sometimes this can be challenging, especially when students are pursuing a topic generated from a business enterprise, where priorities and goals are focused on competitive advantage and earnings;

however, even then, students are made aware of ethics in research, the benefits of open data and the possibilities as well as prospects of making their results available to the public for how to create an AI ecosystem.

**Trustworthy solutions**. Open source and explainable Artificial Intelligence XAI-based solutions can increase the reliability of the proposed AI solutions. The lack of explainability does not meet the need for transparency, trust, and a good understanding of the expected results. Explainability is very important for companies to apply Artificial Intelligence because people do not easily trust machine recommendations that they do not fully understand. Therefore, students need to more often pursue thesis topics related to XAI-based decisions and AI ecosystem development.

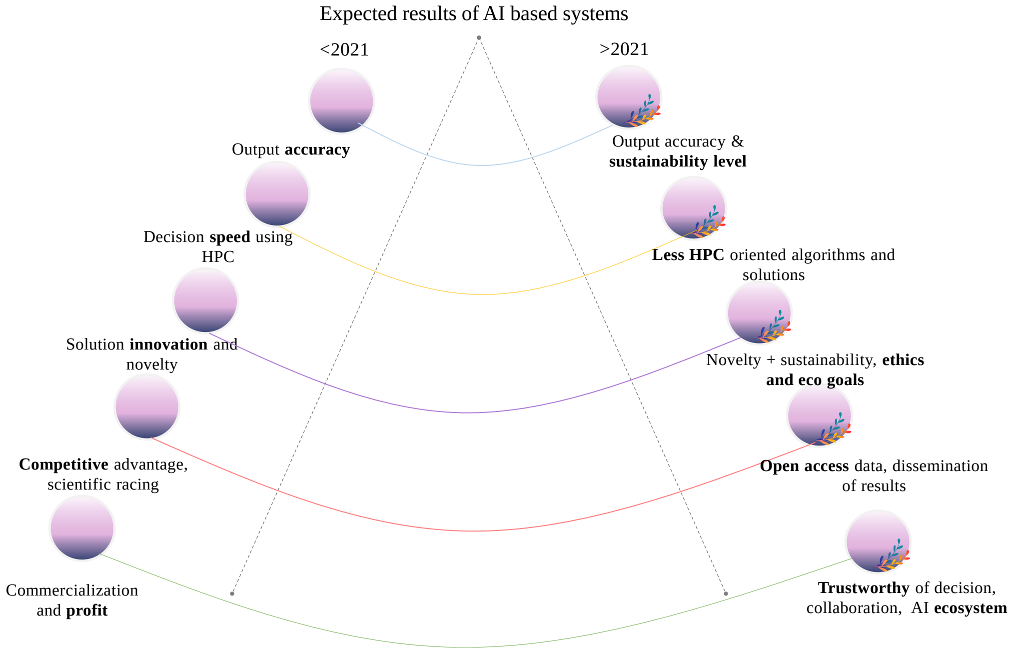


**Figure 6.** The proposed criteria for assessing the AI study programs by highlighting sustainability.

We believe that all mentioned criteria should be highlighted in AI-related study programs which would like to incorporate and enhance sustainability criteria in their curricula and study processes. Moreover, these aspects may be relevant to any study programs which include AI technologies in their curriculum as well as other engineering fields, especially Computer Science and Informatics Engineering.

## 5. Discussion

After an extensive investigation on sustainability in SPs, some reflections have been made upon the enhancement of the sustainability component in Computer Science and IT Engineering-related study fields. Sustainability development in Computer Science SPs is complicated not only by the importance of the fundamental basics and technical aspects (programming, algorithms, etc.) of the modules, but also by the fact that it is not entirely clear how educational principles and program syllabus need to be transformed towards sustainable Computer Science. A detailed analysis of the courses in various SPs has shown that the content of sustainability is not adequately or transparently addressed, which is also supported by previous studies by other scholars. For instance, the analysis of the survey also revealed that students studying technology-related disciplines were unaware of the concepts of sustainability [56,57]. The goals of applying IT/AI technologies are obvious and understandable, but how these technologies can be related to sustainability issues from a methodological or theoretical perspective is not clear. This is evident by the review and analysis of the content of available SPs for sustainable Computer Science that contained buzzwords like 'green IT', 'eco', etc. For example, the SP called 'Sustainable Computer Science' that is delivered at Tier University of Applied Sciences, (Tier, Germany) includes modules (up to 30 ECTS) in the fields of information, IoT, cyber security (e.g., 'Remote Sensing', 'Information Technology' or 'Cyber-Physical Systems') and there are only two modules, namely, 'Solar energy' and 'Geo Engineering' that, although not purely from the IT field, have an interface with sustainability goals. Two other examples include the one-year long MSc study programs called 'Computer Science, Emphasizing Sustainable Development' and 'Applied Computer Science for Sustainable Development'. These SPs are offered in Kristianstad University (Kristianstad, Sweden). Based on the curriculum description, few subjects were identified as being related to sustainability issues. Even though the subject name 'Computer Science Methods and Sustainable Development' would be expected to analyze the direct relationship between IT methods and sustainability issues, the intended learning outcomes are more related to scientific research analysis, ethical aspects, development and implementation of projects oriented to sustainability problems. The outcomes of the subject 'Sustainable Projects in Multidisciplinary Contexts' involves the understanding of how project requirements should be identified and formulated, what the accountability for system performance evaluation is, and it finally involves a deep discussion about projects for sustainable development. Other subjects in various SPs were in the field of mobile platforms development, wireless network security, the internet of things, and data mining. It should be mentioned that in almost all cases, these were one-year MSc study programs oriented to specific objectives (e.g., 'Master's in Computer Science: Software Engineering and Green IT'), regional problems (e.g., 'Smart Cities and Urban Informatics', which focuses on solving problems provided by the Jerusalem Municipality,) or IT project development for sustainability goals. Conversely, all subject and learning outcomes were relatively the same as in classical Computer Science, IT engineering, automatic and electronic SPs (Figure 7).

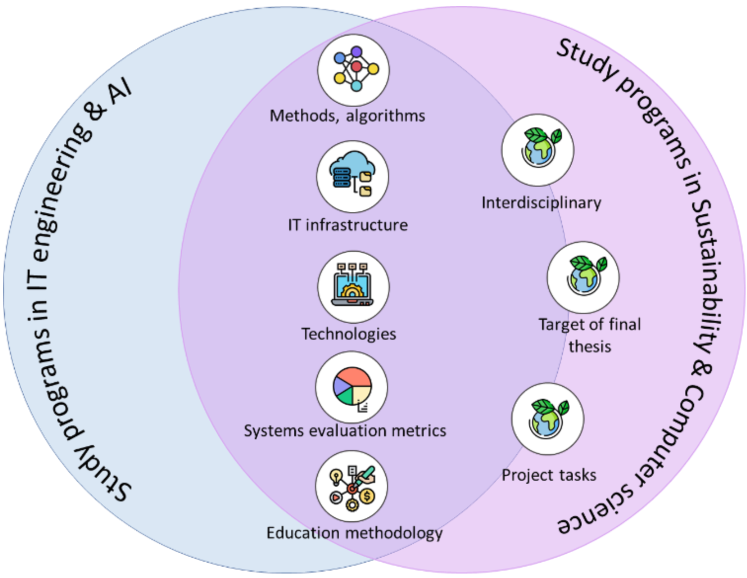


**Figure 7.** Similarities between AI study programs and sustainability-oriented Computer Science study programs.

Recently, most IT programs include sustainability-oriented projects (e.g., through challenge-based learning (CBL)) and interdisciplinary projects, thus increasing the number of the final thesis related to sustainability or the SDGs. Comparing CS programs, including those which are specially oriented for sustainable development purposes, and the study programs of IT engineering and AI, there were many similarities in terms of algorithms, infrastructure, systems performance evaluation metrics and educational methodologies (Figure 7).

As for the AI study programs, from Figure 7 we can see that the subjects of AI ethics, data security, data analysis, and cloud computing technologies are included. Interdisciplinary competence projects are encouraged in many subjects as well, creating human-oriented assistive systems, smart home solutions, and likewise. Those realizations required the integration of AI technologies together with the synergy of solutions in the social sciences and economics. At this point, the question arises as to whether the existing SPs in the field of Computer Science sustainability differ from many other AI-oriented SPs; however, there are debates about the challenges and risks of AI in education for sustainable development and why it is important to clarify issues of ethics and transparency in data collection, use and dissemination [58]. Our proposed methodology is a step further for reaching a consensus and such ethical practices that embrace transformative education which fosters building a society with a forward-thinking sustainability-based mindset.

## 6. Conclusions

A comprehensive investigation was carried out on ESD study programs, focusing on the engineering SPs to identify the most prevailing areas, specializations, and objectives. For a sustainability level evaluation in engineering studies, a hierarchical methodology employing the SAMR model has been proposed, taking a technological university in Lithuania as a case study. Eight components were included in the SAMR model (i.e., purpose, learning outcomes, study methods, assessment methods, infrastructure/resources, activities, topics, and final projects) that were necessary for an accurate assessment of the level of sustainability. When assessing the level of sustainability implementation, an example of the BSc and MSc courses called 'Artificial Intelligence' was used. Significant qualitative and quantitative changes were observed at various levels of sustainability integration. These observations were also supported by an increasing number of final theses and projects.

On the broader level of analysis, it was discovered that analysis items such as the title of the subjects and final theses often do not include any well-known sustainability keywords, even though the content is related to sustainability and often meets the objectives of the SDGs. Therefore, a much more comprehensive analysis was needed and performed to identify the real situation and exact sustainability level of the SPs. Investigating 'Artificial Intelligence' as the case study, and the result as the AI sustainability components which can be assessed by quantitative or qualitative measures were highlighted. Five tangible criteria that must be emphasized in the learning process in order to ensure the development of sustainability goals in AI study programs in the redefinition level have been proposed. These unique criteria make it possible to offer an area-specific assessment in terms of sustainability; however, these can be also adopted in other IT engineering or Computer science SPs.

Looking to the future perspective it is very important to emphasize that SDG number four aims to ensure that all students acquire the knowledge and skills needed to promote sustainable development. Recommendations for what knowledge should be provided are listed in different guidelines (e.g., what is a sustainable lifestyle, and why human rights, gender equality, the promotion of a culture of peace and nonviolence, citizenship and everyone's contribution to sustainable development are important), but this is not enough, because how this should be implemented is the responsibility of each educational institution. Therefore, the proposed methodology (as well as other frameworks proposed by other authors) could be valuable as it can facilitate the pathway towards ESD.

**Author Contributions:** Conceptualization, A.P.-T., I.L.-B., L.G., V.S. and L.D.-B.; methodology, A.P.-T., I.L.-B., L.G. and V.S.; validation, A.P.-T., I.L.-B. and L.G.; formal analysis, A.P.-T., I.L.-B., L.G., V.S. and L.D.-B.; investigation, A.P.-T., I.L.-B. and L.G.; resources, A.P.-T., I.L.-B. and L.G.; data curation, A.P.-T., I.L.-B. and L.G.; writing—original draft preparation, A.P.-T., I.L.-B., L.G., V.S. and L.D.-B.; writing—review and editing, A.P.-T., I.L.-B., L.G., V.S. and L.D.-B.; visualization, A.P.-T., I.L.-B. and L.G.; supervision, A.P.-T. and V.S.; funding acquisition, A.P.-T. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and according to the guidelines of the Institutional Research Ethics Commission. All data used in the study adhere to the General Data Protection Regulation (GDPR) requirements.

**Informed Consent Statement:** Not applicable.

**Acknowledgments:** We would like to express our gratitude to the educational managers of Kaunas University of Technology for granting access to the relevant data on study programs and the technical staff for retrieving the results based on our search queries.

**Conflicts of Interest:** The authors declare no conflict of interest.

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