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THE ROLE OF DIGITAL TRANSFORMATION IN EDUCATION IN PROMOTING SUSTAINABLE DEVELOPMENT

Regina Veckalne and Tatjana Tambovceva

Abstract. The crucial role education plays in fostering sustainable development, moving society toward a more environmentally and socially conscious future, and influencing the attitudes and behaviours of both the present and the future generations are explored in this article. The authors analyse the concept of education for sustainable development (ESD), a transformative learning technique designed to provide individuals and communities with the knowledge, skills, and values necessary to encourage moral behaviour. ESD must be integrated into a number of learning contexts in order to have a full and all-encompassing impact, underscoring the need for interdisciplinary and holistic methods that are considerate of different learning styles, backgrounds, and circumstances. Moreover, the article examines the role of key stakeholders, such as educators, policymakers, and local communities, in designing and implementing transformative learning experiences that foster behavioural change, critical thinking, and social engagement. It discusses the significance of teacher training, curriculum development, and innovative educational resources in nurturing a culture of sustainability and encouraging collective action. Additionally, the article investigates the potential barriers to adopting ESD, including resistance to change, insufficient funding, and a lack of awareness, and proposes strategies for overcoming these challenges. The authors conduct a survey among university students to detect the key challenges of ESD and how to address them from their perspectives.

Keywords: education for sustainable development, sustainability awareness, sustainable development

JEL Classification: Q01, Q56

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1. Introduction

Sustainable development is defined as the process of evolution that addresses the needs of humans without sacrificing the capacity of future generations to meet their demands (Brundtland, 1987). Education is one of the key tools in achieving Sustainable Development Goals (SDGs). The 2030 Agenda for Sustainable Development emphasizes the importance of quality education, lifelong learning, and global citizenship education (United Nations, 2015). Since education is seen as a powerful tool for reforming communities and cultivating responsible and sustainable behaviours, it has been receiving more and more attention from academics and policymakers in recent years (McKeown, 2002).

Education for sustainable development (ESD) is expected to equip people and communities with the values, knowledge, and skills they need when dealing with difficult socio-ecological problems (UNESCO, 2014). ESD aims to actively engage students in contributing to sustainable development through the promotion of sustainability awareness. Various scholars (Mochizuki & Fadeeva, 2008; Barth & Michelsen, 2013) suggest that interdisciplinary and integrative approaches to ESD are to be utilized when addressing the interconnection of social, environmental, and economic concerns.

A lot of efforts have been made to integrate ESD into different learning environments in recognition of the necessity to modify educational institutions to accommodate a variety of learning styles, backgrounds, and circumstances (Rieckmann, 2012). Nevertheless, a number of challenges, such as a lack of awareness, a lack of money, and resistance to change, still prevail.

In order to better understand how education contributes to sustainable development, this study will look at the notion of ESD, its development, and how it affects students' attitudes, behaviours, and beliefs. Additionally, it will go over the value of interdisciplinary and holistic approaches, how to incorporate ESD into different learning settings, and the function of important stakeholders including educators, policymakers, and civil society organizations.

2. Literature Review

In recent years, education for sustainable development (ESD) has undergone a major evolution. The United Nations' 2030 Agenda for Sustainable Development, which emphasizes the value of education in achieving sustainable development goals (SDGs) and places a focus on quality education, lifelong learning, and global citizenship education, gave rise to the notion of ESD (United Nations, 2015).

Value-belief-norm theorists argue that the intention to perform pro-environmental behaviours is strongly linked to the awareness of adverse environmental consequences (Hansla et al., 2008). From the same point of view, sustainability awareness is key to reaching sustainable development. Environmental Kuznets curve claims that economic development inevitably leads to environmental degradation; nevertheless, some researchers state that the

extent to which this happens depends on moral values and laws within the investigated communities (Stern, 2018).

Since the theory of needs is mostly used to predict behaviours, it is only natural to question whether sustainability awareness may be described at the country or town level; for instance, wealthier countries and cities tend to demonstrate higher awareness levels when it comes to sustainability and sustainable development. A hierarchy of needs proposed by Maslow suggests that humans need to fulfil their basic needs first before proceeding to higher levels on the pyramid; thus, sustainable development requires meeting all the basic needs, including food, shelter, clothing, and jobs, prior to extending their aspiration for a sustainable life (Clarivate Analytics, 2018).

Following this theoretical framework, we can presume that compared to developing states, wealthy countries have fewer people with unfulfilled lower-level needs, and therefore they move up the pyramid reaching a higher level of sustainability awareness and consequently sustainable development. This, however, does not mean that sustainable development should become a prerogative of developed nations only; on the contrary, this means that we should invest more time and money into raising awareness of sustainability and the importance of sustainable development among those that would otherwise take decades to reach a higher level of Maslow's hierarchy.

To ensure the implementation of Sustainable Development Goals, societies have to make complex fundamental transformations (The Bertelsmann Stiftung and Sustainable Development Solutions Network, 2018). To achieve such transformations, people need to change their daily behaviour in order to lead more sustainable lifestyles. This, however, takes a significant amount of time and is impacted by market, political and individual factors (Foster et al., 2022). Pavalache-Ilie and Cazan (2018) argue that the enhancement of responsible environmental behaviour can be achieved by raising awareness. This idea is backed up by Guan et al. (2019), who claim that raising public awareness of sustainability goals is one of the key factors of their successful implementation.

In addition to that, businesses should be expected to become more active in the implementation of sustainable practices, which can also be achieved through the spread of awareness on both corporate and individual levels. Companies can contribute to sustainable development in various ways, for instance, through Corporate Social Responsibility practices. Sustainable Development Goals may be appealing for private companies due to the possible return on investment; however, businesses can also create value through corporate social responsibility projects because individual stakeholders reward companies engaged in CSR activities.

Another way to raise citizens' awareness of sustainable development is through education. In the past few decades, more and more people have been enrolling at educational institutions at all levels (UN, 2021). Education is expected to improve social and economic indicators (UN, 2021) and eliminate poverty (UNESCO, 2019), which consequently leads to a reduction in

inequality levels. Moreover, education allows people to live healthier and more sustainable lives. Last but not least, education is pivotal to promoting tolerance and making societies more peaceful (UN, 2021). To achieve all the aforementioned benefits of education, many institutions today include education for sustainable development in their programs.

The focus on ESD has increased in the daily practices of many schools across the globe (Pauw et al., 2015). Such education is transformative and learning-oriented. ESD can be very efficient in raising students' awareness. The framework of ESD implementation is presented in figure 1.16. It is clear today that raising awareness is an extremely important thing to do when aiming for sustainable development. Thus, we should do that on each level of personal development – from schools to continuous training at the workplace. When more and more people become aware of their contribution to environmental and societal degradation, they will alter their daily behaviour to lead more sustainable lifestyles.

The development of skills like systems thinking, critical reflection, and anticipatory and collaborative decision-making has been a growing focus of ESD (Wiek et al., 2011; Rieckmann, 2012). The Global Action Programme (GAP) on ESD, which replaced the United Nations Decade of Education for Sustainable Development (2005-2014), places a priority on five key areas for advancing ESD: advancing policy, changing learning and training environments, building educators' capacities, empowering and mobilizing youth, and accelerating sustainable solutions at the local level (UNESCO, 2014).

The global trend toward competency-based education, which emphasizes the development of specialized knowledge, skills, and attitudes necessary for addressing complex sustainability concerns, has had an impact on the idea of ESD (Cebrián & Junyent, 2015). ESD combines ideas from environmental education, development education, and global citizenship education to reflect how social, environmental, and economic sustainability issues are interconnected (Leicht et al., 2018).

The Sustainable Development Goals (SDGs) themselves (United Nations, 2015), the Earth Charter (Earth Charter Initiative, 2016), the UNESCO Roadmap for Implementing the Global Action Programme on ESD (UNESCO, 2014), and the European Union's strategy for ESD are just a few of the frameworks and principles that have been created to support the implementation of ESD (European Commission, 2018). These frameworks emphasize the necessity of ESD integration across disciplines and educational settings as well as transformative learning processes (Mochizuki & Bryan, 2015; Boeve-de Pauw et al., 2018).

The focus of research on ESD has expanded to include a variety of issues related to teaching and learning, such as the function of instructors, the creation of curricula and learning resources, assessment procedures, and the impact of institutional and regulatory contexts (Chawla & Cushing, 2019). Developing topics in ESD research include the use of indigenous and local knowledge systems in ESD, as well as the use of digital technologies for promoting sustainability education.

Thus, ESD has recently developed greatly, reflecting the growing understanding of the importance of education in resolving issues related to global sustainability. To guarantee that educational systems around the world are successfully nurturing the knowledge, skills, and values required for a sustainable future, it will be crucial to draw on the most recent research, frameworks, and recommendations as ESD develops.

Interdisciplinary and Holistic Approaches to ESD. Addressing the complex and interwoven nature of sustainability concerns requires an interdisciplinary and holistic approach to education for sustainable development (Leicht et al., 2018; Mochizuki & Bryan, 2015). This method encourages a thorough comprehension of the interrelationships between the social, economic, and environmental aspects of sustainable development (Broman & Robèrt, 2017). Integrating systems thinking, which entails comprehending the relationships between various components of a system and their impact on the system's behaviour through time, is one strategy to encourage interdisciplinary learning in ESD (Sterman, 2018; Rieckmann, 2012). Learners that utilize systems thinking are better able to understand the underlying causes of sustainability issues, investigate change-making opportunities, and anticipate unintended repercussions of solutions (Wiek et al., 2011).

Integration of various disciplines and viewpoints, including those from the scientific and social sciences, humanities, and the arts, is a crucial component of an interdisciplinary approach to ESD (Brundiers et al., 2009). As a result, learners are better equipped to interact across disciplinary boundaries and co-create knowledge with a variety of stakeholders, such as practitioners and communities (Lang et al., 2012; Mochizuki & Fadeeva, 2018).

Also, holistic approaches to ESD place a strong emphasis on the significance of values-based learning, which involves fostering the growth of moral and ethical principles that inform behaviour and decision-making in favour of sustainability (Chawla & Cushing, 2019; Leighton et al., 2017). Empathy, responsibility, respect for variety, and a sense of justice are a few examples of such principles.

ESD should encourage transformational learning, which entails challenging learners' presumptions, beliefs, and values and empowering them to take transformative actions in the direction of sustainability, in addition to fostering multidisciplinary and holistic learning (Mezirow, 2018). To do this, critical thinking, reflexivity, and agency must be developed.

To support transdisciplinary and comprehensive approaches to ESD, a number of pedagogical techniques have been suggested, including problem-based learning, project-based learning, service-learning, and place-based education, these strategies place an emphasis on authentic, collaborative, and experiential learning events that involve students in real-world sustainability concerns.

In conclusion, interdisciplinary and holistic ESD approaches are crucial for building a thorough grasp of sustainability concerns and equipping students to take revolutionary steps toward sustainable development. Effective ESD must incorporate systems thinking, values-based

learning, transformative learning processes, and pedagogical practices that stress experiential and collaborative learning. Undoubtedly, digitalization plays a crucial role in making ESD more holistic.

In the education sector, digital transformation has become more and more important for encouraging sustainable development. According to Abad-Segura et al. (2020), technological improvements have increased an access to educational materials, resulting in more inclusive and equitable learning opportunities for a variety of populations, including those with impairments and those living in remote locations. By using fewer resources, like paper and electricity, and requiring less travel, online and mixed learning environments have the potential to lessen the environmental impact of traditional education. (Yin, 2022). The incorporation of Education for Sustainable Development (ESD) into the curriculum has also been made easier by digital transformation, promoting the critical thinking and problem-solving abilities required to solve the issues of global sustainability (Tilbury, 2016). Collaboration amongst a variety of stakeholders, such as policymakers, educators, and students, is essential to fully harness the potential of digital transformation for sustainable development in education (Abad-Segura, 2020).
Therefore, the research hypothesis is as follows **H1**: *Digital transformation of education is positively associated with ESD*.

Integrating ESD into Various Learning Environments. ESD must be integrated into a variety of learning environments in order to be effectively implemented. This section highlights current research on ESD incorporation into various educational contexts, including opportunities and problems. The curricula design is a crucial component of incorporating ESD in the formal education. A more thorough understanding of sustainability concerns is promoted through the integration of sustainability concepts, topics, and approaches across disciplines (Holdsworth et al., 2008; Leicht et al., 2018). Studies have emphasized the significance of including ESD in disciplines like science, social studies, and language arts (Chawla & Cushing, 2019). Also, it is becoming increasingly clear that multidisciplinary methods to teaching and learning are necessary for tackling the complexity and interconnection of sustainability concerns (Mochizuki & Bryan, 2015).

For the efficient incorporation of ESD in formal educational contexts, educator competences are also essential. According to the research (Cebrián & Junyent, 2015), professional development programs are needed to give teachers the information, abilities, and attitudes necessary to cultivate ESD capabilities in their pupils. Also, emphasis has been placed on the part that school leadership plays in advancing and bolstering ESD (Boeve-de Pauw et al., 2018).

Via community-based projects, youth programs, and environmental organizations, ESD has been incorporated into non-formal education (Kollmuss & Agyeman, 2002). Non-formal education can enhance ESD competencies and contribute to transformative learning experiences, according to the research (Redman & Larson, 2011). Participatory methods and project-based learning, for instance, have been found to be efficient tools for motivating students to take sustainability-related actions in non-formal contexts.

Moreover, informal learning settings like botanical gardens and museums provide potential for ESD integration. These environments can offer contextualized, experiential learning opportunities that can deepen one's understanding of sustainability challenges and supplement formal schooling (Sterling, 2001). For instance, it has been demonstrated that the use of digital tools in informal learning settings improves student involvement and learning results (Wals et al., 2014).

Thus, it can be concluded that nurturing the knowledge, skills, and values necessary for sustainable development depends on incorporating ESD into a variety of learning situations. Notwithstanding recent success, more study and cooperation among researchers, educators, and policymakers are required to address the potential and problems related to ESD integration across a variety of educational contexts.

Challenges and Barriers to Implementing ESD. There are obstacles and hurdles in properly implementing Education for Sustainable Development (ESD) in educational institutions. The integration of the curriculum, teacher preparation, resources, and institutional support are only a few of the major problems that are discussed in this section as obstacles to the successful implementation of ESD.

The incorporation of sustainability concepts and practices into current curricula is one of the major obstacles to implementing ESD. Rethinking traditional topic boundaries and promoting a more all-encompassing approach to teaching and learning are necessary due to the interdisciplinary nature of ESD (Mochizuki & Bryan, 2015). Due to time restrictions, competing curricular demands, and a lack of clear instructions on how to apply ESD in different disciplines, this can be challenging to do.

The successful implementation of ESD depends on teacher preparation since teachers are crucial in influencing students' sustainability-related knowledge, values, and actions. Yet, according to studies, many teachers do not possess the abilities, expertise, and self-assurance required to successfully teach ESD (Cebrián & Junyent, 2015; Holdsworth et al., 2008). Furthermore, many teacher preparation programs do not stress ESD or offer enough chances for professional growth in this area (Leicht et al., 2018; Wals et al., 2014).

The application of ESD in educational institutions may be significantly hampered by a lack of resources, including money, time, and instructional materials. Effective ESD requires access to high-quality, current, and contextually appropriate resources, but these may not always be easily accessible or affordable for schools and teachers. Moreover, it can be difficult to arrange the collaboration between educators, researchers, and politicians required for the creation and distribution of ESD resources (Rieckmann, 2012).

A crucial element in enabling the successful implementation of ESD is institutional support. This entails the formulation of precise policies and plans, as well as the supply of the required tools and facilities (Chawla & Cushing, 2019). However, not all educational institutions may

place a high value on ESD, and it can be challenging to devote enough time and money to sustainability programs due to competing interests.

It is clear that there are a number of obstacles and problems that must be overcome for ESD to be successfully implemented in educational settings. It will need a coordinated effort by educators, policymakers, and other stakeholders to emphasize sustainability, fund teacher preparation and resources, and create supportive institutional frameworks in order to overcome these challenges. Continuous innovation and research in ESD are crucial to identify and address these challenges and foster the development of more sustainable societies. Thus, there is hypothesised that **H2**: *Challenges and barriers to implementing ESD is associated with quality of ESD*.

Stakeholders' Roles in ESD. Implementation of Education for Sustainable Development depends on the participation and cooperation of a wide range of stakeholders, including educators, students, decision-makers, communities, and business partners. The function of various stakeholders in developing ESD is examined in this section.

ESD is being implemented in classrooms and courses at the forefront by educators. They are in charge of creating and executing stimulating and successful educational experiences that advance students' comprehension of sustainability principles, sharpen their critical-thinking abilities, and encourage responsible environmental actions. Also, teachers ought to act as role models and proponents of sustainable practices both inside and beyond the classroom (Holdsworth et al., 2008).

Students are essential to ESD because they are engaged learners and potential change agents. Individuals are accountable for participating in the learning process, putting their knowledge and skills to be used in solving real-world sustainability problems and acting to advance sustainable development both within and outside of their communities (Chawla & Cushing, 2019; Mochizuki & Bryan, 2015). In addition, students can participate in extracurricular sustainability activities, offer comments, and share their perspectives to help design and implement ESD projects (Boeve-de Pauw et al., 2018).

The development of the structures, rules, and incentives required to promote the integration of ESD into educational systems falls squarely on the shoulders of policymakers. Setting curricular standards, creating national and regional ESD plans, and giving funds for teacher preparation, research, and innovation are all part of this (Leicht et al., 2018). To ensure the success and relevance of ESD policies and programs, policymakers should also work with other stakeholders, such as educators, researchers, and business partners (Wals et al., 2014).

Local communities have a crucial role as partners in ESD because they offer important resources, expertise, and chances for learning and action. Community organizations can work with educational institutions to create and deliver contextually relevant ESD programs and activities, including environmental organizations, cultural institutions, and companies.

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Communities may also help ESD by promoting a culture of sustainability and working together to address regional and global environmental problems.

Industrial partners can support ESD by supplying knowledge, materials, and chances for hands-on learning and cooperation. This involves providing opportunities for students to apply their sustainability knowledge and abilities in professional settings through internships, workshops, and research projects (Wiek et al., 2011). Investing in sustainable technologies, practices, and innovations that promote the objectives of sustainable development is another way that industrial partners can assist ESD (Cebrián & Junyent, 2015; Holdsworth et al., 2008).

In conclusion, active participation and collaboration from a range of stakeholders are necessary for the successful implementation of ESD. Together, educators, students, governments, communities, and business partners can advance ESD and promote the creation of more sustainable societies by utilizing their individual talents and views. Thus, there is hypothesised that **H3**: *Stakeholders' roles have a positive association with quality of ESD*.

3. Bibliometric analysis

Before proceeding to the empirical research the findings of bibliometric analysis for this topic are presented. For this analysis there were searched "education" AND "sustainable" AND "development" AND "digitalization" on Scopus. Then the search results were limited to papers in English. This resulted in only 234 documents, which shows that this topic lacks sufficient research.

If looking at the dynamics of publications (fig. 1), it can be observed that the first article with these keywords was published 15 years ago in 2007. After that there was no evident interest in this topic up until 2015, since when there was a steady uprising movement, reaching its peak in 2022.

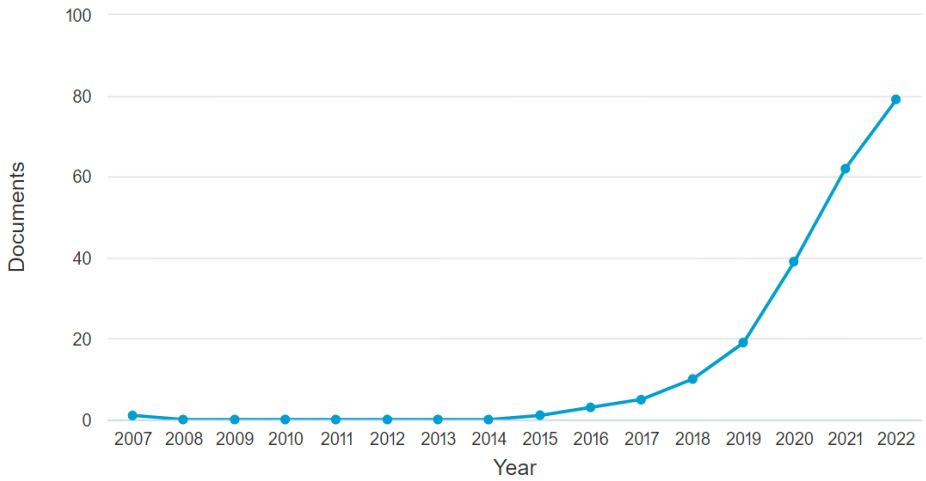

Figure 1. Documents published in Scopus with keywords "education" AND "sustainable" AND "development" AND "digitalization"
Source: devised by the authors.

When it comes to the most relevant sources in the field of ESD and digitalization, the winner is journal "Sustainability" with 26 publications. It is followed by E35 Web of Conferences with 5 publications less. Lecture notes in Networking and Systems comes third with 12 publications. The remaining sources can be seen in figure 2.

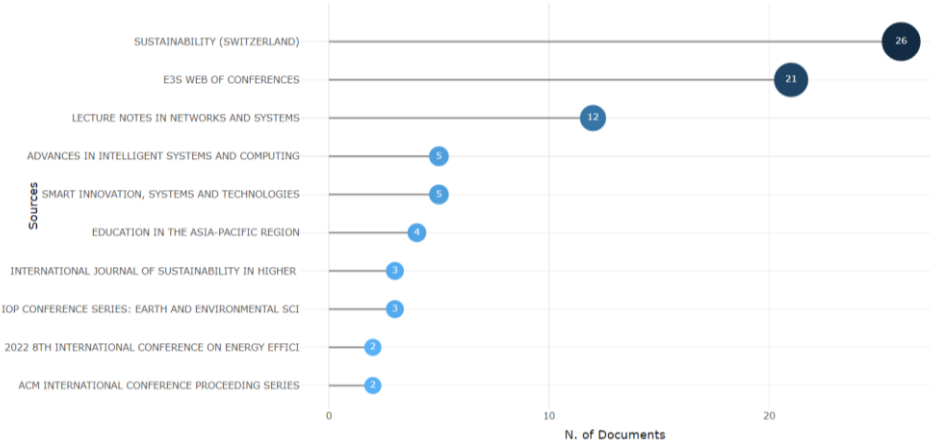

Figure 2. Most relevant sources in digitalization and ESD research
Source: devised by the authors.

Then there were analysed the most common words used in the selected articles and their frequency over time. The most often used keywords were *digital transformation, digitalization, e-learning, education, engineering education, higher education, planning, students, sustainability* and *sustainable development*. Three keywords: sustainability, students and sustainable development appeared the earliest and remained the only ones up until 2014, where the emergence of other key terms can be observed. "*Sustainable development*" was by far the most used one. *Education, engineering education* and *e-learning* followed, with the occurrence over twice as little. Although "*digitalization*" was not as popular among scholars, it started receiving more attention in 2021 which resulted in a rapid growth of its frequency of use.

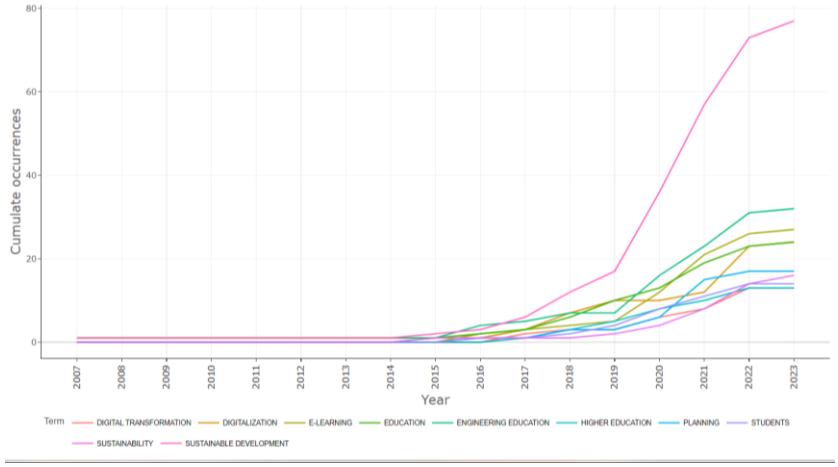

Figure 3. The word frequency over time
Source: devised by the authors.

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Finally, using VOSviewer software there was created a key-words co-occurrence map. Out of 47 offered keywords from the Scopus articles there were selected 32, which were the most relevant. These keywords were then grouped into 4 clusters: 1st containing 10 items, 2nd and 3d 8 items each; and 4th cluster with 6 items. The results of this analysis are presented in figure 4. The size of the bubble represents the frequency of using the keyword, in which the bigger the bubble, the higher the frequency is and vice-versa, whereas the length of the link demonstrates the connection of keywords, where the shorter the link, the more they are connected.

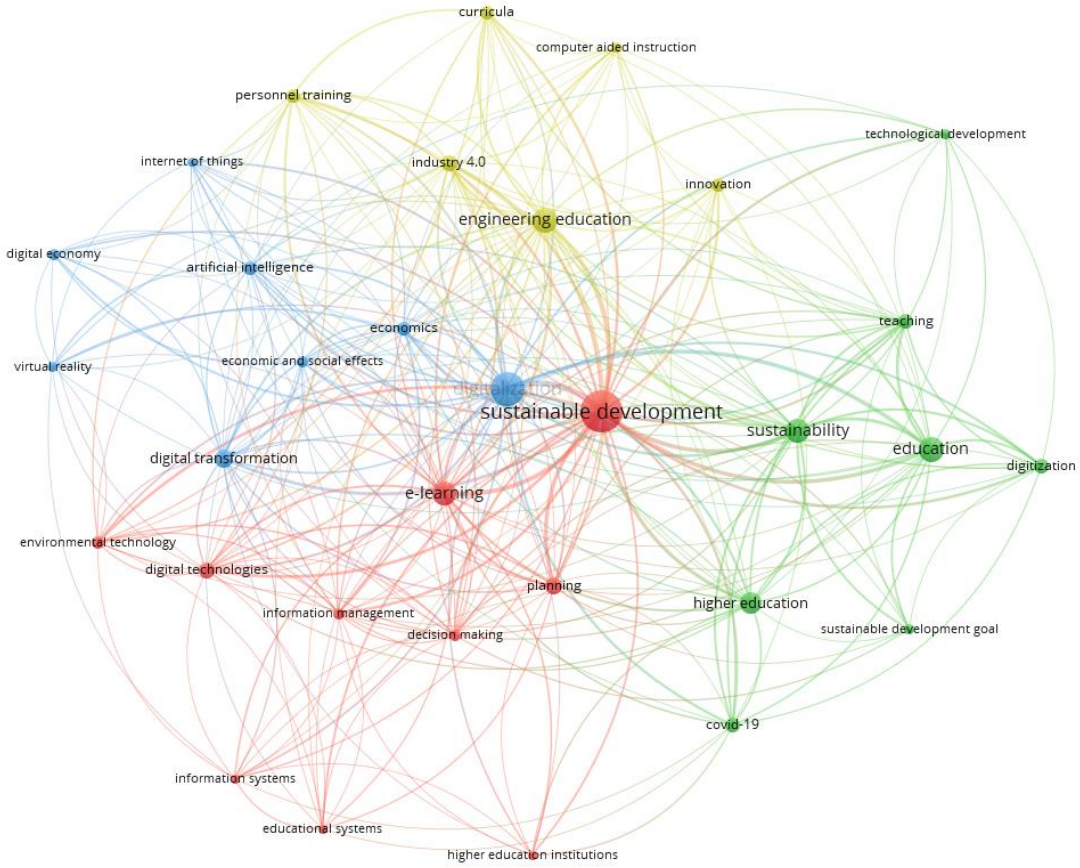

Figure 4. A key-words co-occurrence map
Source: devised by the authors.

As it can be noticed *sustainable development, e-learning, sustainability*, and *education* are among the most often used keywords. They are closely connected with planning, decision making, information management, digital transformation, economic and social effects, industry 4.0 and innovation. Other digitalization related keywords, such as technological development, computer aided instruction, the internet of things, digital economy, and educational systems were also present in the findings. Thus, it can be concluded that there is a noticeable link between digitalization related activities and education for sustainable development.

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4. Methods

An extensive literature review was conducted to explore the existing research on ESD, its challenges and barriers, and stakeholders' roles in promoting sustainable development. A systematic search was performed using several academic databases, including Web of Science, Scopus, and ERIC. The search focused on peer-reviewed articles, books, and reports published within the last seven years. The keywords used included "*Education for Sustainable Development*," "*ESD*," "*sustainability education*," "*challenges*," "*barriers*," and "*stakeholders*." The literature review allowed the researchers to identify trends, gaps, and opportunities in the field of ESD, which informed the design and analysis of the subsequent survey and interviews. A quantitative questionnaire was distributed to students from Riga Technical University. The purpose of the survey was to determine how respondents saw and experienced ESD, what obstacles and challenges they encountered, and what they thought about the roles and responsibilities of various stakeholders in advancing sustainable development. The survey was composed of multiple-choice and closed-ended questions utilizing Likert scales. One question was open-ended. The answers to this question underwent content analysis. To find patterns, correlations, and disparities in the respondents' perspectives, the survey results were examined using descriptive and inferential statistics. The study complied with ethical standards for studies involving human subjects. All survey and interview participants provided informed consent, confirming that they were aware of the study's goals, methods, and rights to anonymity and withdrawal. To maintain the participants' privacy and anonymity, the data were securely stored once all identifying information was obliterated.

5. Results and Discussion

118 students took part in the survey. Most of the respondents (60%) were aged between 18 and 24; 37.1% were between 25 and 34; and the remaining respondents were underage (Fig. 5).

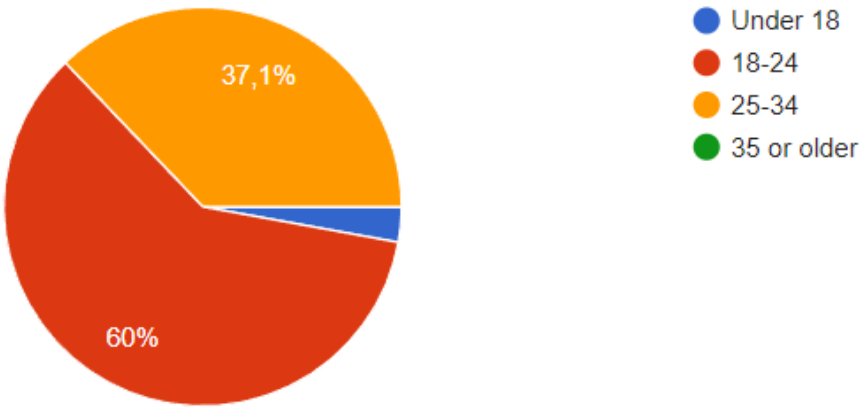

Figure 5. Age distribution among survey participants
Source: devised by the authors.

65.7 % of respondents were identified as men, while 34.7 as women. The vast majority of survey participants studied at the undergraduate level (82.9 %), and the remaining were pursuing Master's degrees.

When asked about their familiarity with the concept of Education for Sustainable Development 37.1 % chose the option "somewhat familiar", and 22.9 % – neutral and very familiar (Fig. 6).

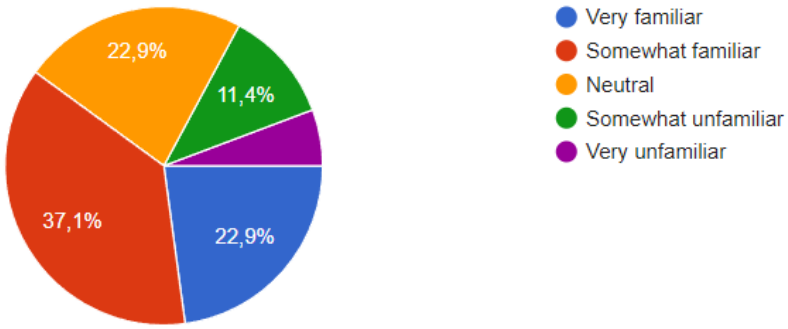

Figure 6. Familiarity with the concept of ESD
Source: devised by the authors.

When it comes to evaluating the quality of ESD, the majority ranked it as fair (34.3%) or good (31.4). Only 20% of students think that it is excellent, while 11.4% and 2.9% consider it poor and very poor respectively.

When asked to what extent ESD aided in critical thinking skills related to sustainable development, 45.7 % of respondents answered "moderately", while 25.7 % selected "greatly"; 20 % of those participating in the survey students believed that ESD has a slight effect on their critical thinking development, whereas 8.6 % noticed no effect at all (fig.7).

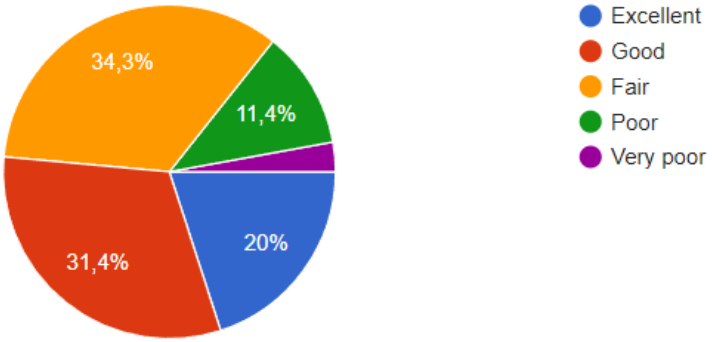

Figure 7. Quality of ESD in the institution under research.

Source: devised by the authors.

Then participants were asked to rank several challenges and barriers to ESD on a Likert scale from 1 to 5.

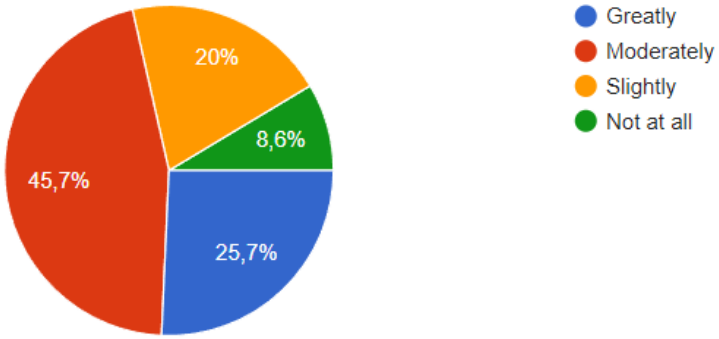

Figure 8. ESD Effect on critical thinking development
Source: devised by the authors.

When it comes to resources, 20% stated that it was extremely challenging, 17.1% marked it as moderately challenging and the majority (48.6 %) found it somewhat challenging. 40% of the participants believe that they receive insufficient training in the field of sustainable development, and therefore lack awareness on the issue. Additionally, 37.1% of students thought that they had very limited time for ESD in their curriculum. 45.7% of the respondents voted that there were not enough elements of ESD incorporated in their courses.

When asked about the importance of stakeholders in promoting ESD, surprisingly, option "other students" received the most votes 34.3%. Educators followed with 18.7%. Industry partners received only 4.8% and the rest was spread out among communities and industry partners.

The last question was open-ended and asked what actions could be taken by various stakeholders to promote ESD successfully. The answers were analysed after 3 themes were formulated.

Theme 1: Mandatory ESD courses. Students believe that there should be a mandatory course allocated specifically for raising awareness on sustainability issues and how to address them.

Theme 2: Raising awareness events. Here, students suggested that to engage more students in the topic of sustainable development stakeholders should organise events: such as planting trees, collecting garbage, recycling seminars, etc. While some such events would encourage students to lead more sustainable lives, others would provide the knowledge that they might lack.

Theme 3: Cooperation with sustainability leaders. Respondents stated that more attention should be paid to cooperation with successful sustainability-related companies in the form of

lectures from the company representatives, visits to such companies and internship opportunities.

Then using SmartPLS software there was created a structural equation model (SEM) based on the survey results. SEM, which links measurement items to their corresponding latent variables, requires the measurement model as a precursor. This section provides the theoretical context and statistical analysis to support the accuracy and dependability of the measurement model.

The conceptual model is made up of four latent variables, which are complex and cannot be assessed by a single observed variable (fig. 9). Therefore, each of the latent variables of the conceptual model is evaluated using numerous observed objects.

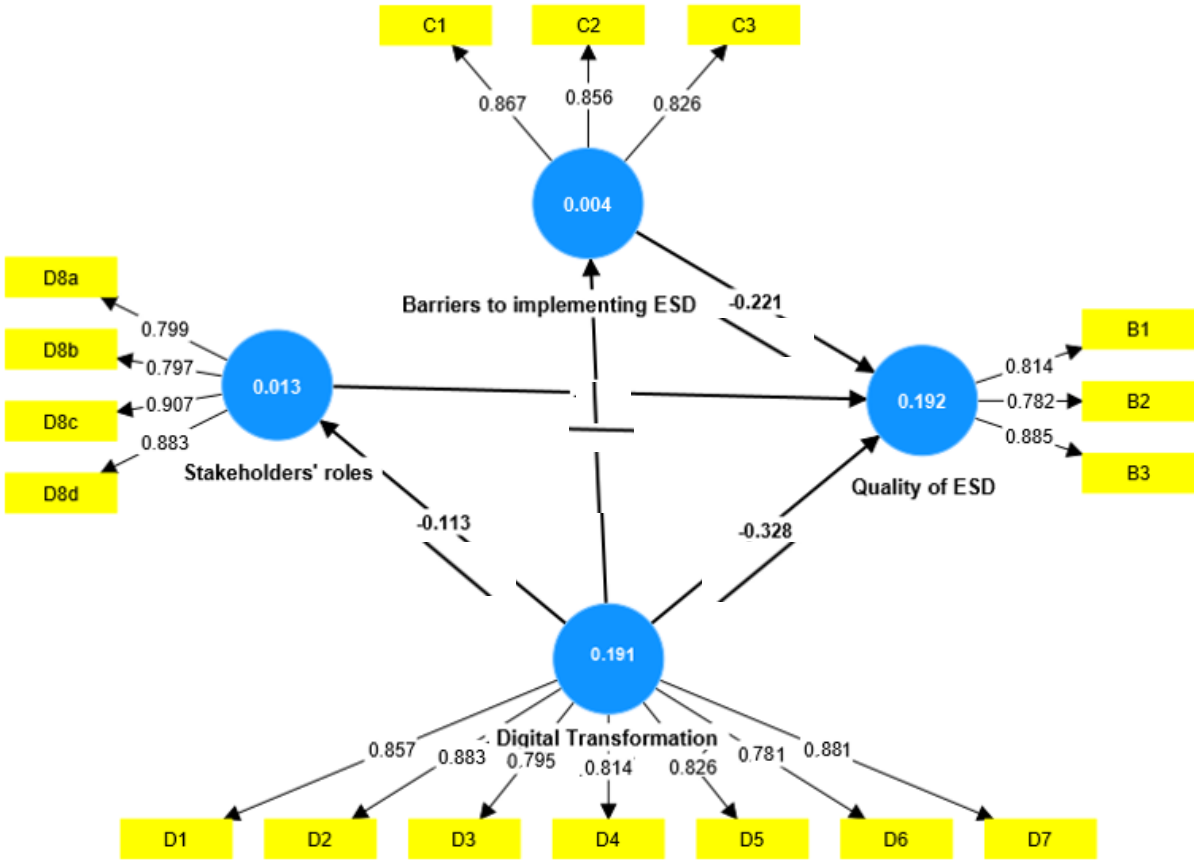

Figure 9. Estimated structural equation model
Source: devised by the authors.

This study uses a variety of assessment scales on how digital transformation in education contributes to fostering sustainable development to assess crucial variables. According to earlier research on ESD awareness, familiarity with Education for Sustainable Development (ESD) is operationalized as a single-item latent variable (Cortese, 2003). A multi-item latent

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variable is used to assess the educational institution's quality of ESD, including questions taken from the research by Sterling (2011) and Mochizuki and Fadeeva (2010). In order to address topics like online learning, technology integration, and blended learning strategies, the concept of digital transformation in education was built by modifying elements from several research, including Bonk (2009), Means et al. (2010), and Zawacki-Richter and Naidu (2016).

Using items derived from Lozano et al. (2015), the stakeholder roles and responsibilities construct is measured with an emphasis on the contributions that educators, students, policymakers, and local communities make to the promotion of ESD. The items used to measure access to educational resources were developed from Jaggars (2014) and Shea and Bidjerano (2014) and take into account factors like the accessibility of online resources and their availability. Items drawn from Latchem (2018) are used to evaluate the environmental impact of education and the expenditures associated with it.

The barriers to implementing ESD, including a lack of resources, insufficient training in ESD, limited time for ESD in the curriculum, a lack of support from school administration, and no integration of ESD in existing subjects, are measured using items adapted from Barth et al. (2007) and Wiek et al. (2011). These items are designed to assess the challenges and barriers educational institutions face when incorporating ESD and digital transformation into their curricula and practices. Table 1 presents the measurement items with their respective latent variables and table 2 demonstrates a validity check.

Table 1. Measurement items

	Barriers to implementing ESD	Digital Transformation	Quality of ESD	Stakeholders' roles
B1			0.814	
B2			0.782	
B3			0.885	
C1	0.867			
C2	0.856			
C3	0.826			
D1		0.857		
D2		0.799		
D3		0.871		
D4		0.903		
D5		0.856		
D6		0.78		
D7		0.83		
D8a				0.799
D8b				0.797
D8c				0.907
D8d				0.883

Source: calculated by the authors.

There are used both multivariate and univariate normality tests to determine whether the measurement items are normal before moving on to the confirmatory factor analysis (CFA)

model. The estimating method used in CFA (and SEM) depends on the normality of the data, hence it is crucial that the data be normal. The Shapiro-Wilk test (all p-values 0.05 of all measurement items) rejects the null hypothesis of univariate normality, much as the Mardia test (p-value 0.05) does the same for the null hypothesis of multivariate normality. Therefore, rather than using the maximum likelihood (ML) estimator to evaluate the measurement model, there is instead utilized the maximum likelihood robust (MLR) estimator, commonly known as the Satorra-Bentler rescaling approach (Rosseel, 2012).

This research used self-reported surveys to get the measurement item data. The items reflect their underlying latent concept, as shown by the statistically significant (p-value 0.001) standardized factor loadings of the CFA model shown in Table 1. This attests to the measurement model's convergence validity (Anderson and Gerbing, 1988). Table 2 lists each factor's composite reliability (CR) and Cronbach's alpha (Cronbach, 1951). According to Hair et al. (2011), all factors' Cronbach's Alpha and CR values are higher than the specified cut-off point of 0.70. As a result, the measurement model's reliability is confirmed.

Table 2. The analysis validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Barriers to implementing ESD	0.808	0.812	0.886	0.722
Digital Transformation	0.846	0.847	0.886	0.565
Quality of ESD	0.771	0.794	0.867	0.685
Stakeholders' roles	0.873	0.91	0.911	0.719

Source: calculated by the authors.

The structural model is used to look at relationships among the latent variables after establishing the measurement model in the previous section. Once more, SEM is evaluated using the MLR method as Rosseel (2012) advised for non-normal data. Figure 9 shows the calculated SEM. Based on the SEM model there can be tested the hypotheses proposed earlier. The first hypothesis is related to the association of digital transformation of education and ESD. Thus, hypothesis is supported with standard coefficient value of 0.16. H2, which refers to challenges and barriers to implementing ESD being associated with quality of ESD is also supported with standard coefficient value of 0.23. And finally, H3 about the stakeholders' roles have a positive association with quality of ESD is also confirmed with standard value of 0.35.

This study employing the SEM model allowed testing the proposed hypotheses related to the role of digital transformation in education toward promoting sustainable development. The results provide support for all three hypotheses. These findings contribute to our understanding of the factors influencing ESD and highlight the potential of digital transformation to enhance sustainable development in education.

6. Conclusions

In conclusion, education for sustainable development (ESD) is essential for promoting sustainable development and influencing the attitudes and actions of current and future generations. For a significant impact, transformative learning methodologies must be adopted, which includes ESD in various learning contexts, highlighting the need for multidisciplinary and integrative approaches that take into account various learning styles, backgrounds, and circumstances. For the purpose of creating and putting into practice transformative learning experiences that promote behavioural change, critical thinking, and social engagement, important stakeholders including educators, policymakers, and civil society organizations must be engaged. Although there may be obstacles to implementing ESD it is necessary to raise awareness of the topic. A brighter future for all depends on the appeal for a renewed commitment to ESD as a critical tool in addressing the global sustainable development agenda.

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