

Article

Factors Affecting the Effectiveness of Sustainable Vocational Education: A Study on Academics in Turkey

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Abstract

Sustainable vocational training refers to the continuous and timely provision of qualified personnel to support a country's economic growth and development. Recognizing the significance of these activities is crucial, as they play a key role in national progress. In recent years, research on the sustainability of vocational education systems across different countries has gained momentum. This study aims to identify the key components that ensure the sustainability and effectiveness of the vocational education system in Turkey. Data were collected from 2450 academicians employed in higher vocational schools across the country. Survey data were analyzed, and hypotheses were tested using Structural Equation Modeling (SEM). The findings reveal four main components essential for sustainable vocational education in Turkey: (1) enhancing digitalization and access opportunities, (2) increasing awareness of energy and resource efficiency, (3) integrating data-driven education policies and (4) online education systems into vocational curricula. Implementing these components in all vocational institutions is considered vital for advancing Turkey's economic and developmental objectives.

Keywords: sustainable vocational education; digital transformation; energy and resource efficiency; data-driven education policies; online education

1. Introduction

Today, technological developments are seen as the most important developments affecting education systems in the world. In particular, this importance has increased even more in vocational education. For example, many tools such as digitalization [1], artificial intelligence [2], and distance education are used. The reason for this situation is the need to meet sector-specific personnel who have completed their vocational education [3]. In order to achieve sustainable education goals, vocational education is expected to contribute to both environmental and economic sustainability. However, the success of this process will only be possible with the active participation of stakeholders in the sector [4]. Vocational education has been found to have a positive impact on employment quality [5].

Sustainable vocational education focuses not only on the transmission of technical skills but also on the nurturing of individuals who are environmentally conscious, possess ethical values, and have the capacity for lifelong learning. Adebisi (2023) posits that vocational and technical education has the capacity to equip individuals with the necessary



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technical skills, thereby enabling them to secure sustainable livelihoods, foster peaceful coexistence, and enhance social cohesion [6]. The functionality of vocational education is not solely measured by economic outputs, sustainability principles such as social equality, environmental awareness, and contribution to quality of life are also taken into consideration in its evaluation. Tong (2024) posits that effective collaborations between industry and educational institutions enhance the effectiveness of vocational education by closing skill gaps in the areas of sustainability and technological innovation [7]. Furthermore, Ya Qiong et al. (2022) posit that sustainable vocational education strengthens environmentally conscious behavior, green skills, and social responsibility awareness among students [8]. This demonstrates that sustainable vocational education contributes directly not only to individual skill acquisition but also to the sustainable development of society. In conclusion, the concept of sustainable vocational education aims to develop individuals' technical, digital, and environmental skills through a holistic approach, support social welfare, and ensure the continuity of economic systems in harmony with the environment. It is therefore imperative that vocational education policies, curriculum designs, and teacher training processes be restructured in line with sustainability principles.

One of the important issues within vocational education is sustainability. Sustainable vocational education is seen as the timely and appropriate training of students within the scope of vocational education. With sustainable vocational education, the foundations of regional development and economic development are laid. Therefore, sustainable vocational education is likely to be seen as the most important criterion for countries. The fact that sustainable education is so important causes it to be included in academic studies. The aim of this study is to investigate the factors that are effective in ensuring the effectiveness of sustainable vocational education. To this end, an effort has been made to conduct a study based on the opinions of academics working at vocational colleges providing vocational education in Turkey.

2. Theoretical Background in Turkey and Literature Review

Beginning in the 18th century and continuing until the present, vocational education which aims to provide students with work and vocational skills [9] has been carried out under various names, including business school and production school. Vocational education is chiefly concerned with the provision of a specific profession to meet the demand for trained personnel and to establish a balance between the number of graduates and the number of individuals seeking employment [10]. Students receiving vocational education contribute to the global economy and production processes. Furthermore, it is regarded as the most efficacious approach for expeditious personnel training in alignment with business lines and personnel requirements [11,12]. Its utilization is particularly prevalent in developing countries, particularly in the context of addressing issues of unemployment [13]. The adoption of practice-based education within the vocational and technical education framework is a strategic measure that aims to align the educational curriculum with the real-world needs and practices of the industry, thereby mitigating the discrepancy between educational outcomes and industry expectations.

Given the importance of education, particularly vocational education, educational institutions hold a vital role in providing the necessary knowledge and skills in this field. The history of vocational education in our country dates back to the Ahi organization, which functioned as a non-formal education institution in the 13th century and continued until the 1860s, when formal vocational art schools were established [14]. The Ahi system comprised two main forms of training: workplace instruction that included both professional skills and ethical principles, and educational activities outside the workplace, where religious, moral, and literacy education were provided. Vocational training typically began before the age of

ten and progressed from apprenticeship to journeyman after an average of 1100 days [15]. After the decline of the Ahi organization, guilds took over vocational education through non-formal means. Apprenticeship training required parental consent and began before the age of ten. After two years, apprentices were promoted, and after three more years, they became journeymen. This system remained until 1860, when vocational education shifted to formal institutions in the Ottoman Empire. The guilds were officially dissolved by law in 1912 [14].

The Republic witnessed the adoption of a novel, school-based structure for vocational education. In 1927, the Ministry of National Education assumed responsibility for vocational and technical education, which was previously overseen by the Directorate General of Vocational and Technical Education. The latter was established within the Ministry in 1933. In 1934, the Inter-Ministerial Council convened and, in accordance with the reports presented by foreign experts, recommended that the need for qualified personnel be met through apprenticeship programs, evening art schools, and short-term courses [16,17]. The Vocational Tedrisatın İnkişaf Planı, formulated between 1934 and 1936, is a seminal document in the realm of vocational education and the collaboration between educational institutions and the employment sector. The plan was a collaborative effort between the Ministry of National Education, the Ministry of National Defense, the Ministry of Agriculture, the Ministry of Public Works, and the Ministry of Economy. The plan called for the establishment of apprentice schools, art and secondary art schools, evening art schools, technician schools, engineer schools, and mobile village courses. The measures delineated in the Plan were expeditiously executed, resulting in a substantial augmentation in the number of students, educators, and institutions offering vocational and technical education [18]. In 1941, the General Directorate of Vocational and Technical Education was replaced by the Undersecretariat for Vocational and Technical Education. In 1960, the Undersecretariat for Vocational and Technical Education underwent a restructuring, resulting in the formation of the General Directorate of Technical Education for Boys, the General Directorate of Technical Education for Girls, and the General Directorate of Trade Education.

Following the enactment of Law No. 2089 in 1977, apprenticeship education was incorporated into the national vocational education framework. Legislation No. 3308 on Vocational Education, enacted in 1986, underwent a comprehensive reorganization of fundamental vocational education, encompassing the domains of “formal,” “apprenticeship,” and “non-formal” education. According to Law No. 3308, social partners are assigned pivotal roles in the planning, implementation, and evaluation of formal, apprenticeship, and non-formal vocational education. Consequently, Vocational Education Councils were established within the Ministry of National Education, functioning at the national level, and Provincial Vocational Education Councils, functioning at the provincial level [19]. Law No. 3797 on the Organization and Duties of the Ministry of National Education, published in 1992, established the General Directorate of Technical Education for Boys, General Directorate of Technical Education for Girls, General Directorate of Trade and Tourism Education, Department of Health Affairs, Department of Apprenticeship, Development and Dissemination of Vocational and Technical Education, and Department of Educational Research and Development. With the 2011 Decree Law No. 652 on the Organization and Duties of the Ministry of National Education, six units responsible for the execution of vocational and technical education in the Ministry of National Education were merged under the name of General Directorate of Vocational and Technical Education. Non-formal vocational education and open education institutions were also gathered under the General Directorate of Lifelong Learning [20].

Subsequently, it assumed its contemporary form through educational institutions such as vocational high schools and vocational colleges, where vocational education is prioritized. In the contemporary educational landscape, there are institutions such as vocational and technical Anatolian high schools, multi-program high schools, vocational training centers, vocational open education high schools, fine arts high schools, and sports high schools. Vocational training centers are also in place to provide apprenticeship training. At the university level, vocational colleges and universities are the institutions primarily responsible for offering vocational education. In recent years, sustainable vocational education studies have been implemented in higher education by implementing vocational education projects in enterprises, especially in vocational colleges. The transition of associate degree institutions that provide vocational education to the 3 + 1 system and the transition of undergraduate institutions to the 7 + 1 system have increased the importance of sustainable vocational education. While enrolled in institutions that offer associate degrees, students receive three semesters of theoretical education. Concurrently, they are provided with the opportunity to receive practical training in workplaces for one semester. Similarly, at the undergraduate level, a total of seven semesters of theoretical instruction and one semester of practical training are provided. The implementation of data-based education policies is facilitated by this situation, concurrently ensuring the provision of adequate personnel training.

A pivotal concern in the context of sustainability within Turkey's vocational and technical education system pertains to the necessity of fortifying the nexus between the labor market and educational institutions. For instance, the report entitled "Integration of Vocational and Technical Education into the Labor Market: Adaptation and Future Forecasts," a publication by the Ankara Chamber of Industry, asserts that digitalization and green transformation have profoundly altered job descriptions. It is imperative for vocational education in Turkey to maintain congruence with these transformations to ensure a sustainable labor supply [21]. The competencies of teaching staff, in conjunction with the quality of in-service training, are of pivotal significance in the context of the sustainability of vocational education. A further study undertaken on the sustainability of the education system identified a further dominant theme, namely the development of quality, accessibility, and institutional structures in vocational education. The 'Project for Improving the Quality of Vocational and Technical Education in Turkey' was initiated by the Ministry of National Education with the stated objectives of enhancing the quality of vocational education, fostering the development of skilled human resources, mitigating regional disparities, and contributing to the establishment of a sustainable economy [20]. In a similar vein, the compilation study entitled 'A Conceptual Framework on Teachers' Professional Development and Implications for the Turkish Education System' emphasizes the importance of providing teachers with contemporary knowledge and skills for the long-term functionality of the education system. The study specifically draws conclusions for Turkey [22].

The study entitled 'Workplace Application and Student Gains within the 3 + 1 Education Model in Vocational Colleges' posits that the '3-term education + workplace application' model implemented at a vocational college in Turkey contributes to students acquiring skills suitable for the labor market and, consequently, to the sustainable functioning of the education system [23]. The study titled 'Quantitative Changes in Vocational and Technical Education in Turkey' examined how indicators such as enrollment, number of teachers, and budget in vocational and technical education institutions in Turkey have changed over the years. The study revealed that these indicators are metrics that should be monitored for a sustainable system [24]. The study titled 'Paradigm Shift in Vocational Education in Turkey', emphasized the necessity for transformations in the field of vocational education

in Turkey due to factors such as labor market alignment, transition to higher education, and technological change. The study further stated that these transformations would provide advantages in terms of the system's sustainability when they become permanent [25].

3. Research Hypotheses Development

The objective of this study is to ascertain the factors that may influence the efficacy of sustainable vocational education in universities with associate degree programs offering vocational education in Turkey. To this end, the objective was to formulate study hypotheses by taking into account a range of studies found in the extant literature. Concurrently, the objective is to formulate hypotheses that are consistent with the study and align with the findings reported in the extant literature.

Digitalization and the provision of access opportunities have brought about a number of positive impacts on society. In particular, sustainable development and education are some of these impacts. Ensuring the digital literacy of educators and trainees has become a prerequisite for the emergence of these positive effects [26–28]. Therefore, it is very important to provide digitalization and access opportunities to the development processes of educational institutions [29,30]. In the studies conducted, it has been documented that increasing digitalization and access opportunities contributes to professional development. In particular, many studies have been conducted on the necessity of including digital literacy in the curricula of vocational colleges [31–34]. Based on these studies, the following hypothesis was developed:

H1. *Digitalisation and access opportunities have an impact on sustainable vocational education.*

Zografakis et al. (2007) see education as an important factor in the development of energy-saving behaviors and attitudes at all levels of society [35]. Hobley (2015) criticized that theoretical education in vocational education overshadows vocational and technical education [36]. He also stated that students have deficiencies in energy and resource efficiency in education. He argues that this situation will cause students to be inadequate in business life. Hiim (2017) contributed to this debate by emphasizing the importance of work–life practice in vocational curricula [37]. Another study revealed that energy efficiency is critical for mitigating climate change and promoting sustainable development at the corporate level [38]. Barbero et al. (2023) emphasize the critical importance of educational accessibility and awareness as factors affecting energy efficiency outcomes and reveal the important role of vocational education in developing these competencies [39]. In addition, the study states that there is a direct proportion between increasing energy efficiency and improving vocational competencies. Based on these studies, the following hypothesis was developed:

H2. *Energy and resource efficiency have an impact on sustainable vocational education.*

Many studies on online education reveal the existence of an interaction between vocational education and technological developments, student behaviors and approaches. Maddison et al. (2016) stated that with online education, students participate more in the course and cause detailed topics to be covered [40]. Collins (2017) also reported that online education leads to increased student engagement in the course [41]. Canales et al. (2018), in his study, determined that online education increased student motivation and satisfaction [42]. Kara et al. (2019) emphasized the disadvantages of online education and also stated that it plays an important role in adult education [43]. Again, [44], focusing on the impact of online learning on academic staff, revealed the challenges faced by instructors

who transition to online education. Based on these studies, the following hypothesis was developed:

H3. *Online education has an impact on sustainable vocational education.*

In higher education institutions, data-driven educational policies are widely recognized as an important tool used by leading educational institutions. There are very few studies on this topic in the existing literature. Analyzing educational data is seen as a fundamental element in the implementation of new educational policies and will become increasingly important in the future [45]. Yan and Wu (2025) report the impact of technological developments on educational policies [46]. As a result of the study, it was stated that technological developments cause curricula to be renewed and interdisciplinary development. In their study, Fodor et al. (2021) provided information about the usage areas of data-based education policies [47]. In the study, it was stated that the creation of data-based policies in education will lead to the completion of deficiencies by providing feedback in education. Moreover, in a study examining quantitative changes in vocational and technical education in Turkey, insights into the long-term sustainability of the system were gained by analyzing changes in indicators such as enrollment, teacher numbers, and budget [24]. A study conducted in China has demonstrated that the utilization of data at the school level enhances the decision-making processes guided by education leadership and improves the quality of vocational education [8]. Such analyses emphasize the importance of data-driven monitoring and evaluation mechanisms for the sustainability of vocational education. Based on these studies, the following hypothesis was developed:

H4. *Data-driven education policies have an impact on sustainable vocational education.*

The hypotheses formulated in this study aim to examine the multidimensional factors determining the effectiveness of sustainable vocational education. Sustainable vocational education encompasses a multifaceted array of components, including pedagogical methodologies, digital transformation, environmental sustainability, the promotion of equitable educational opportunities, and the utilization of data-driven approaches in policy formulation. Moreover, extant literature suggests that the development of sustainable vocational education should integrate technological advancements and enhance the effectiveness and efficiency of educational policies. Consequently, hypotheses were formulated on the basis of both theoretical foundations and current empirical research. These hypotheses were selected to represent the technological, environmental, pedagogical, and managerial dimensions affecting sustainable vocational education. Therefore, a comprehensive model is hereby proposed for the enhancement of the long-term sustainability and effectiveness of vocational education in Turkey.

4. Research Method

4.1. The Study's Model

The goal of this study is to figure out what it takes to make sure that vocational education in Turkey is sustainable and effective. To this end, we asked academics working at associate degree institutions offering vocational education in Turkey for their opinions. A thorough review of the existing literature and an analysis of current practices in the country were conducted to identify the factors affecting the effectiveness of sustainable vocational education. This analysis showed four key components. These are digital tools in education that use energy and resources efficiently, use data to make education policies, and use online tools in education. The ideas mentioned in this study were then checked using something called a “structural equation model” (or SEM for short). We

chose to use SEM instead of other methods because it can look at the complex connections between hidden and visible factors at the same time. Furthermore, SEM is a great tool for research that wants to find out what happens because of different factors, both directly and indirectly. This issue is the main focus of our research on how to improve sustainable vocational training. However, a second reason to use SEM is its ability to manage multiple dependent variables and evaluate their relationships within a comprehensive model. It allows for the complete modeling of connected factors such as digital technology and easy access, energy and resource efficiency, data-driven education policies, and online education applications [48]. Furthermore, the Structural Equation Modeling (SEM) approach allows us to test hypotheses about the relationships between variables. This helps to support the theoretical framework underpinning our research, particularly the SVE model. The SEM framework allows us to examine how perceived relative advantage and compatibility influence the adoption of sustainable SVE. This provides strong validation of the theoretical framework within the context of SVE.

The conceptual model of this study is illustrated in Figure 1. As demonstrated in Figure 1, the independent variable, sustainable vocational education (SVE), was measured based on the mean of seven concepts/items using a Likert five-point scale (1 = strongly disagree; 5 = strongly agree). A parallel methodology was employed to assess the dependent variables of digitalization and accessibility (DA), energy and resource efficiency (ERE), the implementation of data-driven education policies (DDEPs), and online education (OE).

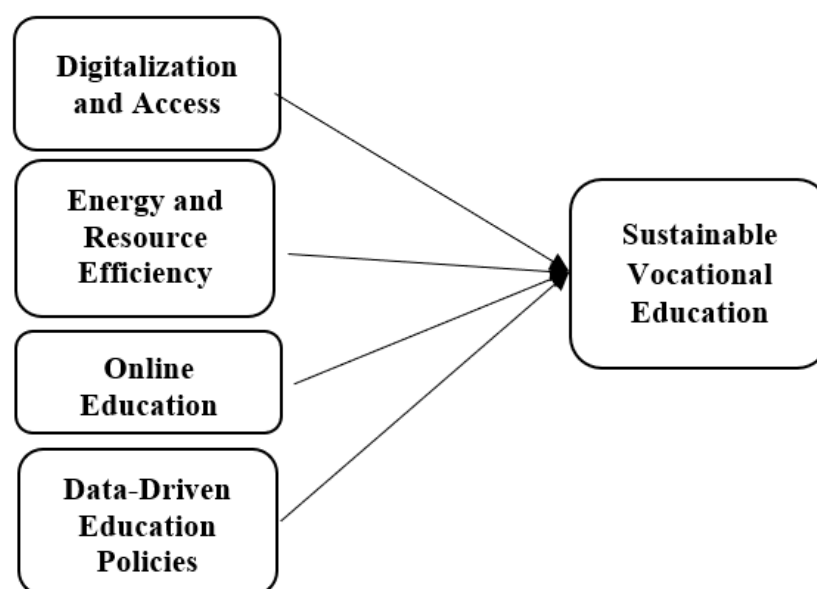


Figure 1. The conceptual model of the study. Source: Created by the authors.

4.2. Data and Sample

Selecting Turkey as the main population for this study emphasizes the importance of vocational education in developing countries and its direct contribution to the national economy. It also highlights the critical role of vocational education in a country's development. Academicians, in particular, play an important role in sustainability by providing direct transfer of vocational education. Therefore, the opinions of these academics are of great importance in this study. This study aims to determine the perceptions of academic staff working in vocational education institutions (vocational colleges) regarding the criteria for ensuring the effectiveness of sustainable vocational education. To this end, a questionnaire was administered to 24,140 academics working in vocational education institutions in Turkey [49]. The Google Docs website was used to collect the necessary data for the study. The questionnaire was created based on the opinions of various academics

and practitioners. The questionnaire was presented as a 5-point Likert scale. To ensure the validity and reliability of our Likert scale, we took several steps and applied relevant statistical techniques. Thus, we strengthened the reliability of our research findings.

Initially, a pool of statements was formulated by considering institutional foundations and literature in the formulation of research statements. Subsequently, in the pre-test phase, the questionnaire was administered as a pre-test to 20 academics and five practitioners. Subsequent to the analysis of the results, statements were either added or clarified where ambiguity or absence was identified. The evaluation process encompassed the assessment of question comprehensibility, the appropriateness of language, and the alignment with the measurement objective. In the final stage of the refinement process, items exhibiting low reliability or consistency were eliminated. This decision was made on the basis of feedback from the pretest and statistical analyses. The elimination of these items served to enhance the scale's validity and reliability.

The questionnaire has two parts. The first part consists of five questions designed to assess the demographic characteristics of academic staff. The second part consists of 40 carefully selected statements based on the scope of the study and existing literature that reflect the views of academics. The study encompasses seven statements designed to ascertain academics' perceptions of sustainable vocational education, nine statements aimed at gauging their views on the significance of digitalization in this context and the extent to which it is incorporated into educational practices, nine statements intended to assess their awareness of energy and efficiency in sustainable vocational education, seven statements to evaluate the utilization of online education and its convenience within the education system, and eight statements to ascertain their opinions on the reflection of sustainability in education policies in sustainable vocational education. The study thus comprises a total of 40 statements that form the questionnaire employed to solicit academics' opinions. The questions were prepared using a 5-point Likert scale. Additionally, Cronbach's alpha value was calculated to assess the study's reliability. The result was 0.895, indicating a high degree of reliability. The entire study population of academicians working in vocational colleges in Turkey was targeted using the snowball sampling method. The questionnaire was distributed via email to academic staff email addresses listed on university websites. Of the 2750 academics who filled out the questionnaire, it was determined that 2450 did so in accordance with the scope of the study, yielding an 89% response rate. At this stage, the study encountered a limitation. While it was hypothesized that all of the participants determined by the random-access method would complete the questionnaire in its entirety, it was observed that 11% of the academics did not do so, either filling out the questionnaire incompletely or not in accordance with the scope of the study. However, this rate is at a level that will not affect the reliability of the study. Correlation analysis was conducted on the 2450 completed questionnaires to evaluate the study's hypotheses. Frequency analysis was also used to identify demographic factors. The results were then analyzed and interpreted.

5. Results

5.1. Descriptive Analysis

Table 1 presents the demographic characteristics of the participants. As indicated by the data presented in Table 1, the genders of the participating academics were selected to be quite evenly represented. A subsequent analysis revealed that more than half of the participating academics fell within the 30–40 age range. It was determined that the vast majority of participants had 4–20 years of professional experience. Sixty-seven percent of the participants have a master's degree, while only 14% have a doctoral degree. While this percentage is low academically, it is normal considering that most educators at private schools in Turkey are lecturers. Academic staff with doctorates usually work at institutions

that offer undergraduate programs. In addition, 93% of participants are academics teaching professional courses, while 7% are academic staff teaching service courses (Turkish, foreign languages, history, etc.). This result is important for understanding the effectiveness of sustainable vocational education, the main focus of our study.

Table 1. Statistical information on participants' demographic characteristics.

Gender	n	%	Age	n	%
Female	1150	47	30 years old and under	654	27
Male	1300	53	30–40 years old	1296	53
Total	2450	100.0	41–50 years old	300	12
Professional Experience	n	%	51 years old and over	204	8
3 years and under	263	11	Total	2450	100.0
4–10 years	998	41	Level of Education	n	%
11–20 years	1030	42	Bachelor's	474	19
21 years and over	159	6	Master's	1639	67
Total	2450	100.0	PhD	337	14
Vocational Field	n	%	Total	2450	100.0
Vocational Courses	2289	93			
Service Courses	161	7			
Total	2450	100.0			

The following investigation seeks to establish the relationships between vocational education, digitalization and access, energy and resource efficiency, online education, and data-driven education policies (see Table 2). The table indicates that there are statistically significant and strong relationships between some variables. Specifically, the correlation between vocational education and energy and resource efficiency is significant ($r = 0.702$, $p < 0.01$). This finding indicates that vocational education plays a significant role in the development of skills focused on sustainability and resource management. In addition, a notable correlation was identified between vocational education and digitalization, as well as access ($r = 0.564$, $p < 0.01$) and online education ($r = 0.492$, $p < 0.01$). The findings of this study suggest a correlation between vocational education and the development of digital skills, as well as the integration of technology-supported learning processes. A high level of correlation is evident between digitalization and access, and online education ($r = 0.737$, $p < 0.01$).

Table 2. Statistical summary of the constructs: means, standard deviations, and correlations ($N = 2450$).

	Mean	Std. Dev.	1	2	3	4	5
(1) Sustainable Vocational Education	4.0005	0.56938	1	0.564 ** (0.000)	0.702 ** (0.000)	0.492 ** (0.000)	0.019
(2) Digitalization and Access	3.9876	0.49672	0.564 ** (0.000)	1	0.467 ** (0.000)	0.737 ** (0.000)	−0.024
(3) Energy and Resource Efficiency	3.9428	0.55537	0.702 ** (0.000)	0.467 ** (0.000)	1	0.343 ** (0.000)	0.066
(4) Online Education	4.0821	0.56120	0.492 ** (0.000)	0.737 ** (0.000)	0.343 ** (0.000)	1	−0.042
(5) Data-Driven Education Policies	3.9527	0.46873	0.019	−0.024	0.066	−0.042	1

** Correlation is significant at the 0.01 level (2-tailed).

Consequently, it is posited that digital infrastructure and access are pivotal factors in the efficacy of online education processes. The positive relationship between digitalization and energy and resource efficiency ($r = 0.467$, $p < 0.01$) highlights the contribution of digital transformation to sustainability policies. Furthermore, the relationships between data-driven education policies and other variables were found to be quite weak and statistically insignificant. To illustrate this point, consider the correlation between data-driven policies and online education, which is found to be negative and very low ($r = -0.042$, $p > 0.01$). This finding suggests that data usage is not sufficiently integrated into education policies or is limited in practice.

5.2. Hypothesis Testing

Pursuant to the findings of the SEM results, it was ascertained that the general fit level of the study model was at a satisfactory level. This is particularly evident when examining the value of χ^2/df , which is found to be 3.259. As the figure falls below 4, it is deemed to be at an acceptable level. Given that $RMSEA = 0.06 < 0.08$, it can be concluded that the model exhibits a satisfactory degree of fit. The values of the CFI, TLI, NFI, and GFI, which are 0.965, 0.973, 0.988, and 0.993, respectively, are all above 0.95, indicating an excellent fit. Finally, the AGFI was found to be equal to 0.872. Given that the result is above the 0.85 limit, it can be concluded that there is an acceptable fit at an adequate level. These values indicate that the theoretical structure of the model is in harmony with the study data, and the reliability of the findings will be high.

As indicated by Table 3, it has been ascertained that the independent variable, sustainable vocational education, in the model, exerts a statistically direct, significant, and substantial effect on the four variables specified in the study. The findings of structural equation modeling (SEM) indicate that sustainable vocational education (SVE) has significant and strong effects on the relevant sub-variables. When direct effects are examined, SVE is seen to have high and significant effects on DA ($\beta = 0.785$, $p < 0.001$), ERE ($\beta = 0.791$, $p < 0.001$) and OE ($\beta = 0.815$, $p < 0.001$). This finding lends further credence to the proposition that sustainable vocational education practices exert a substantial influence on the efficacy of work performance, the efficient utilization of educational resources, and the attainment of organizational learning outcomes. Despite its comparatively diminished impact on the DDEP variable ($\beta = 0.107$, $p < 0.001$), SVE exerts a discernible influence on direct decision-making processes and interdepartmental cooperation, albeit with a limited extent. Standardized total effects once again confirm the strong effects of SVE on DA, ERE and OE (0.701, 0.715 and 0.752, respectively), thus indicating that the impact of sustainable vocational education strategies in practice is important both directly and indirectly.

Table 3. SEM analysis result.

<i>Variables and Description</i>	Estimate	S.E.	C.R.	p
DA←SVE	0.785	0.048	14.458	***
ERE←SVE	0.791	0.050	14.756	***
OE←SVE	0.815	0.055	15.685	***
DDEP←SVE	0.107	0.042	18.678	***
Mean for SVE	3.721	0.173	35.899	***
$\chi^2/df = 3.259$, $RMSEA = 0.06$, $RMR = 0.05$, $CFI = 0.965$, $NFI = 0.988$, $GFI = 0.993$, $AGFI = 0.872$, $TLI = 0.973$				

Table 3. *Cont.*

<i>Variables and Description</i>	<i>Estimate</i>	<i>S.E.</i>	<i>C.R.</i>	<i>p</i>
<i>Intercepts</i>				
DA	2.383	0.198	9.164	***
ERE	2.645	0.215	9.525	***
OE	2.433	0.201	9.287	***
DDEP	2.339	0.162	9.111	***
<i>Variances</i>				
SVE	2.924	0.259	9.775	***
e1	2.256	0.152	9.775	***
e2	2.226	0.143	9.775	***
e3	1.976	0.135	9.775	***
e4	2.153	0.139	9.775	***
Effects of EV—Estimates	DA	ERE	OE	DDEP
Total effects	0.785	0.791	0.815	0.701
Standardized total effects	0.701	0.715	0.752	0.653
Direct effects	0.785	0.791	0.815	0.701
Standardized direct effects	0.701	0.715	0.752	0.653

*** Correlation is significant at the 0.01 level (two-tailed). Source: created by the authors.

6. Discussion

The model developed within the scope of the study comprehensively reveals that digitalization and access, energy and resource efficiency, online education and data-based education policies have an important place in sustainable vocational education. The findings of this study demonstrate that multidimensional constructs such as digitalization, energy efficiency, and data-based approaches in sustainable vocational education can be significantly influenced by a single central variable. Furthermore, the present study will furnish ideas for vocational education planners and programmers, as well as managers and decision makers involved in vocational education activities. These individuals will be able to implement concrete improvements, especially in areas such as online education infrastructure and energy efficiency. This will be especially relevant in cases where strategies to strengthen vocational education will be implemented. Furthermore, data-based education policy-making, despite its apparent absence from the realm of sustainable vocational education, underscores the necessity for the development of data literacy, analytical infrastructure, and analytical systems integrated into the education system.

A statistically significant result was found between sustainable vocational education and digitalization and access opportunities. The OECD (2022) asserts that the success of sustainable vocational education is contingent upon the reconstruction of education methods on a digital foundation [50]. However, as the European Commission (2021) has indicated, vocational education institutions are obligated to provide not only technical skills within the scope of sustainability but also transversal skills such as digital literacy, information management, and online communication [51]. The Digital Competence Framework (DigComp), a product of the European Commission, offers a reference model for CVET systems. The model delineates five core competence areas, including access to information, digital content production, security, collaboration, and problem solving [52]. These competencies are regarded as fundamental rights that should be imparted to trainees by educational institutions to ensure the sustainability of vocational education. In the context of Turkey, the Ministry of Education's (MEB) Distance Education Platform and e-Certificate programs have been adopted as models of digital CVET practices in the aftermath of the pandemic [53]. In addition to the challenges posed by digitalization and the

effective provision of sustainable vocational education, significant issues have emerged concerning the provision of these systems and access. For instance, Yalçinkaya and Kuzu (2021) highlighted this outcome in their study [54]. The study indicated a pressing need for the professional development of teachers and educators in the effective use of technological equipment.

A substantial body of research has established a nexus between energy and resource efficiency in education and the efficacy of sustainable vocational education. Among these studies, Sterling (2011) demonstrates that energy and resource efficiency are critical components of sustainable development and education [55]. It has been asserted that this component fulfills an awareness-raising and implementing role in achieving sustainability goals in educational institutions [56]. The study's findings suggest that enhancing energy and resource efficiency in vocational education can lead to several key outcomes. These include the enhancement of sustainable education effectiveness, the optimization of energy performance within educational institutions, and the increased adoption of renewable energy systems. Consistent with this finding, analogous results were reported in the studies of [57], and [58]. However, within the scope of sustainable vocational education, courses and practices that are suitable for sustainable vocational education in today's conditions are being added to the curricula of educational institutions. For instance, refs. [59,60] discovered analogous outcomes in their respective studies, including sustainable campus practices [61] environmental education and sustainable development [62,63], energy conservation [64], awareness of renewable energy technologies and resources [65], climate change [66–68] and resource management [69].

Moore et al. (2011) stated that the distance education system has emerged as an important method that increases accessibility, flexibility, and learning opportunities in continuing education with technological developments [70]. As stated in the results of the study, a distance education system is an important component in sustainable vocational education. The biggest advantage of the distance education model is seen as the absence of time and space restrictions in providing sustainable education, allowing employees to receive education from wherever they want [71,72], providing accessibility and flexibility [73], encouraging individualized learning [74], and providing cost-effectiveness [75]. In Turkey, distance education in all education systems, especially in sustainable vocational education, has started to be implemented after the pandemic [76].

Another important component of sustainable vocational education is the development of data-driven education policies, as stated in my study results. Data-based education policies are of great importance in ensuring effectiveness in sustainable vocational education, improving quality and accessibility [77,78], addressing students' achievement levels and needs [79], training personnel suitable for the needs of the labor market [80,81] and feedback [82]. Especially in ensuring the effectiveness of sustainable vocational education, needs analysis [83], program evaluation [84], personalized learning [85] and policy development [86] play an important role in the creation of many strategic education systems. In Turkey, the Ministry of National Education and the Council of Higher Education play an important role in providing these systems. With the sensitive education policies of these institutions, it is ensured that the effectiveness of sustainable vocational education in Turkey is increased and personnel are trained for the needs of the labor market [87].

7. Conclusions

In line with sustainable vocational education, vocational education is transforming into a multi-dimensional, efficient and effective structure through digitalization and ease of access, energy and resource efficiency, implementation of data-based education policies and integration of online education applications. Digitalization and accessibility increase

the accessibility of vocational education, making learning processes more flexible and accessible, while data-based education policies improve quality by continuously analyzing the effectiveness of educational content and methods. These approaches contribute to achieving the sustainable development goals of vocational education.

The present study has demonstrated that the transition to digitalization in sustainable vocational education enhances both the quality and accessibility of educational processes. Moreover, geographical and temporal constraints have been eliminated, facilitating the continuity of professional development for working individuals and thereby promoting lifelong learning processes. The integration of sustainable and energy-efficient technologies into the physical infrastructure of educational institutions is imperative to ensure energy and resource efficiency in sustainable vocational education. It is imperative to incorporate content pertaining to energy and associated disciplines, notably environmental awareness, within the educational curriculum. The development of comprehensive awareness of sustainable vocational education among educators and trainees is of great importance. The integration of distance learning systems is considered to have the potential to improve the quality, accessibility, and motivational resources of sustainable vocational education. The implementation of data-driven education policies, complemented by sustainable vocational education, is set to play a pivotal role in addressing the quality and individual learning requirements within the context of vocational education.

Consequently, this study has determined that within the context of sustainable vocational education in Turkey, endeavors are underway to ensure development in alignment with global trends in vocational education. In particular, academics working in higher education institutions offering vocational education have stated that significant progress has been made, or is underway, in the universities where they work in terms of digitalization and ease of access in vocational education, awareness of the importance given to energy and resource efficiency, implementation of data-based education policies, and integration of online education applications. The prevailing hypothesis suggests that the effective implementation of sustainable vocational education is contingent upon the effective and efficient operation of these four critical criteria.

The present study is constrained by its exclusive focus on academics employed at vocational colleges in Turkey. It is recommended that future studies be conducted on the effectiveness of sustainable vocational education in different fields and institutions (e.g., vocational and technical high schools, institutions offering undergraduate education, etc.). Furthermore, it is hypothesized that this study will provide a foundation for subsequent research by measuring the regional or national impact of sustainable vocational education.

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