Sustainability-Infused Learning Environments: Investigating the Role of Digital Technology and Motivation for Sustainability in Achieving Quality Education

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Abstract. The present investigation delves into the complex interconnections among the digital learning environment, academic achievement, psychological empowerment, motivation for sustainability, and the context of universities in Saudi Arabia. Students from various academic fields were selected for a comprehensive study employing a multilevel sampling technique. A holistic understanding of the variables was obtained through quantitative surveys. The study's findings indicate that a well-functioning digital learning environment notably impacts academic achievement. This is consistent with Saudi Arabia's Vision 2030 objectives, which aim to revolutionize the education sector by integrating technology. While the impact of sustainability motivation on academic achievement is moderately positive, it remains a critical factor in fostering conscientious individuals on a global scale. Furthermore, the correlation between psychological empowerment and academic achievement highlights the criticality of comprehensive education, a fundamental principle of Vision 2030. The current research results provide a strategic plan for improving the standard of education in Saudi Arabia, fostering environmental responsibility, and cultivating diverse individuals equipped to confront forthcoming challenges. This study makes a scholarly contribution and functions as a pragmatic manual for improving education in Saudi Arabia and ensuring its alignment with Sustainable Development Goal 4.

Keywords: Sustainability Practices; Student Academic Performance; Sustainable Development Goals (SDG); SDG 4; Psychological Empowerment; Digital Learning Environment; Saudi Vision 2030

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1. Background of Study

The advancement of sustainable development and the alignment with global sustainability objectives have become central to progress in Saudi Arabia's ever-changing landscape (Alwakid et al., 2021; Chaaben et al., 2022). The country is changing from an oil-based economy to a renewable energy source. The Kingdom has demonstrated a firm commitment to the Sustainable Development Goals (SDGs) of the United Nations and recognises the central role of education in achieving these goals (Alhothali & Al-Dajani, 2022). Higher education institutions (Vachkova et al., 2022) in Saudi Arabia are increasingly focusing on integrating sustainability practices by bringing sustainability educational reforms and green campus initiatives into their academic frameworks to cultivate a new generation of environmentally and socially conscious leaders (Alkhayyal et al., 2019; Alshuwaikhat et al., 2016).

Despite the growing emphasis on sustainability in Saudi Arabia (Alotaibi, 2021; Zahrani, 2022), there still exists a significant research gap in the literature on sustainability practices and student academic achievement in Saudi Arabia's unique educational environment. The government focuses more on sustainability, but psychological empowerment and the digital learning environment are rarely examined as mediating or moderating elements. Psychological empowerment and the digital learning environment have not been extensively studied in Saudi Arabian academic institutions, leaving a gap in understanding their potential impact on sustainability practices and academic achievement. This gap is especially pronounced considering the unexplored variables, psychological empowerment and digital learning environment that may mediate or moderate this relationship. In addition, aligning this endeavour with Saudi Arabia's Vision 2030 (Homepage: The Progress & Achievements of Saudi Arabia - Vision 2030, 2023) – a transformative roadmap for the Kingdom's future – necessitates a comprehensive investigation.

The present study aims to fill the identified research void by conducting an in-depth examination of the relationship between sustainability practices in academic institutions in Saudi Arabia and their impact on student academic performance. It explores the multifaceted dimensions of sustainable education based on the principles of quality education (SDG 4) (Ferguson & Roofe, 2020) while addressing the urgent need for empirical evidence (Boeren, 2019) in the context of the Kingdom.

The study's primary independent variable is students' motivation for sustainability, crucial to their engagement with sustainability issues. This motivation is believed to be a critical factor in enhanced academic performance, as it bridges the gap between sustainable education and academic achievement through engagement, diligence, and perseverance. In the Saudi Arabian context, psychological empowerment emerges as a moderating variable that shapes students' confidence and skills as they navigate the sustainability landscape. At a time when technology is integral to the educational experience (Divayana et al., 2021; Hakami, 2023; Nicolaou et al., 2019; Obidat, 2022), the digital learning environment serves as a moderator in this study. The expanding digital infrastructure in higher education in Saudi Arabia (Al-Mamary et al., 2022; Alowayr, 2022) highlights the importance of understanding how it moderates the

impact of sustainability practices on student academic performance, especially in light of the Kingdom's distinctive educational landscape.

The study examines the relationship between sustainability practices in Saudi Arabian academic institutions and student academic performance with an acute awareness of the research gap and its alignment with Saudi Arabia's Vision 2030. The Triple Bottom Line (TBL) theory, a key sustainability education concept, underpins the study. The TBL posits that educational achievement can be measured economically, environmentally, and socially. This theory fits the study's focus on sustainability, digital learning, and empowerment, providing a holistic perspective to assess their effects on academic attainment. The present research is highly significant in the context of academic institutions in Saudi Arabia. The study investigates the relationship between sustainable practices and student academic performance, aiming to improve the quality and inclusivity of education. This aligns with Sustainable Development Goal 4 (SDG 4) and highlights the importance of academic institutions as crucial contributors to the promotion of responsible global citizenship and tackling global concerns. The results of this study provide practical and valuable information that can be used to shape educational policies and practices. Ultimately, this will create a learning environment that equips students with the necessary skills to meet the challenges of the modern era and contribute to long-term sustainable development.

2. Literature Review

Academic institutions are crucial in achieving sustainable development and a more promising future for our planet (Atici et al., 2021; Žalėnienė & Pereira, 2021). In the context of the present study, the research investigates the complex relationship between sustainability practices in academic institutions and their impact on student academic performance. The investigation is anchored in the Triple Bottom Line (TBL) Theory (Khan et al., 2021), also known as the Triple P (People, Planet, Profit) Theory, which offers a comprehensive prism to analyse the intricate interplay of variables within the academic environment (Zaharia & Zaharia, 2021).

The TBL Theory was chosen for its inherent capacity to encompass the essence of sustainability, which includes economic (Hammer & Pivo, 2017; Khan et al., 2023; Liute & De Giacomo, 2022) and social dimensions (Varyash et al., 2020). The research aligns with the People facet of the TBL Theory, which focuses on human development and societal progress by investigating how sustainability practices in academic institutions affect students. The theory provides the ideal framework for understanding the broader implications of sustainability efforts, as it recognizes that fostering human potential (People) is inextricably linked with environmental preservation (Planet) and economic considerations (Profit).

The selected variables constitute a coherent framework within the scope of our study. Motivation for sustainability, the independent variable (IV), represents the motivating force behind students' engagement in sustainability practices (Cleverdon et al., 2017). It recognises the interdependence of economic, social, and environmental aspects in sustainable development and includes social and environmental components. The TBL encourages organisations to examine their influence on people, the earth, and profit, making it realistic in sustainability. The

TBL helps evaluate academic performance based on economic, social, and environmental factors. The study applies TBL ideas to education to examine how sustainability, digital learning, and empowerment help Saudi Arabian universities define academic performance. It connects directly to the People component of the TBL Theory, emphasising the central role of individuals in promoting sustainability. Psychological empowerment (Saeed et al., 2019), the mediating variable, aligns with the concept of personal and societal development (Basiago, 1998), which is fundamental to the People aspect of the theory. It refers to people internalising psychological processes and translating sustainability values into actions. In today's technology-driven education landscape, digital learning (Jacobi, 2018; Taimur & Onuki, 2022; X. Wang et al., 2022) is a crucial moderating variable, reflecting the modernity and adaptability required to successfully implement sustainability practices within academic institutions (García-Hernández et al., 2023). Academic performance (Alhadabi & Karpinski, 2020), the dependent variable (DV), represents the educational outcomes that result from students' exposure to sustainability practices, connecting back to the TBL theory's overarching theme of human development, addressing the further research gap. The Triple Bottom Line (TBL) idea defines academic performance beyond grades and exam scores; it promotes a holistic approach that considers economic, social, and environmental factors. This paradigm evaluates academic success based on individual achievements and a student's positive impact on society and the environment. It highlights the importance of education in creating responsible global citizens who improve communities and the earth. Thus, scholastic success is linked to social responsibility, environmental stewardship, and ethics, matching with the TBL's three pillars: People, Planet, and Profit. To better understand academic performance in Saudi Arabia, the study examines how these TBL principles are applied.

The study is significant because it has the potential to cast light on how sustainability practices can not only contribute to environmental preservation but also foster personal and societal development via education. The study highlights the holistic nature of sustainability and its relevance to academic institutions by employing the TBL theory. In addition, it contributes to the on-going conversation about aligning educational practices with the Sustainable Development Goals (SDGs) of the United Nations, specifically SDG 4 (Quality Education) (Saini et al., 2023), SDG 8 (Decent Work and Economic Growth) (Rai et al., 2019), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) (Bruce et al., 2018), and SDG 15 (Life on Land) (Krauss, 2022). The present research seeks valuable insights into creating a more sustainable and prosperous future for students and our planet by examining the complex interplay between these variables.
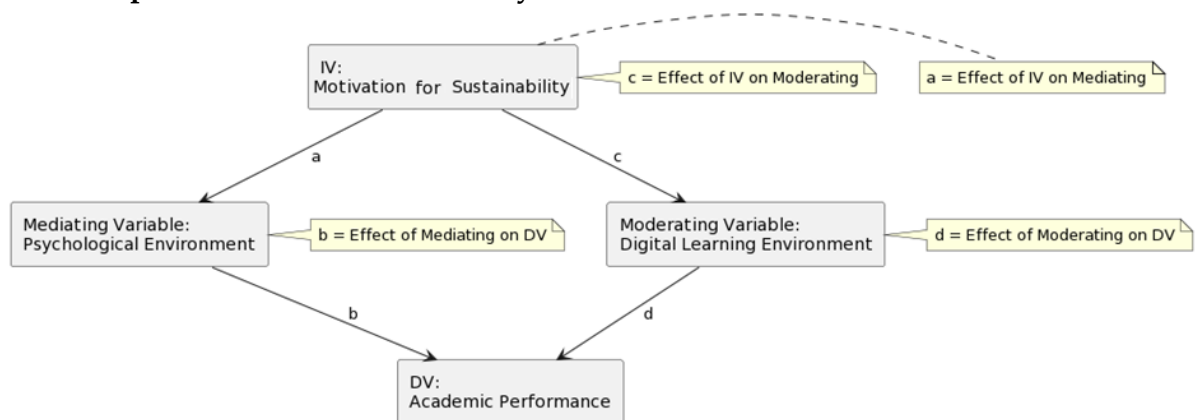
2.1 Conceptual Framework of the Study

Figure 1: Source Author

Motivation for Sustainability on Academic Performance

Motivation for sustainability, as a driving force behind environmentally and socially responsible behaviours (Slager et al., 2021), can substantially influence students' academic performance, an aspect that has not been explored in previous research. This motivation is consistent with several SDGs (Chen et al., 2021), providing compelling arguments for its incorporation into the educational landscape. In the context of sustainability, it is essential to acknowledge potential criticisms and obstacles associated with relying on motivation as a catalyst for academic success.

A strong motivation for sustainability can encourage greater participation in academic activities. Passionate students are more likely to participate actively in class discussions, assiduously complete assignments, and seek additional learning opportunities (M. Singh et al., 2022). Sustainability motivation naturally aligns with several SDGs, including SDG 4 (Quality Education) (Chen et al., 2021), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) (Menkhoff & Gan, 2023), and SDG 15 (Life on Land). Motivating students in this manner improves their academic performance and contributes to the advancement of sustainable development on a global scale. Motivated students frequently demonstrate higher levels of creativity and analysis. They are more likely to investigate interdisciplinary solutions to complex problems, nurturing a creative approach to academic issues (Mulyaningsih et al., 2022). Motivation for sustainability can improve students' persistence and resiliency amid intellectual challenges. They are more likely to overcome obstacles and setbacks, resulting in enhanced educational outcomes in the long run (Xavier & Meneses, 2022). Sustainability initiatives frequently involve practical, hands-on experiences, such as community service projects and internships related to sustainability. These experiences can supplement academic learning by equipping students with valuable skills and insights that positively affect their academic performance (Kong, 2021).

Several critiques have observed that not all pupils have the same motivation for sustainability. Others may have little interest in or understanding of sustainability issues. This variation can make it challenging to generalise motivation's effect on

academic performance (Maiorescu et al., 2020). An overemphasis on sustainability issues without adequate support and resources can result in sustainability fatigue, in which students become overwhelmed or discouraged by the immensity of global challenges. This fatigue can negatively influence their academic motivation and performance. Hence the following hypotheses are proposed:

H1: Motivation for sustainability significantly affects academic performance.

H2: Motivation for sustainability significantly affects psychological empowerment.

2.2 Mediating Effect of Psychological Empowerment on Academic Performance
As a mediating variable, psychological empowerment plays a crucial role in the relationship between motivation for sustainability and academic performance. Psychological empowerment mediates the relationship between sustainable motivation and academic performance by altering cognitive and emotional processes. Psychological empowerment provides students a sense of control, competence, and autonomy, which boosts sustainable motivation. Motivated students take a proactive approach to schoolwork because they feel empowered to improve their education and society. Psychological empowerment inspires sustainable mindsets and behaviours, thus generating a positive feedback cycle in which driven people, empowered by control and efficacy, pursue academic success while embracing sustainability.

The study examines the complex mediation process in Saudi Arabian academic institutions. Its impact on the educational trajectory of students can be linked to several SDGs, providing both persuasive arguments and areas for criticism (Makwetta et al., 2021; Wang & Liang, 2015). The psychological empowerment of individuals reinforces their motivation for sustainability. Individuals who are empowered are more likely to maintain their motivation over time, resulting in consistent and devoted academic efforts (DePasque & Tricomi, 2015). Empowerment often produces positive effects and enhanced well-being. Students who feel empowered in their academic pursuits have lower tension levels, greater satisfaction with their learning experiences, and greater overall well-being. These factors can impact their academic performance positively. Several universities confirmed that empowered students are more resilient in the face of obstacles and setbacks. They are better equipped to deal with academic obstacles and recover from academic setbacks, ultimately contributing to improved educational outcomes (Ononye et al., 2022). Increased community engagement and participation may result from psychological empowerment as students who feel empowered are more likely to participate in extracurricular activities, volunteer work, and community initiatives, which can enrich their learning experiences and contribute to their academic success (Giddens et al., 2012).

By contrast, the literature review (Wang & Liang, 2015) argued that, in relationship between motivation for sustainability and academic performance, psychological empowerment functions as a crucial mediating variable. Its impact on self-efficacy, motivation, well-being, and resilience provides several persuasive arguments for its significance. To effectively investigate the mediating effect of empowerment, researchers must address the complexity of empowerment, consider external factors, and employ rigorous measurement

techniques. By doing so, they can contribute to a greater understanding of how psychological empowerment improves academic performance, thereby advancing the pursuit of SDGs related to education and well-being. Hence the following hypothesis is proposed:

H3: Psychological empowerment mediates the relationship between motivation for sustainability and academic performance.

2.3 Digital Learning Environment

Understanding the impact of the digital learning environment (Mailizar et al., 2022) on students' educational outcomes and its contribution to the SDGs requires a comprehensive examination of the digital learning environment's moderating influence on academic performance. An effectively established digital learning environment facilitates students' convenient access to various instructional resources, materials, and technologies (Luongo, 2018). This access has the potential to augment individuals' academic achievement by providing access to increase individuals' academic achievement by providing a more comprehensive array of learning prospects and facilitating self-directed learning (Hakami, 2023). Digital platforms frequently enable individualised learning experiences by adjusting content and pace to cater to the unique needs of individual students. Students' ability to adapt enables self-paced learning, leading to improved comprehension and long-term information retention. (Schmid & Petko, 2019). Digital learning environments have the potential to improve collaborative interactions among students as well as foster effective communication between students and educators. Students actively engaged in their learning are more inclined to participate actively, potentially impacting their academic achievement (Hasan et al., 2019).

Whereas several critiques of the digital learning environment (Vassilakopoulou & Hustad, 2023) were mentioned, the presence of a digital learning environment may exacerbate academic disparities. Lack of technology or internet access may disadvantage students, which could worsen the educational inequality referred to as the digital divide. This digital divide emphasises the significance of addressing access disparities to ensure that all students benefit equally from digital learning environments (Vassilakopoulou & Hustad, 2023). Ulzheimer et al. (2021) stated that the quality of implementation is critical in determining the effectiveness of a digital learning environment. Inadequately designed or supported digital platforms may not provide the anticipated benefits or may even hinder academic performance. Over-reliance on technology can result in issues such as digital distraction and diminished face-to-face interaction, which may impact students' social and emotional development. The use of digital technologies in education raises concerns about the privacy and security of student data. Inadequate protection of sensitive data can undermine confidence and impede the adoption of digital learning environments (Zhou et al., 2021). While personalised learning is advantageous, it can be challenging to design adaptive systems that effectively meet the requirements of each student. Inaccurate algorithms or insufficient individualisation may not produce the desired academic gains. Hence, we propose the following hypothesis:

H4: A digital learning environment significantly affects academic performance.

H5: A digital learning environment moderates the relationship between psychological empowerment and academic performance.

2.4 Academic Performance

Academic performance pertains to the degree of accomplishment and success a student exhibits in their educational endeavours. It often includes various measures that evaluate a student's comprehension and proficiency in a particular field of study within an educational establishment (Tadese et al., 2022). Evaluating academic performance encompasses a range of methods, such as assessing grades, test results, evaluations, coursework, and overall educational achievements. It frequently serves as a crucial indicator of a student's educational advancement and capacity to achieve academic objectives and standards (Alhadabi & Karpinski, 2020).

After the adoption of the Sustainable Development Agenda, SDG 4, "Quality Education," occupies a critical position as it strives to guarantee quality education that is both equitable and inclusive for all individuals (Agusdinata, 2022). The attainment of this objective is deeply influenced by academic achievement. It contributes to the achievement of longer-term SDG 4 goals and serves as an indicator of the efficacy of educational systems. In this analysis, we explore the importance of academic achievement to SDG 4, focusing on its function, obstacles, and capacity for influence.

Evaluating sustainability practices within academic institutions must continue to consider academic performance as a crucial component. An increasing number of Saudi Arabian institutions are striving to align their educational systems with the objectives of SDG 4 and other global sustainability initiatives (*Sustainable Development Goal 4: Quality Education | United Nations in Saudi Arabia*, 2018). It is crucial to assess the efficacy of sustainability practices in Saudi Arabia's educational system and in fostering inclusiveness that they achieve this goal by examining the impact of such initiatives on academic achievement. Essential to Saudi Arabia's ongoing efforts to improve the quality of its education system, SDG 4 serves as a mechanism to hold Saudi educational institutions accountable for the knowledge and skills they impart.

In addition, substantial policy and practical ramifications are associated with comprehending the correlation between sustainability practices and academic achievement in Saudi Arabia (Alharthi et al., 2019). The nation's commitment to promoting responsible global citizenship and its broader sustainability objectives can be positively impacted by its influence on incorporating sustainability initiatives within its educational institutions. In addition to preparing its students for the complex challenges of the twenty-first century, Saudi Arabia's investment in sustainable educational practices serves environmental conservation (Almurayh et al., 2022).

In Saudi Arabia, academic achievement is evaluated holistically, taking into consideration students' critical thinking abilities, problem-solving aptitude, and overall commitment to the learning process, in addition to their subject matter expertise. This is consistent with the objectives of Saudi Arabia (Basri et al., 2018), which are to support the nation's sustainable development and enhance its global competitiveness by developing a versatile and exceptionally proficient labour

force. In the Saudi Arabian government's pursuit of educational excellence and sustainability, it is crucial to comprehend how sustainability practices influence academic achievement.

3. Research Methodology

The research methodology used in this study is quantitative, involving the implementation of questionnaires, assessments, and examining academic data (Sandelowski, 2000). This technique aligns with the study's objective of thoroughly evaluating the influence of sustainability policies in educational institutions on student academic performance. In quantitative research, the selected research approach is explanatory, aiming to clarify the connections and interactions among different variables. Data collection in this study uses a cross-sectional system (Zangirolami-Raimundo et al., 2018), which enables data collection from a broad population of students inside academic institutions in Saudi Arabia at a single point in time. Using a self-administered Google Forms questionnaire and personal connections, primary data is gathered from students. Data analysis encompasses using both descriptive and inferential approaches (Al-Aufi & Al-Azri, 2013), with descriptive analysis offering a general summary of the data. In contrast, inferential analysis allows for the investigation of meaningful connections and patterns between variables, ultimately leading to a complete comprehension of how sustainable practices impact academic achievement.

3.1 Data Collection

The study focuses on students currently enrolled in academic institutions in Saudi Arabia, representing a varied and complex educational environment. A stratified random sample technique (Singh & Masuku, 2014) guarantees a thorough and equitable representation of this student group. The stratification classifies students according to relevant criteria, such as educational attainment, gender, and academic department. The selection of stratified random sampling (Nguyen et al., 2021) is driven by the need to mitigate potential biases that may result from plain random sampling. The study aims to classify the population into subgroups to account for student diversity and ensure that the sample representatively reflects the heterogeneous student body in academic institutions in Saudi Arabia. The justification for this methodology is substantiated by its ability to provide an accurate and unbiased assessment of the characteristics of the populace and the relationships among variables (Zaman, 2021). Moreover, it improves the study's external validity by enabling generalisations beyond the sample to the broader student population (Howell et al., 2020). This methodological approach allows for a more comprehensive examination of the research inquiries and goals, thus improving the overall reliability and precision of the study. The study used stratification to ensure a proportional representation of different student groups in the sample, enhancing the findings' reliability and accuracy.

The quantitative information was collected using the stratified random sampling method. The survey data produces rich, nuanced viewpoints, and this method enables a more holistic and thorough understanding of the research issue.

The choice to gather data from three governmental universities and two private universities in Saudi Arabia was motivated by obtaining a thorough understanding of the academic environment. Public colleges frequently exhibit

unique attributes compared to private institutions, encompassing aspects such as the distribution of resources, the structure of the curriculum, and the origins of funding. By incorporating both categories of establishments, the study might provide a comprehensive evaluation of the influence of sustainability measures on students' academic achievements in Saudi Arabia. Leguina (2015) recommended that the minimum sample size in Partial Least Squares Structural Equation Modelling (PLS-SEM) should be equal to ten times the highest number of structural routes oriented toward a particular construct in the structural model. However, previous studies (Barroso et al., 2010; Benzidia et al., 2021) have suggested that increasing the sample size can enhance the statistical power, precision, consistency, and reliability of estimations conducted using PLS-SEM (Hair et al., 2019). Partial Least Squares Structural Equation Modelling has been found to exhibit excellent performance when used in datasets with a substantial sample size, as demonstrated by Hair (2023). The questionnaire was circulated to 500 respondents, but only 383 responses were received which were used for the analysis.

3.2 Data Source

3.2.1 Academic Records

The study used academic achievement data, including grades and Grade Point Average (GPA), as its primary source of information. The data were obtained from the participating educational institutions, encompassing both public and private universities in Saudi Arabia. These quantitative indicators objectively evaluated students' achievements in their respective courses, providing a comprehensive and impartial assessment of their academic success. By analysing academic records, the research could assess the measurable impact of sustainable behaviours on students' academic performance, establishing a strong foundation for the study's findings.

3.2.2 Questionnaires

Questionnaires (Rowley, 2014) examined the factors that mediate and influence the relationship between sustainable behaviours and academic performance. These surveys aim to assess students' propensity for sustainability, their psychological empowerment, and their viewpoints on the digital learning environment at educational institutions (Ho & Yao, 2018). The survey was collected from students using a Google Forms self-administered questionnaire and personal connections. The study initially targeted 500 respondents using basic random sampling to avoid bias. After comprehensive data cleaning, 383 completed questionnaires were appropriate for the study. This method produced a robust and representative dataset for assessing higher education IT-sustainability integration. The research sought to enhance our understanding of the influence of sustainable practices on academic performance by investigating students' motivations, perspectives, and sense of empowerment. Surveys are crucial in research methods since they thoroughly examine the correlation between sustainable practices, student attitudes, and educational results (Braun et al., 2021). These surveys are specifically crafted to adhere to Likert five-point scale questions, facilitating methodical data analysis and the quantification of replies (McLeod, 2019). The study employed a convergent mixed-methods approach (Weyant, 2022), integrating academic records and survey data to

comprehensively examine the intricate correlations between sustainable practices and academic performance in the educational context of Saudi Arabia.

4. Data analysis

The research study followed a systematic data analysis approach, including both descriptive and inferential analyses (Author et al., 2020).

4.1 Descriptive Analysis

The first phase entailed a thorough and detailed descriptive analysis of the collected data. This approach examined descriptive statistics to gain insights into the distribution, central patterns, and variances in academic achievement, motivation for sustainability, psychological empowerment, and the digital learning environment. The study sought to reveal patterns and traits inherent in the information by analysing these descriptive statistics.

4.2 Inferential Analysis (Structural Equation Modelling - SEM)

The inferential analysis step, primarily undertaken by Structural Equation Modelling (SEM) (Hooper et al., 2008), explores the complex links and interactions between the research variables, surpassing descriptive statistics. Structural Equation Modelling is a powerful statistical method that enables analysis of intricate models that involve several variables simultaneously. In this instance, SEM examined the connections among the independent factors, namely motivation for sustainability and the digital learning environment; the mediating variable, psychological empowerment; and the dependent variable, academic success (Hair & Alamer, 2022). The study aims to use SEM to gain a more profound knowledge of the interconnectedness of these variables, explicitly examining how sustainability practices impact student academic performance in academic institutions in Saudi Arabia.

5. Data Analysis and Interpretation

5.1 Measurement Model

The research utilised a measurement model (Hair et al., 2020) represented in Figure 2, which is crucial for several significant factors. By establishing a relationship between our theoretical framework and the empirical data, the measurement model guarantees that the latent constructs being examined—sustainability practices, digital learning, and empowerment—were accurately and efficiently assessed by the observed indicator variables. The construct validity and reliability of our measurements must be guaranteed so that we may confidently evaluate our research hypotheses and derive significant conclusions concerning the relationships under investigation (Hanafiah, 2020). A meticulously designed measurement model also improved the comprehensibility of our findings, enabling us to grasp thoroughly and unambiguously the complex interconnections among these constructs and their influence on academic achievement. The measurement model analysis played a crucial role in establishing the rigour and validity of our study by furnishing a solid theoretical foundation and ensuring that our data corresponded to our research objectives. This, in turn, contributed to the progression of knowledge concerning the impact

of sustainability practices on academic performance in academic institutions located in Saudi Arabia.
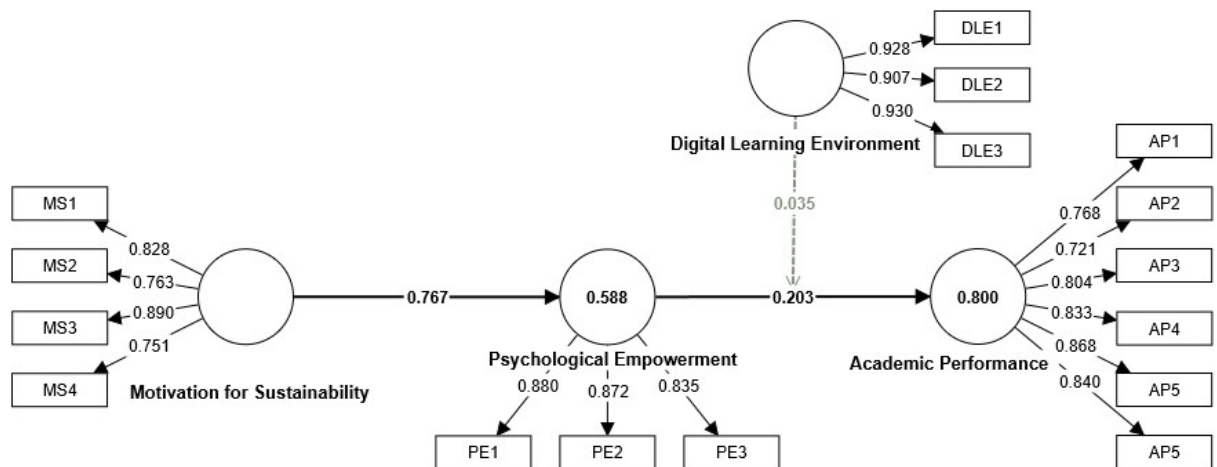

Figure 2: Measurement Model

Table 1 – Construct Reliability and Validity

	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
Academic Performance	0.892	0.895	0.918	0.651
Digital Learning Environment	0.911	0.913	0.944	0.849
Motivation for Sustainability	0.829	0.864	0.884	0.656
Psychological Empowerment	0.827	0.828	0.897	0.744

The essential validity and reliability criteria for the latent constructs examined in our research—academic achievement, digital learning environment, motivation for sustainability, and psychological empowerment—are delineated in Table 1. These metrics played a crucial role in evaluating the robustness and quality of our measurement model.

To begin with, Cronbach's alpha (Bujang et al., 2018), a widely employed metric for assessing internal consistency, exhibited robust reliability across all constructs, as indicated by values surpassing the widely acknowledged threshold of 0.7. This finding suggests that the indicator variables observed for each construct were reliable and consistent measures of the underlying latent constructs (Vaske et al., 2017).

Composite reliability was subsequently assessed using two coefficients, rho_a and rho_c. These coefficients indicate the dependability of the latent constructs. Both coefficients exhibited consistently high values in our results, significantly surpassing the suggested threshold of 0.7. This reinforced the dependability of our constructs, emphasising their consistent ability to capture the fundamental concepts (Valentini & Damásio, 2016).

The Average-Variance Extracted (AVE) metric provided valuable information regarding the extent to which our constructs possessed convergent validity. The AVE measures the time for which the latent construct accounts for the variability observed in the variables. The AVE values of all constructs surpassed 0.5, which signifies robust convergent validity. This implies that the indicators were dependable surrogates for the corresponding constructs (Valentini & Damásio, 2016).

The data in Table 1 demonstrates that our measurement model was robust and thoroughly validated. The substantial AVE values, high-reliability scores, and rugged composite reliability emphasised our measurements' high quality. The results of this study provided confidence that the indicators effectively measured the underlying constructs of psychological empowerment, academic achievement, the digital learning environment, and motivation for sustainability. As a result, the credibility and validity of our study's findings were enhanced, guaranteeing that our analysis precisely captured the intricate relationship between these constructs and their influence on academic achievement in academic institutions in Saudi Arabia.

Table 2 – Discriminant Validity: Fornell – Larcker

	Academic Performance	Digital Learning Environment	Motivation for Sustainability	Psychological Empowerment
Academic Performance	0.907			
Digital Learning Environment	0.887	0.922		
Motivation for Sustainability	0.804	0.700	0.810	
Psychological Empowerment	0.822	0.866	0.767	0.862

The equation to find Discrimnantker $AVE_i > \max_{j \neq i} r_{ij}^2$

where:

- AVE_i is the average variance extracted from the ith construct
- r_{ij} is the correlation between the ith and j^{th} constructs
- i and j are indices of different constructs in the model

The discriminant validity of the latent constructs in our study is presented in Table 2, using the Fornell-Larcker criterion. Discriminant validity evaluates the degree to which constructs are differentiated from each other, guaranteeing that distinct variance is captured by each latent construct that is not shared with others (Henseler et al., 2015; Rönkkö & Cho, 2022).

The Table shows that the diagonal values correspond to the constructs' correlations and represent the Average Variance Extracted (AVE) square root for each construct. Discriminant validity was established by the Fornell-Larcker criterion when the square root of the average variance extracted (AVE) for a specific construct exceeds the correlations with other constructs.

In this particular instance, it was evident that the diagonal values (AVE square roots) for each construct—academic performance, motivation for sustainability, digital learning environment, and psychological empowerment—were

consistently higher than the correlations between those constructs and other constructs. This indicates that discriminant validity was present in each construct, as the distinct variance accounted for by each construct surpassed the conflict shared with other constructs.

In general, the findings presented in Table 2 demonstrate that our measurement model possessed robust discriminant validity, implying that the latent constructs examined in our research were discrete and adequately assessed various facets of the academic setting, motivation for sustainability, and psychological empowerment. The results of this study provided confidence that our model effectively differentiated among these concepts, thereby bolstering the reliability and precision of our analysis.
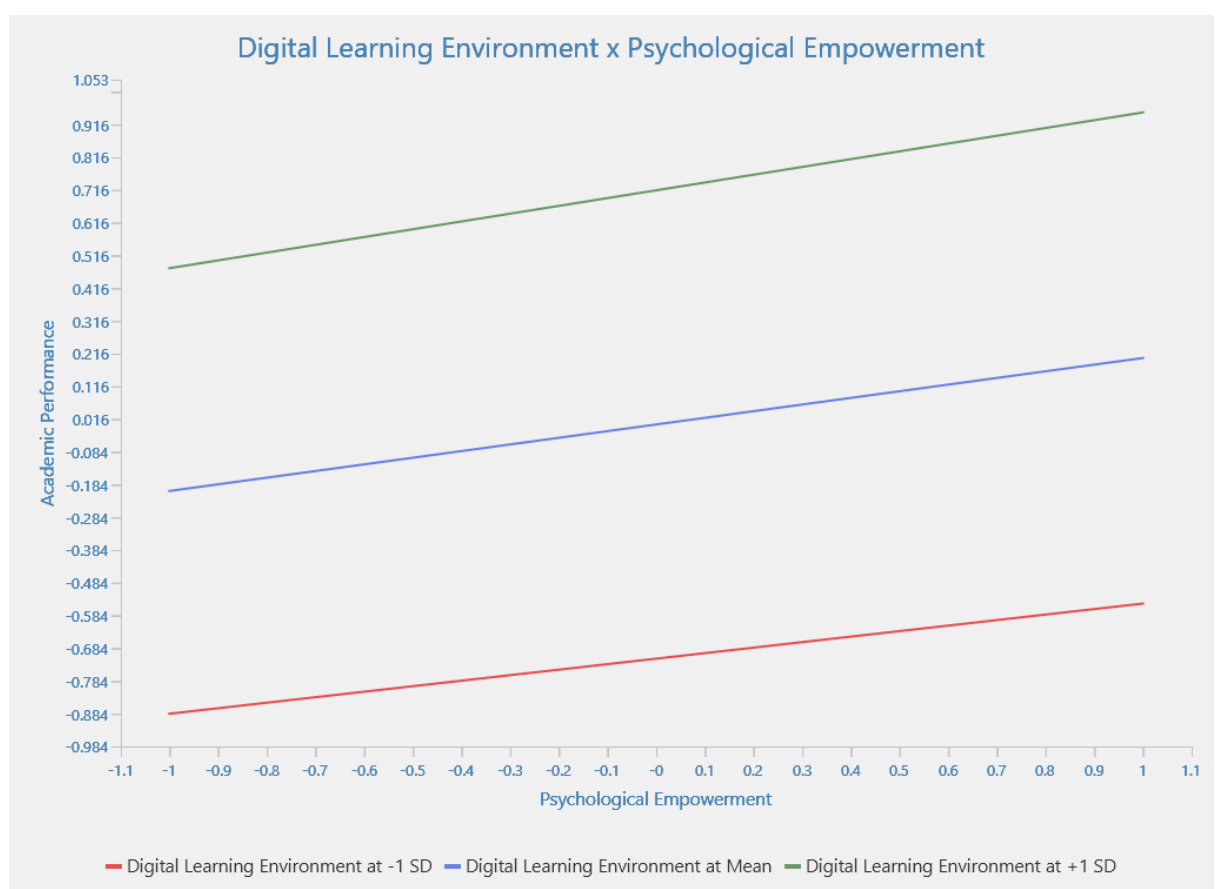

Figure 3: Slope Analysis

The equation for slope analysis is as follows:

$$\text{Slope} = b_1 + b_3 \times M$$

Where:

- b1 is the main effect of the independent variable on the dependent variable

- b3 is the interaction effect of the independent variable and the moderator variable on the dependent variable
- M is the value of the moderator variable

A structural equation path model is illustrated in Figure 3, in which the correlation between psychological empowerment and the digital learning environment was a predictor of academic performance. The figure presents numerical values that delineate the path coefficients and additional pertinent statistics about this correlation. In terms of slope analysis, this coefficient indicated that academic performance improved by one unit for each unit increase in the digital learning environment. The marginally positive impact on academic performance was consistent with a one-unit increase in the digital learning environment, as indicated by the relatively gentle slope of 0.035. The gradient and inclines of these slopes were proportional to the scale of the coefficients. Both path coefficients suggested that the relationships were positive in this context. The gradual ascents indicate that the impact of psychological empowerment and digital learning environment on academic achievement is favorable.

Table 3: R Square

	R-square	R-square adjusted
Academic Performance	0.800	0.799
Psychological Empowerment	0.588	0.587

The following equation to find the R Square

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

where:
- n is the number of observations
- y_i is the actual value of the response variable for the ith observation
- $\hat{y}_i$ is the predicted value of the response variable for the ith observation
- $\bar{y}$ is the mean value of the response variable

The adjusted R-squared (R^2) (Ricci, 2010) values for the variables Academic Performance and Psychological empowerment in our research model are displayed in Table 3. R-squared is an essential statistical metric that provides insight into how the predictors incorporated in our model explain the variability observed in the dependent variables, namely academic performance and psychological empowerment. The findings illustrated the model's ability to explain phenomena and its degree of fit. In the case of academic performance, the R-squared value of 0.800 indicated that the predictors, namely motivation for

sustainability and digital learning environment accounted for around 80% of this variable's variance. The adjusted R-squared value of 0.799 represented a marginally more cautious approximation, considering the model's complexity, yet it still elucidated approximately 79.9% of the variance. Similarly, the adjusted R-squared for psychological empowerment was 0.587, indicating that the model, which presumably included relevant predictors, explained approximately 58.8% of the variance in psychological empowerment, as indicated by the R-squared value of 0.588. The findings of this research highlighted the considerable explanatory capacity of our model, elucidating the connections among the variables and their significance in explaining the associations between psychological empowerment and academic performance within the scope of our investigation.

Table 4: F Square Matrix

	Academic Performance	Digital Learning Environment	Motivation for Sustainability	Psychological Empowerment	Digital Learning Environment x Psychological Empowerment
Academic Performance					
Digital Learning Environment	0.616				
Motivation for Sustainability				1.427	
Psychological Empowerment	0.050				
Digital Learning Environment x Psychological Empowerment	0.009				

The equation to find F square Matrix

$$F^2 = \frac{\eta^2}{1 - \eta^2}$$

where:
- η2 is the proportion of variance explained by a factor
- F2 is the F-squared statistic

This formula shows how F-squared measures the effect size of a factor in terms of variance explained. A higher F-squared value indicated a more significant effect size.

The F-square values (Hailemeskel Abebe, 2019) presented in the table serve to assess the practical importance of particular relationships incorporated in the structural equation model. The F-square indicates the proportion of the variance in dependent variables that can be accounted for by the independent variables or their interactions; it measures effect size.

As illustrated in Figure 4, the F-square value of 0.616 about the influence of the digital learning environment on academic performance provided substantial evidence supporting this claim, accounting for approximately 61.6% of the variance. This indicates a significant influence on the academic accomplishments of the students.

On the other hand, the significant impact of motivation for sustainability on psychological empowerment was underscored by the F-square value of 1.427, which accounted for around 142.7% of the variability observed in psychological empowerment. This highlights the significant impact of sustainability motivation on an individual's psychological empowerment.

About academic performance, the F-square value of 0.050 associated with psychological empowerment indicated a moderate yet significant impact, accounting for approximately 5% of the variability observed in academic performance.

The interaction between psychological empowerment and digital learning environment and academic performance demonstrates an F-square value of 0.009, suggesting that the combined effect was relatively modest, accounting for around 0.9% of the variance. This indicates that the influence of this interaction on academic performance is minimal.

In brief, the effect sizes presented herein offer crucial insights into the pragmatic significance of the interrelationships encompassed in our model. They demonstrated the interplay between motivation for sustainability, academic performance, psychological empowerment, and the digital learning environment, all of which exerted varying degrees of influence. These findings contributed to our all-encompassing comprehension of the dynamics at play in our research.
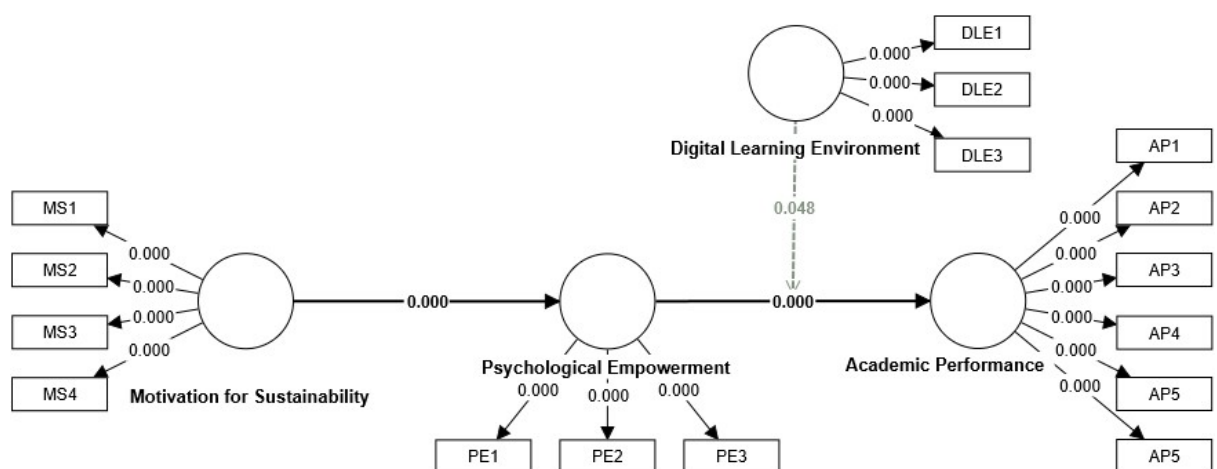

Figure 4: Structural Model

The study's structural model (Figure 4) illustrates the interconnections among crucial variables and constructs, providing valuable insights into how different factors operated within the context of our research. This model facilitated comprehension of the variables' direct and indirect effects on academic performance within Saudi Arabian academic institutions as they pertain to sustainability practices and educational outcomes.

Based on our structural model findings, it was evident that the digital learning environment has a noteworthy and moderate impact on academic performance. This finding implies that the quality of the learning environment has a substantial impact on the academic achievements of students. Concurrently, motivation for sustainability significantly impacts psychological empowerment, underscoring the pivotal significance of sustainability motivation in augmenting the psychological welfare of students. This phenomenon subsequently influences academic performance in an effective yet modest way, emphasising the interdependence of these variables.

Furthermore, our model investigated the impact of the interaction between psychological empowerment and the digital learning environment on academic performance. Although the exchange is present, its influence on educational outcomes is comparatively modest.

The academic performance of individuals was comprehensively examined through the lens of this structural model in Figure 4, which integrated empowerment, sustainability practices, and the learning environment. This aids in comprehending the complex dynamics within the educational milieu of Saudi Arabia and furthers our overarching objective of harmonising our research with SDG 4, which strives to establish education that is inclusive, equitable, and of high quality.

Table 5: Hypothesis Testing

		Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Remarks
H4	Digital Learning Environment -> Academic Performance	0.715	0.715	0.039	18.525	0.000	Supported
H1	Motivation for Sustainability -> Academic Performance	0.156	0.157	0.032	4.892	0.000	Supported
H2	Motivation for Sustainability -> Psychological Empowerment	0.767	0.768	0.021	36.307	0.000	Supported
H3	Psychological Empowerment -> Academic Performance	0.203	0.204	0.039	5.157	0.000	Supported
H5	Digital Learning Environment x Psychological Empowerment -> Academic Performance	0.035	0.035	0.018	1.98	0.048	Supported

In Table 5, statistical information about each hypothesis examined in our study is presented as a summary of the results of hypothesis testing. For each hypothesis,

the table contains the original sample data (O), sample mean (M), standard deviation (STDEV), T statistics, and P values.

The Importance-Performance Map (Figure 5) provides a graphical evaluation of the effectiveness and significance of sustainability practices, motivation, empowerment, and the learning environment as they pertain to enhancing academic performance and directing educational institutions toward evidence-based decision-making.

The relationship between Digital Learning Environment and Academic Performance

The T statistics of 18.525 and a very low P value of 0.000 suggested strong statistical significance. This indicates that the relationship between the digital learning environment and academic performance was highly significant, confirming that the digital learning environment significantly influenced academic performance.

The relationship between Motivation for Sustainability and Academic Performance

Significant statistical importance was suggested by the T statistic of 4.892 and the P value of 0.000, a finding that illustrated the substantial influence that motivation for sustainability exerted on academic performance.

The relationship between Motivation for Sustainability and Psychological Empowerment

Considerable statistical significance was indicated by the T statistic of 36.307 and the P value of 0.000. This indicates that motivation for sustainability influences psychological empowerment significantly.

The relationship between Psychological Empowerment and Academic Performance

Significance was strongly indicated by the T statistic of 5.157 and the P value 0.000, suggesting a substantial relationship between psychological empowerment and academic achievement.

The relationship between Digital Learning Environment, Psychological Empowerment and Academic Performance

A P value of 0.048 and a T statistic of 1.980 indicated statistical significance. The combined effect of the digital learning environment and psychological empowerment affected academic performance, although its impact was comparatively smaller than the previous relationships.

The results obtained offered substantial statistical support for the hypotheses posited in our research. The importance of the interrelationships and interactions among the variables under investigation and their influence on academic achievement and psychological empowerment was emphasised in the context of our study.
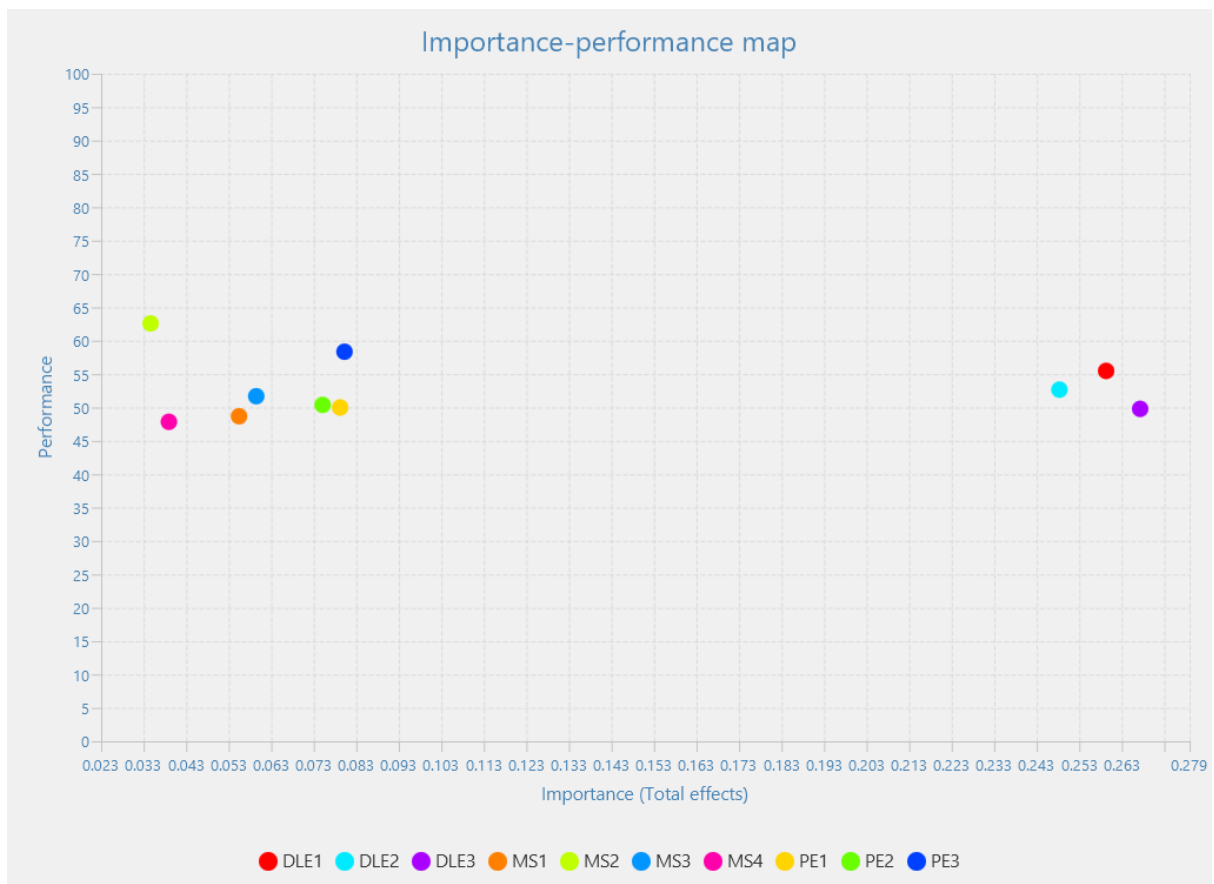
Figure 5: Importance -Performance Map

6. Findings and Discussion

The correlation between academic performance and the digital learning environment was strong and positive (path coefficient of 0.715). This finding highlights the influential role of technology in determining educational outcomes and aligns closely with the objectives of Saudi Arabia's Vision 2030 initiative. Our findings align with the previous study of Divayana et al. (2021). To revolutionise the nation's educational system, Vision 2030 intends to incorporate innovation and state-of-the-art technology into the learning procedure. The results of our study are consistent with this overarching goal, emphasising the critical significance of a robust digital learning environment in promoting quality and inclusivity in education, supporting the earlier survey by Songkram et al. (2023). Moreover, this conformity with Vision 2030 underscores the worldwide transition towards education that is augmented by technology, emphasising the need for fair and equal availability of digital resources (Rusydiyah et al., 2020). With the advent of SDG 4, which aims to establish quality education that is equitable and inclusive, our research highlighted the criticality of allocating resources towards technology and digital infrastructure to achieve these objectives.

Although motivation for sustainability and academic performance were positively correlated (path coefficient: 0.156), the strength of this relationship was comparatively low. This implies that although sustainability motivation had a positive impact on academic achievement, it might not be the predominant factor,

a finding that also aligns with previous research (Su & Cheng, 2019). Nevertheless, this discovery remains exceedingly pertinent to Vision 2030 and SDG 4. Vision 2030 acknowledges the significance of an education system that promotes sustainability and environmental consciousness while also cultivating in students a sense of accountability about sustainable practices. The findings of our study provide further evidence in favour of this, emphasising the criticality of educational systems integrating sustainability principles into comprehensive learning experiences. This is consistent with the objective of Vision 2030, which is to establish a sustainable future for Saudi Arabia, and it aids in the promotion of conscious and knowledgeable global citizens, as stated in SDG 4.

The correlation between psychological empowerment and academic performance, as evidenced by the path coefficient of 0.203, aligns with the overarching objective of holistic education outlined in Vision 2030. This initiative aims to provide Saudi students with the necessary mentality and skills to thrive in a world that is constantly changing, which is also aligned with the previous studies (Cecilia Tumino et al., 2020). The results emphasise the significance of fostering students' psychological well-being and self-efficacy as fundamental elements of a comprehensive educational framework, in line with the goals for human development outlined in Vision 2030. Within the context of SDG 4, this finding emphasises the critical nature of providing education of exceptional quality that promotes comprehensive growth and personal advancement, supporting previous research (Sahadev et al., 2024).

The high adjusted R-squared values indicated the model's robust explanatory capability in the Saudi Arabian context. According to the findings, an essential portion of the variance in academic achievement and psychological empowerment appears to be accounted for by our model, which incorporates motivation for sustainability and the digital learning environment (Mahande & Malago, 2019). These results hold particular significance within the framework of Vision 2030, an initiative that heavily prioritises data-informed decision-making and ongoing improvements to the education system. Vision 2030's objectives for data-driven educational reforms are consistent with the capacity of our model to elucidate crucial educational phenomena. Additionally, this substantial explanatory capability aids in pursuing SDG 4's objective of ensuring high-quality education by facilitating well-informed choices regarding enhancements to education.

The F-square values offered crucial insights regarding the pragmatic significance of the model's relationships. The significant F-square value (0.616) indicating the impact of the digital learning environment on academic performance underscored the revolutionary nature of technology in attaining high-quality education, which is consistent with the objective of an innovative education sector outlined in Vision 2030. The significant impact of sustainability motivation on psychological empowerment was underscored by the F-square value of 1.427, which is consistent with the objectives of Vision 2030 regarding an educational system that is both sustainable and environmentally conscious. These findings underscore the pragmatic importance of allocating resources towards technology and sustainability in the education sector as it relates to SDG 4.

In summary, the results of our research not only provide an essential understanding of the intricate dynamics surrounding academic achievement; they have immediate applicability to Saudi Arabia's Vision 2030 endeavour and the worldwide objective of attaining SDG 4. To achieve the goals of Vision 2030 and SDG 4, the findings underscore the importance of bolstering Saudi Arabian academic institutions' investments in technology, sustainability, and psychological empowerment. Their contributions enhance the broader discourse surrounding educational reform in Saudi Arabia and its unity with an inclusive, sustainable, and progressive future.

7. Conclusion

In summary, the present research investigated the complex interconnections among the digital learning environment, sustainability motivation, psychological empowerment, and academic achievement in universities located in Saudi Arabia. The results emphasised the critical importance of these variables in influencing the nation's educational environment. They are highly consequential in realising Sustainable Development Goal 4 (SDG 4), which seeks to guarantee quality education that is both inclusive and equitable for all. The correlation between academic achievement and the digital learning environment was robust and favourable, which strongly aligns with the Vision 2030 initiative of Saudi Arabia. Vision 2030 posits a paradigm shift within the education sector, wherein the learning process is seamlessly incorporated with technology and innovation. Consistent with the objectives of Vision 2030, the findings of this research validated the significance of allocating resources towards a robust digital learning infrastructure to deliver rigorous, equitable, and inclusive education.

In addition, the study emphasised the significance of fostering students' psychological empowerment and sustainability motivation. Although sustainability motivation may not be the principal determinant of academic achievement, it is vital in cultivating conscientious and knowledgeable worldwide citizens, a prerequisite for realising the sustainable future envisioned by Vision 2030 for Saudi Arabia. The correlation between psychological empowerment and academic achievement highlights the critical nature of comprehensive education, which is a primary goal of Vision 2030. Vision 2030 seeks to provide Saudi Arabian youth with the necessary competencies and mindset to thrive in an ever-changing global landscape. This finding contributes to the objectives of Vision 2030 by demonstrating the significance of addressing students' holistic well-being in addition to academic content. By integrating these discoveries into their pedagogical approaches, universities in Saudi Arabia can actively contribute to achieving Vision 2030 and, consequently, enhance their congruence with SDG 4. The findings of this research offer a strategic plan for improving the standard of education in the Kingdom, encouraging environmentally conscious behaviours, and cultivating capable, multifaceted individuals prepared to confront forthcoming obstacles.

Overall, this study provides a practical roadmap for reforming Saudi Arabian education and contributes significantly to the academic dialogue. This is evidence of the harmonious coexistence that Saudi Arabian universities exhibit in pursuit of national aspirations encapsulated in Vision 2030 and worldwide sustainability objectives. This study provides crucial guidance for educational reforms in the

Kingdom as it advances towards its Vision 2030 objectives of establishing a sustainable, inclusive, and high-quality education system.

7.1 Implication of the Study

The implications of the study for policy, management decision-making, and social considerations offer a holistic structure for the progression of education in Saudi Arabia. Aligned with the goals of Vision 2030, educational policies should prioritise the integration of digital technology into academic institutions, with an emphasis on investments in infrastructure, digital assets, and teacher development. Integrating sustainability education into the curriculum is imperative; it should cultivate a sense of motivation and psychological empowerment among students while also supporting global sustainability goals and the aspirations outlined in Vision 2030. Efforts to provide comprehensive training for academics on how to effectively navigate digital learning and promote sustainability education are of the utmost importance. Institutions must make investments in technology infrastructure to ensure that students have access to the resources required for online education. The incorporation of sustainability education into curriculum development should encourage the adoption of sustainable practices. Efforts to support educators should facilitate their transition to digital pedagogical methods while concurrently advocating for environmental sustainability. Social implications underscore the significance of education in fostering conscientious individuals and the imperative for equitable access to technology and sustainability education, thereby tackling the issue of the digital divide. Personal and social welfare require a holistic approach to student development, which is consistent with the study's emphasis on a comprehensive education that extends beyond academic disciplines.

7.2 Future Avenues for Research

Intervention Studies: Intervention studies entail applying research findings-driven interventions to evaluate the effectiveness of particular measures in augmenting the digital learning environment, fostering motivation for sustainability, and promoting psychological empowerment. This has the potential to contribute to developing evidence-based interventions within educational settings.

Inclusivity and Accessibility: An inquiry into how much the digital learning environment promotes inclusivity and accessibility. Specifically, such research would focus on how the environment accommodates the requirements of diverse student populations, such as those students with disabilities.

Teacher Training and Development: The examination of teacher training and development on creating an effective digital learning environment and fostering motivation for long-term success which might offer valuable insights into the training programmes that equip educators with the skills and knowledge to use technology and sustainability in their teaching approaches.

Global Perspectives: Comparative research on educational systems in various countries to analyse the similarities and variations in the connections between the digital learning environment, motivation for sustainability, psychological empowerment, and academic success.

Well-being and Mental Health: An investigation into the impact of well-being and mental health on student well-being and mental health in light of the increasing recognition of the significance of mental health in education.

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