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Improving E-learning mediating green innovation and green technology for green management practice

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Abstract
The development of green technology (GT) and green innovation (GI) in green management practices (GMP) is an impor- tant key in today's digital and sustainable era. This article discusses how e-learning (EL) acts as an antecedent variable in strengthening green innovation (GI) and the application of green technology (GT) to green management practices(GMP). This study analyzes whether e-learning influences green management practices by mediating green technology and green innovation. This study uses cross-sectional data that collects population data at one point to analyze the prevalence of variables or relationships between variables in the sample. The population consisted of lecturers in higher education in Indonesia. The results show that e-learning influences green innovation, technology, and management practices. Simi- larly, green innovation and green technology significantly affect green management practices. It is also firmly established that green innovation and technology are effective mediator variables for e-learning and green management practices. Therefore, green management practices in universities cannot ignore the important role of e-learning, investing in green innovation and green technology to support the achievement of sustainable education.

Keywords E-learning · Green technology · Green innovation · Green management practices

1 Introduction

This study highlights the need for sustainability transformation in business management and how e-learning (EL) can play a critical role as an intermediary in driving green innovation (GI) and the application of green technology (GT). Explain the framework of the green innovation concept, describing how business practices can innovate to reduce environmental impact and promote sustainability [1, 2]. Focus on the role of e-learning in supporting learn- ing and awareness of green innovation and highlighting the advantages of e-learning in providing universal access and continuous learning. Analyze how technology can be used in green management, including energy manage- ment systems, carbon footprint monitoring, and supply chain optimization. Provide an in-depth understanding of the benefits of integrating e-learning and green innovation, including cost efficiency, increased productivity, and reduced environmental impact. Discusses challenges that may be encountered during the integration of e-learning and green innovation, including organizational resistance and lack of infrastructure [3–11].

Green innovations provide environmental and economic improvements. Promoting ecological benefits that have a financial impact can improve company performance [12]. However, green innovations present various challenges that can reduce the likelihood of their implementation, depending on costs and benefits, expected performance, and the company's ability to introduce innovations [13, 14]. Previous finding arguments that support the view that innovation positively impacts economic performance include increasing sales and reducing costs [15, 16]. Compa- nies that adopt green innovations can reduce costs through value-added activities such as recycling materials to reduce waste and effective utilization of input resources contributing to profitability. This phenomenon explains why researchers consider studying organizations that adopt green innovations to increase efficiency and increase capital. Regardless of the approach chosen to invest in green innovations from an economic performance perspective, green innovations can have a significant positive impact on employment [17].

This research focuses on the development of e-learning in promoting green innovation and green technology for sustainable management practices. This research needs to be done because E-learning is becoming more important in education and training in the digital age, amid concerns over climate change and environmental sustainability, green innovation and green technology are increasingly needed to reduce negative impacts on the environment, the integration of green innovation and green technology in management practices brings double benefits, namely reducing environmental impact and increasing company efficiency and profitability, and explore how e-learning can be an effective tool in supporting learning and implementation of sustainable management practices [18].

The purpose of the study is to analyze e-learning as an antecedent variable towards advancing green innovation and green technology for green management practices. From the background of the problem, problems that must be solved can be formulated: does e-learning, green innovation, and green technology affect green management practices? Can green innovation and green technology mediate e-learning with green management practices? GI and GT were used as mediators in this study because they explained the relationship between independent and dependent variables, while they were not used as moderators because the focus of the study was on the mediation mechanism, not on the influence of changes in relationship strength.

2 Literature review

2.1 Elearning (EL)

A form of delivery called eLearning is utilized in remote learning, enabling the synchronous and asynchronous shar- ing of materials via a communication network [19]. It is a system that encircles the instructor and student in terms of technical and social elements that encourage interaction and cooperation between teachers and students [20–23]. Distance education, sometimes known as e-learning, is a structured approach to teaching and learning that is specifi- cally designed to be performed remotely by electronic mail [24]. Course management systems, such as Blackboard, LMS, WebCT, and Moodle, are widely used by higher education institutions to offer online courses that supplement conventional classroom instruction. According to literature writers, eLearning provides a balance between the issue of acceptance and technological enablers [25]. An important road map for maintaining the sustainable and ongo- ing expansion of e-learning was made available [26], providing a 20-year history of e-learning evolution. Using the most modern technology Web 2.0 in education is complicated, but it also has the potential to change the way that people learn and are trained. e-Learning 2.0 was made possible by the emergence of podcasts, weblogs, wikis, and online sharing tools. The emphasis of the E-Learning 2.0 environment is primarily on getting students involved in the learning process [27]. Previous research found that EL has a significant influence on GI [28, 29]. El also has a significant effect on GMP, as well as on GT [30, 31].

So the following hypotheses can be formulated:

- H01: EL affects GI
- H02: EL affects GMP
- H03: EL affects GT

2.2 Green innovation (GI)

The concept of green innovation does not require a reduction in overall environmental impact [5]. But it must provide significant benefits to the environment. Green innovation is hardware or software related to environmentally friendly products or processes, including energy-saving technology innovations, pollution prevention, waste recycling, eco- friendly product design, or operational environmental management innovations. In the literature, green innovations are classified into eco-friendly products, eco-friendly processes, and eco-friendly management innovations. Product innova- tion involves modifying existing user features or packaging goods and services in response to environmental concerns. Process innovation involves changing methods, processes, and equipment to produce environmentally friendly products that meet environmental objectives. Eco-management innovation involves new management techniques regarding a company's business practices and external relations [5, 32]. Green innovations in e-learning and green management practices in higher education combine the principles of technology and sustainability to create an eco-friendly learning environment and raise awareness of environmental issues among students and lecturers [33]. Green innovations include the use of energy-efficient online platforms, such as eco-friendly servers, and the use of cloud technology to reduce carbon emissions [34]. To reduce the carbon footprint of travel, higher education institutions are implementing energy- saving strategies by providing access to digital learning materials, reducing paper use, and encouraging participation in online learning [35–40]. Previous research has found that GI has a significant effect on GMP, and GI can also mediate between e-learning and GMP [41–43].

So that the following hypotheses can be formulated:

- H04: GI affects GMP,
- H06: GI mediates EL and GMP

2.3 Green technology (GT)

Green technology is using technology to reduce negative impacts on the environment and improve sustainability [44]. The main goal is to create environmentally friendly solutions, use resources efficiently, and contribute to environmental protection. Green technology covers areas such as renewable energy, energy efficiency, waste management, sustainable transportation, and eco-friendly development. Examples of popular green technologies include renewable energy such as solar energy, wind power, and bioenergy. The technology uses renewable natural resources to produce energy without significant carbon emissions, thus helping to reduce dependence on polluting fossil fuels. Energy efficiency is also an important aspect of environmentally friendly technology. Devices and systems are used to reduce energy consumption, such as energy-efficient LED lights, efficient cooling systems, and automatic sensors that regulate energy consumption within buildings [45, 46]. In addition, green technology also includes innovations in waste management, such as material recycling, organic waste processing, and plastic waste reduction. Elearning can reduce environmental impact and extend the life cycle of materials so that eLearning has an impact on green technology [10, 47–50]. Previous research has found that GT has a significant effect on GMP, and it has been found that GT is a mediating variable for EL and GMP [47–49].

From the review literature, the following hypotheses can be formulated:

- H05: GT affects GMP,
- H07: GT mediates EL and GMP.

2.4 Green management practice (GMP)

Green management practices in higher education represent the implementation of strategies and policies aimed at reducing the environmental impact of higher education institutions and raising awareness of social and environmental responsibility among students, faculty, staff, and the general public [50–53]. Green management practices in higher education by adopting energy-saving technologies, installing LED lights, improving building insulation, and optimiz- ing energy consumption to reduce energy consumption and carbon dioxide. Manage waste by recycling paper, plastic, glass, and metal and promote waste reduction practices and responsible waste management across campus. Promote sustainable transportation such as bicycles, electric vehicles, and public transport by providing eco-friendly parking options and incentives for their use. Buy environmentally friendly products and materials, such as recycled paper, eco- friendly cleaning products, and energy-intensive electronics. Integrate environmental and sustainability topics into the academic curriculum and support research and projects related to environmental solutions and sustainable innovation [54–56]. They were organizing educational programs and environmental awareness campaigns to encourage the active participation of students, staff, and lecturers in green activities such as tree planting, environmental restoration, and environmental seminars. Maintain regular reporting on campus environmental performance, including energy con- sumption, waste generated, and sustainability measures taken to ensure transparency and accountability. Eco-friendly management practices in higher education reinforce an institution's commitment to sustainability, encourage positive behavior among campus residents, and help set a good example for the surrounding community.

From the literature review and hypothesis development described above, the research model can be seen in Fig. 1.

3 Method

This study uses cross-sectional data that collects population data at one point in time to analyze the prevalence of variables or relationships between variables in the sample. Data was collected from lecturers in Indonesia, who had an unknown population. A self-administered questionnaire is employed for the data collection from sample firms by applying a systematic sampling technique using the number of indicators multiplied by 5 so that the sample used totals 180 [57]. The questionnaire is designed in Bahasa and English, the items were chosen from prior studies. All items were measured using a five-point Likert scale, ranging from '1' representing strongly disagree to '5' representing strongly agree. Five items for EL (12); six items for GI (4), five items for GT (16), and nine items for GMP (4). Researchers collected data from the lecturers who were actively involved in adopting green practices. For data collection, we adopted an instrument from prior studies while ensuring the reliability and validity of the instrument. The researchers analyzed the data using SMART PLS to evaluate the hypotheses after ensuring the reliability and validity of the outer model [58].

All methods used in this study have been carried out under applicable guidelines and regulations and approved by the Universitas Mercu Buana Research Ethics Committee (Ethics approval number: Surat Keputusan Rektor UMB Nomor 01/085/B-Skep/XII/2023).

4 Result and discussion

Table 1 illustrates the characteristics of respondents who are willing to fill out the questionnaire in this study consisting of age, gender, marital status, place of residence, teaching experience, field taught, rank, availability of wifi in their place of residence, online teaching experience, and type of material taught.

Table 1 provides an overview of respondents who contributed the most, namely; lecturers aged 31–40 years (37.8%), Males (54%), Married (78%), residents in the same city as the workplace (59.5%), Teaching Experience for more than 15 years (35.1%), scientific field Department of Social (67.5%), Associate Professor position (35.1%), supported by fast Internet at home (93.5%), Have Taught Online Courses Before Covid-19 14 (92.4%), taught theory sessions (47%), a combination of practice and theory (42.7%), Online Teaching Duration Before Covid-19 between 1 and 2 years (41%).

Table 2 shows the value of an AVE that is considered adequate is 0.50 or more, which means that the construct can account for at least 50% of the variance of its indicators. Composite Reliability measures the internal consistency of latent constructs by taking into account indicator weights, providing more accurate results in the context of SEM; A value above 0.70 is considered adequate. Alpha Cronbach measures internal consistency based on correlations between items, with values above 0.70 indicating good reliability, although it has limitations in assuming the homogeneity of the indicator. Next, the Fornell-Larcker Criterion is needed to ensure the validity of discrimination, i.e. that each construct in the model is more related to its indicator than to the indicators of other constructs. This helps identify potential overlaps

Fig. 1 Research model

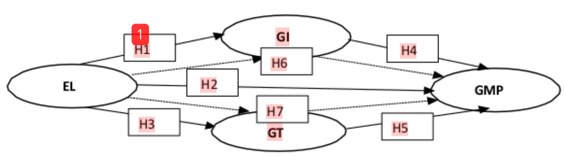

Table 1 Description of respondent characteristics

Variable	Category	Freq.	%
Age	20–30	7	3.8
	31–40	70	37.8
	41–50	50	27
	> 50	58	20.1
Gender	Male	100	54
	Female	85	46
Marital Status	Single	41	22
	Married	144	78
	Widowed	–	–
Residence	In the same city as the workplace	110	59.5
	Away from the workplace	75	40.5
Teaching experiences (years)	0–5	14	7.6
	6–10	50	27
	11–15	56	30.3
	> 15	65	35.1
Work sector	Basic science departments	60	32.5
	Social departments	125	67.5
Rank	Lecturer	59	31.9
	Assistant professor	49	26.5
	Associate professor	65	35.1
	Professor	12	6.5
Have your high internet speed at home:	Yes	173	93.5
	No	12	6.5
Have you ever taught a course online before Covid-19:	Yes	171	92.4
	No	14	7.6
If yes, in which areas?	Practical sessions	19	10.3
	Theoretical sessions	87	47
	Both	79	42.7
If yes, what is the duration?	< 1 year	41	22.3
	1–2 years	76	41
	>2 years	68	36.7

or redundancies between constructs, ensuring that each construct measures a different concept to improve the quality and validity of the research results.

Table 3 shows the square root of the AVE (diagonal) and the correlation between constructs (below the diagonal). The root AVE for each construct, such as EL (0.675), GI (0.830), GMP (0.806), and GT (0.760), must be greater than the correlation with other constructs to indicate good discriminatory validity. The correlation value between constructs, such as between GMP and GT (0.831), indicates how strong the relationship between these constructs is. Since the diagonal value is greater than the correlation between constructs, this table shows that the validity of the discrimi- nation is met, where each construct is better at explaining the variance of its indicators.

Table 4 shows the correlation values between indicators (such as EL1, GI1, GMP1, GT1, etc.) and latent constructs (EL, GI, GMP, GT). Indicators in a single construct should have the highest correlation with the constructed being measured, for example, EL1 is higher at EL (0.788) compared to its correlation with GI, GMP, and GT, indicating good convergent validity. Overall, the validity of convergence seems to be good, it can be seen that each indicator in each variable has a higher value compared to the indicators in other variables when cross-loading analysis.

Table 5 gives an overview of the HTMT values being below 0.85, indicating that each construct differs adequately from the others. This signifies good validity of discrimination, where each construct measures a different concept clearly and has no discrimination validity issues so that the interpretation of relationships between variables in the model can be done.

Table 2 The convergent validity and reliability

Variables	Indicator	Outer loading	AVE	Composite reliability	Cronbach alpha
EL	EL1	0.791	0.555	0.901	0.880
	EL2	**0.339**			
	EL3	0.668			
	EL4	0.714			
	EL5	0.625			
	EL6	0.680			
	EL7	0.685			
	EL8	0.677			
	EL9	0.630			
	EL10	0.684			
	EL11	0.657			
	EL12	0.596			
GI	GI1	0.911	0.689	0.898	0.789
	GI2	0.762			
	GI3	0.818			
	GI4	0.823			
GMP	GMP1	0.882	0.649	0.880	0.818
	GMP2	0.701			
	GMP3	0.795			
	GMP4	0.834			
GT	GT1	0.807	0.578	0.938	0.927
	GT2	0.688			
	GT3	0.732			
	GT4	0.774			
	GT6	0.727			
	GT5	0.545			
	GT7	0.781			
	GT8	0.684			
	GT9	0.780			
	GT10	0.668			
	GT11	0.653			
	GT12	0.767			
	GT13	0.758			
	GT15	0.753			
	GT16	0.791			

Table 3 Fornell–Larcker criterion

	EL	GI	GMP	GT
EL	0.675			
GI	0.554	0.830		
GMP	0.598	0.780	0.806	
GT	0.597	0.722	0.831	0.760

Table 6 compares the two models, the Saturated Model and the Estimated Model, based on various fit indices. An SRMR value below 0.10 indicates that both models have an acceptable fit, although the Estimated Model is slightly higher (0.083). A low NFI value (0.655) in both models indicates that this model can be improved.

Table 7 shows that the GI, GMP, and GT constructs have fairly high R Square values, with GMP (0.793) having the highest value, followed by GT (0.710) and GI (0.523), indicating that the independent variables in the model can

Table 4 Cross-loading analysis

	EL	GI	GMP	GT
EL1	0.788	0.652	0.756	0.738
EL3	0.668	0.441	0.560	0.535
EL4	0.714	0.555	0.598	0.618
EL5	0.625	0.501	0.522	0.597
EL6	0.680	0.496	0.514	0.512
EL7	0.685	0.470	0.535	0.462
EL8	0.677	0.447	0.428	0.503
EL9	0.630	0.436	0.452	0.412
EL10	0.684	0.418	0.530	0.614
EL11	0.657	0.493	0.572	0.645
EL12	0.596	0.392	0.520	0.524
GI1	0.729	0.915	0.765	0.707
GI2	0.477	0.756	0.590	0.547
GI3	0.592	0.819	0.612	0.613
GI4	0.574	0.823	0.607	0.547
GMP1	0.801	0.752	0.881	0.787
GMP2	0.519	0.569	0.698	0.586
GMP3	0.599	0.545	0.796	0.657
GMP4	0.683	0.627	0.835	0.691
GT1	0.760	0.672	0.729	0.796
GT10	0.584	0.509	0.614	0.667
GT11	0.572	0.507	0.584	0.653
GT12	0.624	0.471	0.637	0.755
GT13	0.589	0.533	0.618	0.725
GT14	0.593	0.556	0.614	0.657
GT15	0.601	0.523	0.591	0.746
GT16	0.618	0.554	0.653	0.764
GT2	0.583	0.511	0.557	0.702
GT3	0.626	0.592	0.646	0.725
GT4	0.619	0.491	0.606	0.782
GT5	0.545	0.485	0.570	0.689
GT6	0.610	0.565	0.640	0.735
GT7	0.644	0.559	0.657	0.772
GT8	0.555	0.391	0.558	0.684
GT9	0.644	0.557	0.588	0.769

Table 5 Heterotrait-Monotrait Ratio (HTMT)

	EL	GI	GMP	GT
EL		0.75	0.70	0.80
GI	0.75		0.78	0.82
GMP	0.70	0.78		0.85
GT	0.80	0.82	0.85	

account for most of the variances of these constructs. R Square Adjusted is slightly lower for each construct, reflect- ing adjustments to the number of predictors in the model, but still demonstrating good explanatory power. Overall, this model has quite strong predictive capabilities, especially for GMP and GT constructs.

Table 8 shows the Variance Inflation Factor (VIF) values for various indicators of the EL, GI, GMP, and GT con- structs, which are used to measure multicollinearity between indicators. Most VIF values are below 3, suggesting

Table 6 Fit summary

	Saturated model	Estimated model
SRMR	0.080	0.083
d_ULS	4.014	4.350
d_G	1.902	1.935
Chi-Square	1516.813	1522.495
NFI	0.656	0.655

Table 7 R square

	R square	R square adjusted
GI	0.523	0.520
GMP	0.793	0.789
GT	0.710	0.708

that multicollinearity between indicators is not a significant issue, although some values are close to or above 2.5, such as GI1 (3.202) and GT4 (2.921), which may require further attention. Overall, the model seems to be free of multicollinearity.

Table 9 shows the SSO (Sum of Squares Observed), SSE (Sum of Squares Error), and Q^2 values for the EL, GI, GMP, and GT constructs. The Q^2 value indicates the predictive ability of the model, with GMP having the highest value (0.487), fol- lowed by GT (0.360) and GI (0.303), indicating that the model has good predictions for these constructs. The EL construct does not have a calculated Q^2 value because SSE is the same as SSO.

From Table 10 it can be seen that all hypotheses tested proved influential and significant. It can be seen that the influ- ence of e-learning on green technology is greatest, followed by the influence of e-learning on green innovation. It was also found that green innovation and technology can mediate e-learning against green management practices.

Figure 2 depicts the Bootstrapping Model, which is the method of determining the significance level or likelihood of direct, indirect, and total effects. Furthermore, bootstrapping can determine the relevance of other parameters such as r square and modified r square, f square, outer loading, and outer weight.

5 Discussion

E-learning has a positive and significant effect on green innovation with a T-stat of 11.700 and a P-value of 0.000. These findings reinforce that E-learning is an integral part of green innovation. E-learning allows lecturers to access learning materials from anywhere and anytime, without having to be present at a specific location, where 40.5% of respondents live far away from the campus. And the rest as many as 59,5% also can reduce the need for mobility, which in turn can reduce the carbon footprint of travel. By using an e-learning platform, lecturers do not need to travel to campus every day to teach or attend training. This can reduce fuel consumption and exhaust emissions produced by motor vehicles. E-learning enables the use of electronically accessible digital materials, reducing reliance on paper and printed materials. This helps reduce tree felling and other negative impacts on the environment. Through e-learning courses that focus on environmental and sustainability issues, lecturers can be more aware of the importance of green innovation and contribute to positive changes in their behavior and practice [59, 60]. E-learning allows lecturers to engage in a wider online learning community, where they can share knowledge, experience, and ideas about green innovation [3, 11, 61]. This expands their network and enables greater collaboration in developing sustainable solutions.

E-learning has a positive and significant effect on green management practices with a t-stat of 2.347 and a P-value of 0.019. Through e-learning courses on green management, lecturers can increase their understanding of environmen- tally friendly practices and the importance of sustainability [6, 62]. This can change their perceptions and attitudes toward environmental issues and encourage them to implement green management practices in their daily activi- ties on campus. E-learning allows lecturers to access learning materials on green management from anywhere and anytime. This makes it easier for them to continue learning and developing their knowledge of the latest practices in green management without having to attend conventional courses that may require long trips. Through the

Table 8 Outer VIF

	VIF
EL1	2.212
EL3	1.819
EL4	1.788
EL5	1.757
EL6	1.633
EL7	1.872
EL8	1.866
EL9	1.896
EL10	1.742
EL11	1786
EL12	1.532
GI1	3.202
GI2	1.603
GI3	2.199
GI4	2.115
GMP1	2.276
GMP2	1.374
GMP3	1.718
GMP4	2.019
GT1	2.809
GT2	2.701
GT3	2.654
GT4	2.921
GT5	2.179
GT6	2.321
GT7	2.728
GT8	2.090
GT9	2.555
GT10	2.165
GT11	2.178
GT12	2.580
GT13	2.532
GT14	1.895
GT15	2.266
GT16	2.727

Table 9 Construct cross validated redundancy

	SSO	SSE	Q^2 (=1−SSE/SSO)
EL	1749.000	1749.000	
GI	636.000	443.406	0.303
GMP	636.000	326.285	0.487
GT	2544.000	1626.950	0.360

e-learning platform, lecturers can connect with their peers from other universities, as well as with experts and practi- tioners in the field of green management. This creates opportunities to collaborate, share experiences, and exchange ideas to improve green management practices across the institution. Through the use of technology in e-learning, such as the use of energy-efficient servers, the use of environmentally friendly software, and the promotion of the use of recyclable electronic devices, lecturers can practice green management in the use of their own information and communication technology [50, 51, 53, 63]. Lecturers can use e-learning platforms to teach green management

Table 10 Hypothesis testing results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EL→GI	0.723	0.721	0.062	11.700	0.000
EL→GMP	0.247	0.244	0.105	2.347	0.019
EL→GT	0.842	0.842	0.038	22.039	0.000
GI→GMP	0.284	0.292	0.098	2.891	0.004
GT→GMP	0.434	0.430	0.109	3.992	0.000
Specific indirect effects					
EL→GI→GMP	0.206	0.210	0.071	2.903	0.004
EL→GT→GMP	0.366	0.361	0.092	3.967	0.000

principles to their students. By demonstrating green practices in online course design, use of digital materials, and waste reduction, they can set a good example for students in applying sustainability principles in their lives.

E-learning has a positive and significant effect on green technology with a T-stat of 22.039 and a P-value of 0.000. This finding confirms that E-learning allows lecturers to access up-to-date and in-depth learning materials about green technology. This helps improve their understanding of the concepts, applications, and benefits of green technology in a variety of contexts [47, 64]. Through e-learning, lecturers can access the latest research resources, case studies, and information about the latest developments in green technology. It helps them in conducting research, developing projects, and introducing innovations in the field. E-learning platforms can provide courses, training, and certifications in the field of green technology [68]. Lecturers can take this course to acquire additional skills and knowledge neces- sary to teach and conduct research in this field. E-learning allows lecturers to integrate material on green technology into their curriculum in a more efficient way [1, 19]. They can use digital resources, learning videos, and simulations to teach green technology concepts to students. E-learning can facilitate collaboration between lecturers from dif- ferent institutions and disciplines in the field of green technology [49]. This enables the exchange of ideas, shared learning, and the development of collaborative projects that can enhance understanding and innovation in the field. *Green innovation has a positive and significant effect on green management practices with a t-stat of 2.891 and a p-value of 0.004*. Green innovation can inspire lecturers to introduce more effective and sustainable green management practices in their work environment [32, 50]. Through the discovery and implementation of new solutions, they can become agents of change in adopting more environmentally friendly practices. Green innovation stimulates research and development in green technologies, policies, and practices. Lecturers can engage in this research to understand its implications and practical applications in the context of green management in higher education. Lecturers can use green innovation as a case study in their curriculum to teach green management practice concepts to students. This helps increase their awareness of the importance of green practices and provides the necessary skills to implement them in the future. Green innovation often involves collaboration between different disciplines and stakeholders. Lecturers can engage in this network to share knowledge, experience, and resources to improve green management practices in higher education. Many green innovations aim to improve resource efficiency and reduce carbon footprint.

Green technology has a positive and significant effect on green management practices with a t-stat of 3.992 and a p-value of 0.000. Green technologies, such as smart sensors, energy management systems, and the use of renewable energy, help colleges manage their resources more efficiently [47, 49, 64]. Lecturers can utilize this technology to optimize the use of energy, water, and other raw materials in their work environment. Adopting green technologies, such as solar energy systems or electric vehicles, helps universities to reduce their carbon emissions. Lecturers can play an important role in selecting, implementing, and managing these technologies to achieve greater carbon emission reduction goals. Green technology enables the development of innovative solutions in higher education and research. Lecturers can use technologies such as environmental simulations, virtual labs, and environmental analysis software to enhance student learning experiences and facilitate ongoing research. The implementation of green technology can be used as a direct example in education about green management practices [65]. Lecturers can use this technology as a case study in their curriculum to increase students' awareness and understanding of the importance of green practices in managing the environment. While initial investment may be required, green technology often results in long-term savings for universi- ties, both in terms of energy savings and reduced operating costs. Lecturers can play a role in identifying and managing green technology investments that provide a good return on investment.

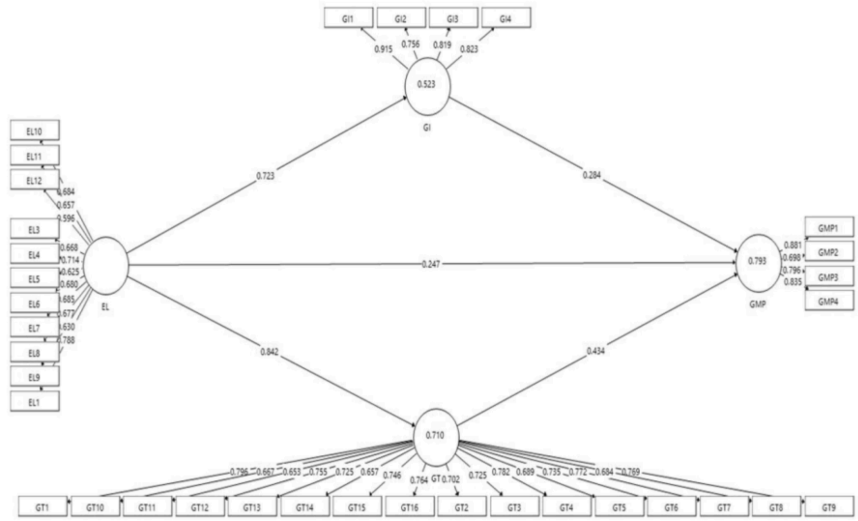

Fig. 2 Bootstrapping model

Green innovation can mediate e-learning with green management practices with a t-stat of 2.903 and a p-value of 0.004. Green innovation can encourage the development of learning content that focuses on green management practices [3, 61, 66]. This includes the preparation of curriculum and learning materials that emphasize the principles of sustainability, energy-efficient use of resources, and environmentally friendly technology. Green innovation can facilitate the devel- opment and application of sustainable technologies in e-learning platforms. These include the use of energy-efficient servers, optimization of algorithms to reduce power consumption, and the development of applications that support green management practices such as energy saving and waste reduction. Green innovation can enable collaboration between lecturers, researchers, and practitioners in the field of green innovation and green management. Through the exchange of ideas and knowledge, they can identify opportunities to implement green innovations in the context of e-learning and green management practices in higher education [65]. Green innovation can support training and professional development for lecturers in terms of green management practices [67]. This includes the provision of online learning resources, webinars, and workshops covering topics such as energy efficiency, waste management, and sustainable development. Green innovation can help in the development of metrics and evaluation tools to measure the performance of e-learning and green management practices. By implementing an effective monitoring and reporting system, lecturers can identify areas where they can improve their green practices and measure the positive impact of those efforts. Thus, green innovation can act as an important link between e-learning and green management practices, helping to create a sustainable learning ecosystem for lecturers in universities.

Green technology can mediate between e-learning and green management practices with a t-stat of 3.967 and a p-value of 0.000. By using environmentally friendly technological infrastructure such as energy-efficient servers and power-efficient computers, educational institutions can reduce their carbon footprint resulting from e-learning operations [68]. Green technology enables the development of e-learning platforms designed to reduce energy consumption and minimize their carbon footprint [2, 19, 69, 70]. This could include the use of cloud technology to reduce the need for physical servers, as well as the design of interfaces that are efficient in energy use. Educational institutions can take advantage of green technology by using renewable energy sources such as solar panels or wind turbines to provide electricity for their e-learning operations. This helps reduce dependence on fossil fuels and reduce greenhouse gas emissions. Green technology can encourage the use of environmentally friendly electronic devices by lecturers, such as laptops and tablets that are designed to reduce energy consumption and are easily recycled. Green technology can also be used to develop applications and supporting tools that assist lecturers in implementing green management practices in their daily activi- ties, such as tools to measure energy consumption or applications to manage waste efficiently. Thus, green technology can be an effective mediator between e-learning and green management practices for lecturers in universities, helping to reduce the environmental impact of e-learning operations and encouraging the adoption of sustainable practices in educational environments. Green technology allows for the incorporation of environmentally friendly resources and procedures into the e-learning process, reducing the waste and energy consumption associated with traditional teaching methods. By encouraging the use of digital resources and renewable energy sources, universities can lower their carbon footprint while also improving the effectiveness of online teaching. In addition, incorporating green management prac- tices into e-learning fosters a sustainable culture among educators and students, promoting long-term environmental accountability. This integration of green technology with e-learning increases higher education's overall sustainability and quality while also benefiting the environment.

5.1 Practical implication

E-learning can be a very effective tool in facilitating green innovation among lecturers in higher education, by reducing environmental impact and encouraging awareness and positive action toward sustainability [1, 2, 19]. E-learning can also be an effective tool in promoting and implementing green management practices among lecturers in universities, bringing about positive changes in campus culture and operations towards environmental sustainability. By utilizing e-learning effectively, lecturers in universities can gain the knowledge, skills, and resources they need to become agents of change in advancing green technology and generating positive impacts on the environment and society. Lecturers can use these innovations to identify new ways to manage resources, reduce waste, and save energy in the college work envi- ronment. By utilizing green innovation effectively, lecturers in universities can play an important role in developing and implementing green management practices that are more sustainable and have a positive impact on the environment and society. By adopting green technologies effectively, lecturers in universities can play a significant role in developing and strengthening green management practices, which in turn will bring positive impacts to the environment, society, and the future of future generations.

In the future, the application of green technology in e-learning can accelerate the transition of universities towards more environmentally friendly operations, while reducing long-term costs related to energy and materials. It can also increase environmental awareness and responsibility among academics and students, forming a generation that cares more about sustainability. In addition, this integration can encourage further innovation in the development of educa- tional technology that is increasingly efficient and sustainable.

6 Conclusion

E-learning has become an important element in integrating eco-friendly technologies and improving eco-friendly man- agement practices in educational environments. E-learning allows us to use environmentally friendly technology more efficiently. By using online learning platforms, universities can reduce paper consumption, save energy, and minimize carbon footprint. Colleges can adopt green cloud technology for data storage and use software to optimize resource utilization. E-learning provides flexibility in accessing learning materials, reducing the need for printouts and physical distribution. This reduces paper consumption, the energy required to deliver materials, and the CO_2 emissions associ- ated with transportation. By making learning materials accessible anytime and anywhere, e-learning reduces the need for travel and can also help reduce carbon footprint. In addition, e-learning supports environmentally friendly manage- ment practices by providing a platform to disseminate information and encourage collaboration between lecturers and students on sustainability projects. This enables best practices to reduce the environmental impact of the campus. Overall, the impact of e-learning on green innovation, green technology, and green management practices shows a major positive change in the sustainability efforts of higher education institutions. By integrating e-learning into its approach, educational institutions can become leaders in fostering eco-friendly technological innovation and strengthening eco- friendly management practices to create a sustainable and responsible learning environment.

Green management practices in higher education include policies and procedures that lessen the environmental effect on campus. Higher education institutions can also implement curricula that promote sustainable learning, such as envi- ronmental management, renewable energy, and eco-design. Furthermore, it strengthens the university's commitment to environmentally friendly practices by promoting extracurricular activities such as campus greening programs, envi- ronmental restoration efforts, and the exchange of sustainability ideas. Universities may set a good example for future generations by using green technologies in e-learning and green management practices. This allows us to identify areas for development and assess the impact of training efforts on the adoption of green management practices. By properly implementing e-learning, companies and individuals can increase their understanding and execution of green management principles, thereby contributing to sustainable development. Green management methods can improve a university's reputation as an environmentally responsible institution and boost student and faculty participation in sustainability.

Author contributions All authors contributed to the study's conception and design. Conceptualization: [Dewi Nusraningrum], Universitas Mercu Buana; Methodology: [Sonny Indrajaya], Universitas Mercu Buana; Formal analysis and investigation: [Winda Widyanti], Universitas Mercu Buna; Writing—original draft preparation: [Dewi Nusraningrum, Universitas Mercu Buana]; Writing—review and editing: [Nimit Soonsan, Suphattra Sangthong, Kanyapat Pattanapokinsakul], Phuket Rajabhat University; Resources: [Dewi Nusraningrum], Universitas Mercu Buana; Supervision: [Dewi Nusraningrum], Universitas Mercu Buana. All authors read and approved the final manuscript.

Data availability The author affirms that the published article contains all of the data produced or analyzed during this work. Furthermore, the primary and secondary sources, as well as the data supporting the study's findings, were all publicly available at the time of submission.

Declarations

Ethics approval and consent to participate The questionnaire and procedures of this study were accepted by the Universitas Mercu Buana Research Ethics Committee (Ethics approval number: Surat Keputusan Rektor UMB Nomor 01/085/B-Skep/XII/2023).

Informed consent All individual participants whose identifying information appears in this publication provided additional informed consent.

Competing interests The authors declare no competing interests.

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