Green Intellectual Capital's Effect on UAE Petroleum Industry Green Innovation through Environmental Knowledge and Learning Orientation

***Maitha Al Kaabi and Muhd Akmal Noor Rajikon**

Institute of Technology Management and Entrepreneurship – IPTK, University Technical Malaysia Melaka Hang Tuah Jaya, 76100, Durian Tunggal, Melaka - Malaysia.

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.90400371

Received: 05 March 2025; Accepted: 15 March 2025; Published: 16 May 2025

ABSTRACT

In the workplace, green prospects are gaining much importance these days, although not much is known about the green intellectual capital and its contribution towards pro-environment behavior and outcomes. As the world experiences environmental concerns, it has become imperative for businesses to look into ways through which they can improve their environmental footprints. Hence, the current study examines the nexus between green intellectual capital's effect on UAE Petroleum industry green innovation through environmental knowledge and learning orientation. The study also tested if environmental knowledge as mediate and learning orientation Moderate the association and examined the role of learning orientation as a moderator. Data were gathered from the ADNOC local employees in the United Arab Emirates and analyzed using a structural equation modeling approach via Smart PLS. The results show a significant association between green intellectual capital's with green innovation; a strong association was also found between environmental knowledge and learning orientation and green innovation. The results also report a significant association between the three factors of green intellectual capital and environmental knowledge and learning orientation. The results found a mediating effect of learning orientation , whereas environmental concern only moderated the association between green intellectual capital's and green innovation. The study presents prominent implications for theory and practice, followed by recommendations for future studies.

Keywords*:* Green intellectual capital's, Green innovation, Environmental knowledge, learning orientation, UAE Petroleum.

INTRODUCTION

In today's business landscape, environmental concerns have emerged as a prominent issue due to the growing pressure from stakeholders, compelling companies to take greater responsibility for the environment. This is evident through the implementation of stricter regulations by authorities and increased public awareness surrounding environmental sustainability. As a result, ecological considerations have become integral to business operations and efficiency (Maldonado-Guzmán and Pinzón-Castro, 2022).To ensure that a company's activities align with environmental safety, it is crucial to foster green innovation. Green innovation encompasses various forms of innovation that address environmental challenges and optimize the efficient utilization of natural resources. By adopting green innovation, businesses can enhance their performance in terms of economic viability, environmental impact, and competitiveness. However, successful implementation of green innovation requires robust governance strategies (Moslehpour et al., 2022).

An important strategy in achieving green innovation is the enhancement of green intellectual capital (GIC). GIC refers to the intangible assets resulting from mental processes that can be utilized in economic activities, generating value for the organization while preserving environmental quality. The competitive advantage of a company is built upon the collective knowledge of its members. GIC consists of three key components: green human capital, green structural capital, and green relational capital (Quynh et al., 2022). Green human capital refers to the presence of employees who possess environmental knowledge, good health, and the skills necessary to effectively manage business operations and utilize resources in an environmentally responsible manner. They assess the environmental impact of business processes, contribute creative ideas, and facilitate the implementation of green innovative practices (Kara et al., 2023).

Green structural capital encompasses the infrastructure, procedures, processes, and databases within the company that support the efforts of human capital in minimizing pollution emissions. The adoption of green structural capital adds value to business operations and facilitates the integration of green innovation (Dat et al., 2023). Green relational capital involves the knowledge, processes, capabilities, and systems specific to establishing relationships with external stakeholders that provide eco-friendly value to the business. The effective utilization of green relational capital contributes to green innovation in business operations and production (Zhao et al., 2022).

Scholars argue that the oil and gas sector is one of the energy-intensive industries that significantly contribute to carbon emissions. In order to mitigate these emissions, the sector needs to implement policies that improve environmental quality. Green innovation has been identified as a potential solution to enhance firm performance and prevent environmental pollution (Zhang et al., 2023). This argument warrants an examination of green innovation in the oil and gas sector of the UAE. As a developing country, the UAE has been steadily progressing with a GDP estimated 30% contribution to the country GDP. The oil and gas industry holds a significant position in the country's economy.

The UAE has emerged as one of the leading exporters of oil and gas worldwide. With a substantial market share in the global oil and gas market, the UAE plays a vital role in meeting global energy demands. The country exports oil and gas products to various regions, including the United States, Europe, and Asia. The oil and gas industry in the UAE has experienced significant growth and development, contributing to the nation's economic prosperity. It plays a crucial role in the country's GDP, employment, and industrial development (Waqar et al., 2023). However, the oil and gas sector, due to its operational activities and environmental impact, poses challenges in achieving sustainability and minimizing environmental pollution (Albeldawi, 2023).

Therefore, the industry requires green innovations to ensure sustainable development and reduce its ecological footprint. Green innovation practices, such as implementing cleaner technologies, reducing emissions, and optimizing resource efficiency, are essential for the oil and gas sector to align with environmental sustainability goals (Munodawafa and Johl, 2022). The present study addresses this need by focusing on green innovation and green intellectual capital, while also examining the mediating role of environmental knowledge between green intellectual capital and green innovation. Additionally, the study analyzes the moderating role of green culture and green learning outcomes between green human capital and green innovation.

Theoretical literature and hypothesis development

The theoretical framework of the study explores the relationship between green intellectual property (GIP) and eco-innovation within oil and gas corporations, with a specific focus on the mediating role of environmental knowledge. The Resource-Based View (RBV) is employed as the theoretical lens to understand how GIP, comprising green human capital, green structure, and green rational capital, contributes to eco-innovation in the oil and gas industry. This perspective emphasizes the strategic significance of GIP as valuable and rare resources that can provide a competitive advantage in the sector.

Eco-innovation

Eco-innovation refers to any form of innovation that seeks to create economic value while simultaneously minimizing adverse impacts on the natural environment (Rennings, 2000). When integrated into a firm's strategic approach, eco-innovation can enhance its ability to remain innovative and competitive, especially amidst the growing prominence of environmental challenges. By adopting eco-innovation, firms can develop strategic problem-solving capabilities at the forefront of their operations (Munodawafa, 2022). In today's context, driven by a heightened sense of environmental protection, Eco-innovation has gained significant momentum. As society becomes more environmentally conscious, industries are compelled to adopt more sustainable practices and explore innovative ways to protect the environment and promote a greener future.

Green intellectual capital

Green intellectual capital is a critical component of sustainability, encompassing the knowledge, skills, and expertise that enable firms to address environmental and social issues. However, it has been noted that green intellectual capital has not received sufficient attention despite its importance (Dat et al., 2023). Green structural capital (GSC) refers to the organizational structures, systems, and processes that support environmental protection and green innovation. This includes the implementation of environmental management systems, knowledge management systems, managerial philosophy, organizational culture, and the value of intellectual property related to environmental protecting is classified into three distinct components, providing a comprehensive framework for understanding the different aspects of environmental intellectual capital, which are green human capital, green rational capital and green structure capital. By understanding and developing these different components of green intellectual capital, firms can enhance their capacity to address environmental challenges, drive innovation, improve performance, and contribute to sustainable development.

(Asiaei et al., 2022), have demonstrated that Green Human Capital (GHC) within an organization, which promotes the application of environmental governance such as Green Supply Chain Management (GSCM), green production lines, and reverse logistics, contributes to achieving sustainability. Unlike GHC, Green Structural Capital (GSC) does not disappear when employees leave. In the context of environmental and cultural factors associated with global development, businesses need to continuously find ways to implement environmental strategies to seek opportunities, create value, and gain competitive advantages, thus establishing a sustainable organizational structure. In response to this, (Irfan et al., 2022), defined GSC as the organizational capacity, organizational commitment, knowledge management system, organizational culture, trademarks, patents, copyrights, and trademarks related to environmental protection or green innovation in an enterprise.

Additionally, (Irfan et al., 2022), developed the concept of Green Relational Capital (GRC), which encompasses the relationships between stakeholders regarding corporate environmental management and green innovation. External organizations and business stakeholders are often more concerned about environmental issues than businesses themselves. To maintain close relationships and receive resource support from external organizations and stakeholders for survival and growth, businesses need to invest more resources in developing relationships that leverage shared environmental benefits. This is particularly relevant for Vietnam's textile and garment industry, which has a significant impact on the environment and plays a crucial role in addressing employment issues, making it necessary to find solutions to promote Green Intellectual Capital (GIC).

In the era of increasing environmental management awareness and sustainable energy development, GHC plays a crucial role in organizational innovation as employees possess valuable knowledge and expertise that can be harnessed for green innovation (Joghee, Alzoubi and Alshurideh, 2021). Dereń and Skonieczny, (2022), argue that GHC serves as a platform connecting employees' environmental knowledge with green innovation. Businesses can leverage their GHC potential to drive GPC and GPD, thereby enhancing operational efficiency. Mansoor et al. (2021) find that discrepancies in GHC investment requirements can lead to significant disparities in the likelihood of success when implementing green innovation among businesses.

On the other hand, unlike GHC, GSC is independent of employees. (Azam et al., 2022)contend that managers must invest in and establish robust GSC to enhance their ability to acquire environmental knowledge and sustain green innovation. Moreover, (Ali et al., 2021), support the importance of GRC for green innovation, suggesting that managers can cultivate green relationships with strategic partners, facilitate the exchange of external environmental knowledge, and foster the development of green innovation.

Based on the aforementioned rationales, the following hypotheses are proposed:

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

H1: GHC has a positive impact on green innovation.

H2: GSC has a positive impact on green innovation.

H3: GRC has a positive impact on green innovation.

Mediate role of environmental knowledge

The study conducted by Wang and Juo (2021) aimed to examine the relationship between green intellectual capital (GIC), including green human capital (GHC), green structural capital (GSC), and green relational capital (GRC), with environmental knowledge and green innovation. The authors collected data from 138 high-tech companies in Taiwan using surveys and employed descriptive statistics, correlation analysis, and structural equation modeling to test their hypotheses.

The authors argued that organizations with high potential in GHC, GSC, and GRC can acquire quality environmental knowledge. This knowledge, combined with the capacity to address environmental issues, creates a platform for green innovation.

A similar study by Ali et al. (2021) investigated the relationships among GIC, including GHC, GSC, and GRC, environmental knowledge, and green innovation. The study surveyed 235 small and medium-sized enterprises (SMEs) in the textile, chemical, steel, and pharmaceutical sectors in Pakistan. Multiple regression analysis was used to assess the proposed relationships. The findings indicated that higher potential in GHC, GSC, and GRC improved professionals' environmental knowledge, leading to green innovation in terms of energy reduction, environmental pollution mitigation, and waste management.

Yong et al. (2019) examined the relationship between GIC (including GHC, GSC, and GRC) and environmental knowledge and green innovation. They surveyed 112 significant manufacturing companies in Malaysia using a quantitative research method. Partial least squares regression analysis was conducted to analyze the proposed associations. The study suggested that integrating green practices into GHC, GSC, and GRC enhances understanding of environmental changes and promotes environmental preservation. The increased environmental knowledge guides management in fostering green innovation.

H4: GHC has a positive impact on environmental knowledge

H5: GSC has a positive impact on environmental knowledge

H6: GRC has a positive impact on environmental knowledge

According to Chen et al. (2014), green knowledge is the process through which firms obtain knowledge related to environmental protection. This knowledge is crucial for firms to effectively utilize environmental information and enhance their environmental technology resources, enabling them to engage in ambidextrous green innovation. In order to survive and comply with environmental regulations, firms must acquire and integrate green knowledge to drive innovation, as highlighted by (Chau et al., 2023). In the study conducted by Liao (2018), it was revealed that knowledge acquisition has a positive influence on green innovation. This finding aligns with the principles of resource-based theory, which suggests that knowledge is a crucial resource for firms' innovation endeavors. Therefore, this research hypotheses that:

H7: Environmental knowledge has positive significant relationship with eco-innovation.

Environmental knowledge plays a crucial mediating role between green intellectual property (IP) and eco-innovation, fostering a sustainable and eco-friendly business landscape. Green intellectual property encompasses patents, trademarks, and copyrights that protect environmentally friendly technologies, processes, and products (Dat et al., 2023). On the other hand, eco-innovation refers to the development and implementation of novel green solutions that reduce environmental impact. Environmental knowledge acts as a bridge between these two concepts by providing firms with essential insights and information on environmentally sound practices, cutting-edge technologies, and sustainable methodologies. Firms equipped

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

with a strong understanding of environmental issues are more likely to recognize the potential value of green intellectual property (Dat et al., 2023). This awareness motivates them to invest in and protect eco-friendly innovations through intellectual property rights. Moreover, environmental knowledge empowers firms to identify gaps in existing green technologies or processes, leading to opportunities for eco-innovation. By leveraging their understanding of environmental challenges and solutions, businesses can devise creative and inventive ways to address ecological concerns. Through eco-innovation, they can develop greener products, services, and processes that align with sustainable practices while enjoying the protection and incentives offered by green intellectual property.

H8: Environmental knowledge mediates the relationship between GHC and green innovation. H9: Environmental knowledge mediates the relationship between GSC and green innovation. H10: Environmental knowledge mediates the relationship between GRC and green innovation.

Moderate effect of learning orientation

The relationship between green intellectual property and eco-innovation in the Oil and Gas sector is influenced by the learning orientation, which has a moderate effect. Previous research has emphasized the significance of a learning orientation as a catalyst for innovation in businesses (Chau et al., 2023). Studies conducted by Bai et al. (2020) have further suggested that the direction of learning has positive effects on innovation. With this in mind, a strong learning orientation (GLO) within an organization can serve as a foundation for promoting green innovation. GLO impacts the learning orientation of human resources and employee attitudes, leading to the acquisition of new skills (Dat et al., 2023). This fosters a sense of initiative and enthusiasm among employees, particularly those involved in green innovation efforts. Businesses with GLO are more likely to embrace environmental changes and encourage proactive thinking among their employees (Nirino et al., 2022). As a result, ideas and thoughts focused on environmental issues and meeting green innovation goals are accumulated and facilitated. Moreover, businesses with a strong learning orientation tend to be better equipped to respond quickly to customer needs and market changes, enabling them to effectively pursue eco-friendly initiatives in the Oil and Gas sector. The ability to learn and adapt to new challenges is crucial for the sector's sustainability efforts and meeting environmental goals. Therefore this research hypotheses that:

H11: learning orientation outcomes moderate the relationship between green human capital and green innovation.

The research framework

The primary focus of the research is to gain insights into how green intellectual property influences eco-innovation among employees in oil and gas corporations. Eco-innovation refers to the introduction of new ideas, products, processes, or practices that enhance environmental performance and sustainability within the industry. In this context, the extent of employees' engagement in eco-innovation serves as the dependent variable. Furthermore, the study recognizes the critical role of environmental knowledge as a mediating variable in the relationship between green intellectual property and eco-innovation. Environmental knowledge represents employees' understanding and awareness of environmental issues, solutions, and the potential implications of eco-innovation initiatives. This knowledge mediates the pathway through which green intellectual property affects eco-innovation outcomes, emphasizing its importance in driving sustainable practices and innovations in the oil and gas industry.

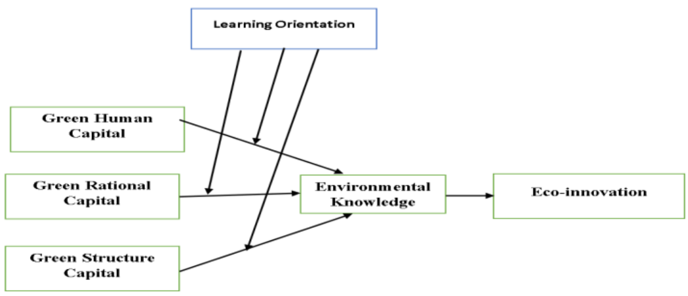

Figure 1. Research framework

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

DATA AND METHODOLOGY

Respondents of the present research are ADNOC local employees in the UAE. However, considering the results of the pilot research, the actual field sample was modified to increase the chances of reaching this minimum sample by the end of the survey. 315 questionnaires were distributed to the sample. Nonetheless, the minimum sample requirement for generalisation was met. A period of six (6) weeks was allocated to collect data. The results were downloaded from the online data collection platform and analyzed with Analysis of (Smart PLS). The collected data was originally entered into the online data collection platform based on the weights of the various responses.

Demographic analysis

Table 1 shows the respondents profile for those who participated in the research.In terms of gender, the majority of respondents were male, comprising 250 individuals, which represents approximately 79.38% of the total respondents, while females accounted for 65 respondents, making up about 20.62% of the sample. Regarding age groups, the distribution was diverse. The largest group falls within the 31-35 years range, with 72 respondents, constituting around 22.86% of the total. Following closely behind are those aged 36-40 years, comprising 55 respondents, or approximately 17.46%. The oldest age group, 61 years and above, had the fewest respondents, with only 7 individuals, representing about 2.22%.

In terms of educational qualifications, the majority of respondents possessed diplomas or postgraduate diplomas, with 87 and 89 respondents, respectively, making up 27.62% and 28.25% of the total. Bachelor's degree holders accounted for 13.65%, while those with doctorates represented the smallest group, comprising approximately 4.44%. Regarding current positions, administrative assistants constituted the largest group, with 143 respondents, representing about 45.4% of the total. Head of Department and Executive positions followed closely behind, with 71 and 69 respondents, respectively, making up around 22.54% and 21.9%.

In terms of work experience, respondents with less than 2 years of experience were the largest group, comprising 109 individuals or 34.6%, while those with over 21 years of experience were the smallest group, with only 3 respondents, making up approximately 0.95% of the total. Across departments, operations had the highest number of respondents, with 112 individuals, representing about 35.56%, followed by HR and Supply Chain, each with 77 respondents, making up approximately 24.44% of the total. Regarding the nature of employment, the vast majority of respondents were full-time employees, comprising 293 individuals, accounting for approximately 93.02% of the total, while those on contract constituted around 7.45%, with 22 respondents. No respondents reported being on a fixed-term contract.

Table 1 Profile of respondents (N = 315)

Category	Number of Respondents	Percentage (%)
Gender		
Male	250	79.38
Female	65	20.62
Age Group		
20-25 years	45	14.29
26-30 years	51	16.19
31-35 years	72	22.86

36-40 years	55	17.46
41-45 years	49	15.56
46-50 years	23	7.3
51-60 years	13	4.13
61 years and above	7	2.22
Highest Qualification		
Diploma	87	27.62
Postgraduate Diploma	89	28.25
Bachelor’s Degree	43	13.65
Honours/BTech	55	17.46
Masters	27	8.57
Doctorate	14	4.44
Other	0	0
Current Positions		
Manager	25	7.94
Executive	69	21.9
Head of Department	71	22.54
Admin Assistant	143	45.4
Others	7	2.22
Years of Work Experience		
< 2 years	109	34.6
2-5 years	71	22.54
6-10 years	67	21.27
11-15 years	53	16.83
16-20 years	12	3.81
> 21 years	3	0.95
Current Department		
HR (Human Resources)	77	24.44

Procurement	37	11.75
Operations	112	35.56
Supply Chain	77	24.44
R&D	12	3.81
Nature of Employment		
Full-time	293	93.02
Fixed-term	0	0
Contract	22	7.45

Convergent validity

Convergent validity, as defined by Hair et al. (2014), reflects the degree of correlation between a measure and alternative measures within the same construct, essentially verifying whether the item effectively measures what it is intended to measure. In the present study, the researcher evaluated the convergent validity based on the AVE (Waddock and Graves, 1997), where AVE of 0.50 and above reflects an acceptable convergent validity. Table 2 lists the AVE for the convergent validity of the constructs. It could be observed that all value exceeds the AVE threshold value (0.50). Hence, this study's measurement model has an acceptable convergent validity.

Table 2 Average variance extracted (AVE) values

	Average Variance Extracted (AVE)
Environmental Knowledge	0.680
Green Human Capital	0.658
Green Rational Capital	0.740
Green Structure Capital	0.617
Green-innovation	0.649
Learning Orientation	0.807

AVE= Average Variance Extracted

Discriminant validity

A construct's discriminant validity can be determined based on the item's cross-loading and the (Fornell et al., 1981) criterion. Using the cross-loading, a measurement model's discriminant validity occurs when the cross-loading value indicates that each item's loading surpasses the specific construct and other constructs. Meanwhile, the discriminant validity based on the Fornell and Larcker (1981) criterion is determined when a construct's AVE square root is higher than its correlation with other constructs. The discriminant validity was derived from the SmartPLS software algorithm function in this study. In this regard, the Fornell-Larcker criterion was used to measure the discriminant validity. Table 3 presents the Fornell-Larcker criterion obtained.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

Table 3 Fornell-Larcker criterion

	Environmental Knowledge	Green Human Capital	Green Rational Capital	Green Structure Capital	Green-innovation	Learning Orientation
Environmental Knowledge	**0.906**					
Green Human Capital	0.629	**0.811**				
Green Rational Capital	0.602	0.668	**0.860**			
Green Structure Capital	0.230	0.234	0.184	**0.594**		
Green-innovation	0.801	0.596	0.521	0.466	**0.653**	
Learning Orientation	0.824	0.596	0.566	0.200	0.625	**0.899**

Multicollinearity

Multicollinearity issues are evident where the correlation between two or more independent variables is high. Potential multicollinearity between the variables could be determined by testing the variance of inflation factors (VIF). It describes that VIF reflects the presence of collinearity among independent variables based on the tolerance of 0.20 or lower and ten or higher VIF values. Table 4 presents the VIF values measured for the independent variables.

Table 4 VIF values

EK1	1.845	GRC1	2.072
EK2	1.644	GRC2	1.817
EK3	1.400	GRC3	1.789
GHC2	2.333	GSC1	2.024
GHC3	2.231	GSC2	2.072
GHC4	2.540	GSC3	1.950
GHC5	1.421	GSC5	1.365
GI1	1.950	GSC6	1.385
GI2	1.792	GSC7	1.451
GI3	2.110	GSC8	1.447
GI4	1.714	LO2	1.612
GI6	1.232	LO3	1.612
GI7	1.284	GHC1	1.915

Figure 2 illustrates the coefficients of the structural model along with their level of importance using the t-statistic after removing the low loaing items.

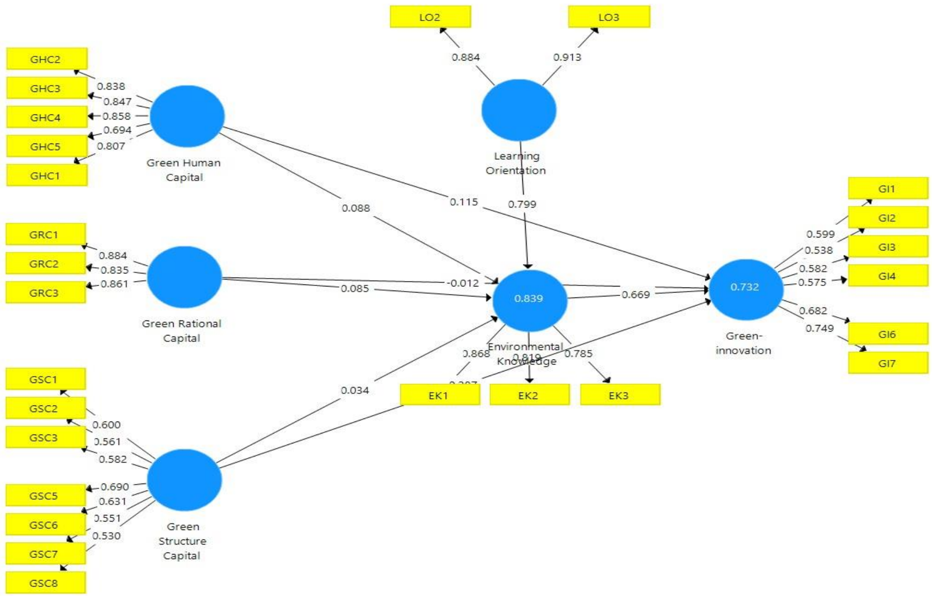

Figure 2 Measurement model of the research

RESULTS AND DISCUSSION

Testing hypotheses is the most important test in the current research since it shows whether or not the goals of the research were met. Since there is a mediation in the current research, the direct effect test, and the indirect effect test will be used to examine the hypotheses.

Hypothesis testing (Direct effect)

This section presents the result of hypotheses testing for direct effect. The direct effect test aims to examine the relationships between the independent variables and the dependent variable. The results are presented in table 4 and explained in the following conclusions.The bootstrapping technique in SmartPLS was used to evaluate the relationships (paths) between the independent and dependent variables. t-statistics and p-values were used to verify the significance of the paths between these variables. Hair et al. (2014) described the coefficient as significant at the determined confidence level when the empirically obtained statistical t-value is higher than the critical value. In this case, the t-value of 0.95 was applied at the significance level of 0.05.The bootstrapping technique in PLS-SEM (Hair et al., 2014) is a nonparametric statistical test that measures whether the estimated path coefficients are significant. Coefficients range between -1 and +1, where path coefficients close to +1 shows a substantial relationship and vice-versa. Table 5 presents the empirically measured t-values, p-values and path coefficients values between variables in the present study, determining whether the hypothesis is accepted or rejected based on the path assessments. As shown, all hypotheses were supported at the 0.05 significance level.

Table 5 Summary of the direct effect

Hypotheses	**Path**	**T Statistics (|O/STDEV|)**	**P Values**
H1: Environmental Knowledge -> Green-innovation	0.669	8.613	**0.000**
H2: Green Human Capital -> Environmental Knowledge	0.088	2.564	**0.011**
H3: Green Human Capital -> Green-innovation	0.115	2.649	**0.008**

H4: Green Rational Capital -> Environmental Knowledge	0.085	2.428	**0.016**
H5: Green Rational Capital -> Green-innovation	-0.012	0.253	**0.800**
H6: Green Structure Capital -> Environmental Knowledge	0.034	1.342	**0.180**
H7: Green Structure Capital -> Green-innovation	0.287	4.022	**0.000**

In summary, these results suggest that at ADNOC, there is a strong positive relationship between Environmental Knowledge and Green Innovation, with Green Human Capital, and Green Relational Capital significantly contributing to Environmental Knowledge. Green Human Capital and Green Relational Capital also positively influence Green Innovation, while Green Structure Capital's impact on Green Innovation is not statistically significant. These findings provide valuable insights into the organizational dynamics at ADNOC and can inform strategic decisions related to environmental sustainability and innovation.

Hypothesis testing (Mediation environmental knowledge)

The results indicate a significant mediating effect of environmental knowledge in the relationship between green human capital and green innovation at ADNOC. The direct effect of green human capital on green innovation is positive and statistically significant (0.097, $p = 0.002$), demonstrating that an increase in green human capital directly contributes to higher levels of Green Innovation. Simultaneously, the indirect effect of green human capital on Green Innovation through Environmental Knowledge is substantial (0.542, $p < 0.001$), confirming that a significant portion of the influence of green human capital on Green Innovation is mediated by the enhancement of environmental knowledge. The positive path coefficient (0.844, $p < 0.001$) in the environmental knowledge -> green innovation relationship further supports the mediating role of environmental knowledge. This implies that as employees with enhanced green human capital acquire greater environmental knowledge, the positive impact on Green Innovation becomes more pronounced. Therefore, fostering a workforce with strong green human capital not only directly stimulates innovation but also indirectly influences innovation through the mediation of environmental knowledge, emphasizing the pivotal role of knowledge enhancement in driving green innovation at ADNOC. Therefore, it can be concluded that the result of the mediator effect is indirect-only (partial mediation) through Environmental Knowledge (Hair et al., 2014).

Table 6: Green Human Capital -> Environmental Knowledge-> Green-innovation

	Path	**SD**	**T Statistics (|O/STDEV|)**	**P Values**	**2.5%**	**97.5%**
Environmental Knowledge -> Green-innovation	0.844	0.037	22.619	0.000	0.766	0.905
Green Human Capital -> Environmental Knowledge	0.643	0.039	16.455	0.000	0.569	0.710
Green Human Capital -> Green-innovation (Direct Effect)	0.097	0.031	3.099	0.002	0.044	0.164
Green Human Capital -> Environmental Knowledge-> Green-innovation (Indirect Effect)	0.542	0.035	15.329	0.000	0.475	0.609
Green Human Capital -> Green-innovation	0.639	0.034	18.873	0.000	0.567	0.703

The results indicate a significant mediation effect in the relationship between green rational capital, environmental knowledge, and green innovation at ADNOC. The direct effect of Green Rational Capital on Green Innovation is not statistically significant (0.032, $p = 0.261$), suggesting that the direct impact is weak and lacks statistical significance. However, when considering the indirect effect through environmental knowledge, a substantial and statistically significant mediation effect is observed (0.536, p < 0.001). This suggests that a significant portion of the influence of green rational capital on green innovation is mediated by the enhancement of environmental knowledge. The total effect of green rational capital on green innovation, considering both direct and indirect effects, is statistically significant (0.568, p < 0.001), indicating that the overall impact of green rational capital on green innovation is primarily driven by the indirect pathway through environmental knowledge. Therefore, the mediation effect in this relationship can be characterized as fully mediating, where the influence of green rational capital on green innovation is entirely explained by its impact on environmental knowledge within the context of ADNOC.

Table 7 Mediating analysis Green Rational Capital -> Environmental Knowledge -> Green-innovation

	Original Sample (O)	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**	**2.5%**	**97.5%**
Environmental Knowledge -> Green-innovation	0.889	0.031	28.972	0.000	0.825	0.945
Green Rational Capital -> Environmental Knowledge	0.603	0.039	15.387	0.000	0.525	0.678
Green Rational Capital -> Green-innovation	0.032	0.028	1.126	0.261	-0.026	0.081
Green Rational Capital -> Environmental Knowledge -> Green-innovation (Indirect Effect)	0.536	0.039	13.917	0.000	0.459	0.608
Green Rational Capital -> Green-innovation (Total Effect)	0.568	0.038	14.937	0.000	0.489	0.635

The results indicate a significant mediation effect in the relationship between green rational capital, environmental knowledge, and green innovation at ADNOC. The direct effect of green rational capital on green innovation is not statistically significant (0.032, p = 0.261), suggesting that the direct impact is weak and lacks statistical significance. However, when considering the indirect effect through environmental knowledge, a substantial and statistically significant mediation effect is observed (0.536, p < 0.001). This suggests that a significant portion of the influence of green rational capital on green innovation is mediated by the enhancement of environmental knowledge. The total effect of green rational capital on green innovation, considering both direct and indirect effects, is statistically significant (0.568, p < 0.001), indicating that the overall impact of green rational capital on green innovation is primarily driven by the indirect pathway through environmental knowledge. Therefore, the mediation effect in this relationship can be characterized as fully mediating, where the influence of green rational capital on green innovation is entirely explained by its impact on environmental knowledge within the context of ADNOC.

Table 7 Mediating analysis Green Rational Capital -> Environmental Knowledge -> Green-innovation

	Original Sample (O)	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**	**2.5%**	**97.5%**
Environmental Knowledge -> Green-innovation	0.889	0.031	28.972	0.000	0.825	0.945

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

Green Rational Capital -> Environmental Knowledge	0.603	0.039	15.387	0.000	0.525	0.678
Green Rational Capital -> Green-innovation	0.032	0.028	1.126	0.261	-0.026	0.081
Green Rational Capital -> Environmental Knowledge -> Green-innovation (Indirect Effect)	0.536	0.039	13.917	0.000	0.459	0.608
Green Rational Capital -> Green-innovation (Total Effect)	0.568	0.038	14.937	0.000	0.489	0.635

Hypothesis testing (Moderate analysis learning orientation)

The results indicate that the moderating effect of learning orientation on the relationship between green human capital and environmental knowledge is negligible (0.017, p = 0.473). While the T-Statistics value (0.718) is less than 1, suggesting a weak effect, the p-value is above the significance threshold, indicating a lack of statistical significance. Similarly, for the moderating effect of learning orientation on the relationship between green rational capital and environmental knowledge, the effect is marginal and not statistically significant (-0.027, p = 0.249). The T-Statistics value (1.154) is slightly higher than 1, but the p-value is not low enough to support significance. Additionally, the moderating effect of learning orientation on the relationship between green structural capital and environmental knowledge is also minimal and lacks statistical significance (-0.013, p = 0.367). The T-Statistics value (0.902) falls below 1, suggesting a weak effect. Overall, these results suggest that learning orientation does not significantly moderate the relationships between green human capital, green rational capital, green structural capital, and environmental knowledge at ADNOC. The lack of statistical significance and the small effect sizes imply that learning orientation has a limited role in influencing these relationships. The organization's learning orientation may not substantially impact how green human capital, green rational capital, and green structural capital contribute to the development of environmental knowledge within the context of this study. It is essential to consider these findings cautiously when interpreting the role of Learning Orientation in moderating these specific relationships at ADNOC.

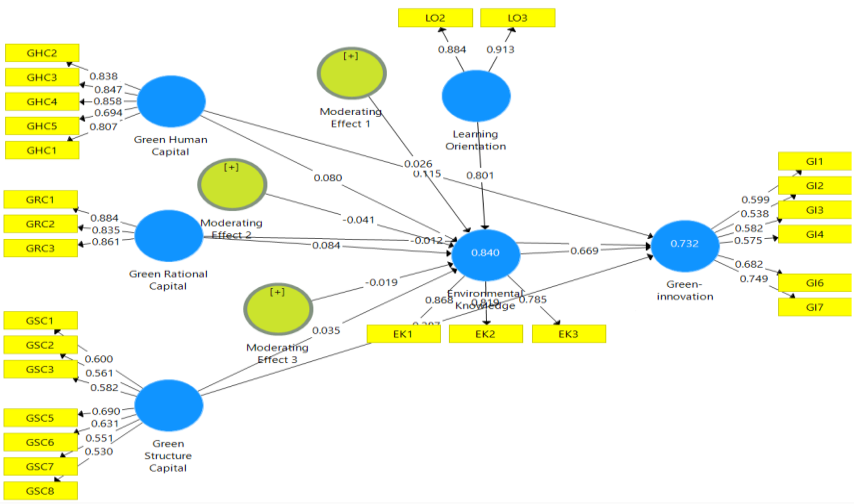

Figure 3 Measurement model with moderate analysis learning orientation

As shown in Table 7, this research investigates the influence of green intellectual capital (GIC) on eco-innovation, with a focus on the mediating role of environmental knowledge and the moderating effect of learning orientation, specifically within the UAE oil and gas industry. The key findings reveal that green human and structural capital significantly promote green innovation, while green relational capital does not. Additionally, green human and relational capital positively impact environmental knowledge, whereas green structural capital does not. Environmental knowledge partially mediates the relationship between green human capital and green innovation and fully mediates the relationship between green structural capital and green innovation. However, green learning outcomes do not significantly moderate the relationship between green human capital and green innovation.

DISCUSSION

By leveraging Green Intellectual Capital through a robust learning orientation and comprehensive environmental knowledge, the UAE petroleum industry can significantly contribute to green innovation. This alignment not only supports the country's ambitious sustainability goals but also ensures long-term competitiveness in a rapidly evolving energy landscape. With regard to the effects of GIC on GI, our research revealed that all three dimensions of GIC (GHC, GSC, and GRC) had significant positive relationships with GI. Specifically, GHC had a significant positive impact on GI, which is contrary to the finding of Subramaniam and Youndt (2005) but consistent with the research of Andersén (2021). Our conclusions about the positive impacts of GSC and GRC on GI are consistent with the results of Jirakraisiri et al. (2018). Thus, our findings reinforce the idea that GI relies on intangible elements such as employee skills and capabilities, process routines, and networking relations between the firm and its business partners related to environmental issues (Albort-Morant et al., 2018).

Green Intellectual Capital (GIC) represents the knowledge assets within an organization that focus on environmental sustainability. These assets, combined with a strong learning orientation and comprehensive environmental knowledge, serve as essential drivers for innovation, particularly in industries like petroleum that face high environmental scrutiny. The synergy among these elements fosters organizational resilience, adaptability, and sustainability in an increasingly eco-conscious global market. The alignment of Green Intellectual Capital with a robust learning orientation and comprehensive environmental knowledge is a strategic approach for achieving sustainable growth. For the UAE petroleum industry, this synergy can drive green innovation, reduce environmental impact, and position the sector as a global leader in sustainability. It underscores the importance of integrating human, structural, and relational capital with a commitment to learning and environmental stewardship.

CONCLUSION

This study aimed to investigate the influence of green intellectual capital (GIC) on eco-innovation in the UAE oil and gas industry, with a focus on the mediating role of environmental knowledge and the moderating effect of learning orientation. Through a rigorous analysis of data gathered via a questionnaire administered to employees in ADNOC, several key findings have emerged. The primary objective was to understand how GIC influences eco-innovation in the industry. The analysis revealed that green human and structural capital significantly promote eco-innovation, while green relational capital does not exhibit a significant impact. Additionally, the study explored the influence of GIC on environmental knowledge, finding that green human and relational capital positively affect environmental knowledge, whereas green structural capital does not. Moreover, the research investigated the mediating role of environmental knowledge in the relationship between GIC and eco-innovation. Environmental knowledge was found to partially mediate the relationship between green human capital and eco-innovation, while fully mediating the relationship between green structural capital and eco-innovation.

Theoretical and practical implications

The findings of this study significantly enrich the theoretical discourse, particularly within the Resource-Based View (RBV) and the broader literature on green intellectual capital and eco-innovation in developing countries, with a specific focus on the UAE's oil and gas sector. This study extends the RBV by incorporating green intellectual capital as a critical resource that fosters eco-innovation. The positive relationship between green human capital and green innovation reinforces the notion that the skills, knowledge, and environmental awareness of employees are vital assets. This supports the RBV framework by highlighting that green human capital is not only valuable and rare but also crucial for sustainable competitive advantage in the highly competitive and environmentally sensitive oil and gas industry.

This research offers several practical contributions for organizations in the UAE's oil and gas industry, particularly in fostering eco-innovation through the strategic use of green intellectual capital (GIC). Firstly, the study highlights the importance of investing in green human capital. By enhancing employees' environmental knowledge and skills, organizations can directly drive green innovation. This suggests that firms should implement targeted training programs and workshops to build this capability.

Secondly, the findings underscore the critical role of green structural capital, emphasizing the need for robust environmental policies and procedures. Companies like ADNOC should develop and implement comprehensive green policies that are well-communicated and understood by all employees. This can be achieved through regular training sessions and effective communication strategies.

The research also indicates that while green relational capital alone may not directly drive innovation, fostering strong external partnerships and knowledge-sharing mechanisms is essential. Organizations should engage in collaborative projects and establish formal partnerships to facilitate the effective transfer and integration of environmental knowledge.

Lastly, the lack of significant moderation by green learning outcomes suggests that firms need to focus on specific aspects of learning that align with their sustainability goals. Creating a supportive environment that encourages continuous learning, cross-functional collaboration, and the application of innovative practices can significantly enhance the impact of green intellectual capital on eco-innovation. Overall, these insights provide a roadmap for organizations aiming to achieve sustainability and innovation in the oil and gas sector.

Limitations and directions for future research

Despite the valuable insights provided by this research, several limitations should be acknowledged. Firstly, the study's focus on the UAE's oil and gas industry may limit the generalizability of the findings to other sectors or geographical regions. Additionally, the reliance on cross-sectional data may restrict the ability to establish causal relationships between variables. Longitudinal studies could offer more robust evidence of the dynamic relationships explored in this research. Furthermore, the measurement of constructs such as green intellectual capital, environmental knowledge, and eco-innovation may be subject to interpretation and measurement error. Future research could employ multiple methods and sources of data to enhance construct validity. Additionally, while the study examines the moderating role of green learning outcomes, other potential moderators, such as organizational culture or regulatory environment, could be explored in further detail.

Based on the findings and limitations of this research, several recommendations emerge for future studies and practical applications. Firstly, longitudinal research designs could provide more robust evidence of the causal relationships between green intellectual capital, environmental knowledge, and eco-innovation. Additionally, comparative studies across different industries and countries could offer valuable insights into the contextual factors influencing these relationships. Practically, organizations in the UAE's oil and gas sector should prioritize investments in employee training and development programs focused on environmental issues. Clear communication of green policies and procedures, along with mechanisms for knowledge sharing and collaboration, can enhance the utilization of green intellectual capital and drive eco-innovation. Moreover, fostering strategic partnerships with external stakeholders can facilitate the exchange of environmental knowledge and best practices, contributing to sustainable business practices in the industry. By integrating GIC with a robust learning orientation and environmental knowledge, the UAE petroleum industry can achieve a competitive edge in sustainable innovation while aligning with global environmental goals.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM), Institute of Technology Management and Entrepreneurship and RG SUITE for the direct and indirect contributions.

REFERENCES

1. Albeldawi, M., 2023. Environmental impacts and mitigation measures of offshore oil and gas activities. In Developments in Petroleum Science.
2. Albort-Morant, G., Leal-Millán, A., Cepeda-Carrión, G., and Henseler, J.2018. Developing green innovation performance by fostering of organizational knowledge and coopetitive relations. Rev. Manag. Sci. 12, 499–517.
3. Ali, W., Wen, J., Hussain, H., Khan, N.A., Younas, M.W., and Jamil, I., 2021. Does green intellectual capital matter for green innovation adoption? Evidence from the manufacturing SMEs of Pakistan. Journal of Intellectual Capital, 22(5), p. 868-888.
4. Andersén, J. (2021). A relational natural-resource-based view on product innovation: the influence of green product innovation and green suppliers on differentiation advantage in small manufacturing firms – ScienceDirect. Technovation 16, 1–9.
5. Asiaei, K., Bontis, N., Alizadeh, R., and Yaghoubi, M., 2022. Green intellectual capital and environmental management accounting: Natural resource orchestration in favor of environmental performance. Business Strategy and the Environment, 31(1), pp.76–93.
6. Azam, T., Songjiang, W., Jamil, K., Naseem, S., and Mohsin, M., 2022. Measuring green innovation through total quality management and corporate social responsibility within SMEs: green theory under the lens. TQM Journal, (202203).
7. Bai, X., Wang, K.T., Tran, T.K., Sadiq, M., Trung, L.M., and Khudoykulov, K., 2022. Measuring China's green economic recovery and energy environment sustainability: Econometric analysis of sustainable development goals. Economic Analysis and Policy, 75, pp.768–779.
8. Chau, K.Y., Lin, C.H., Tufail, B., Tran, T.K., Van, L., and Nguyen, T.T.H., 2023. Impact of eco-innovation and sustainable tourism growth on the environmental degradation: the case of China. Economic Research-Ekonomska Istrazivanja, 36(3), p.2150258.
9. Dat, T., Doan, T., Huan, M., Thu, T., Phan, H., and Lan, H., 2023. The impact of green intellectual capital on green innovation in Vietnamese textile and garment enterprises : mediate role of environmental knowledge and moderating impact of green social behavior and learning outcomes. Environmental Science and Pollution Research, (0123456789).
10. Dereń, A.M., and Skonieczny, J., 2022. Green Intellectual Property as a Strategic Resource in the Sustainable Development of an Organization. Sustainability (Switzerland), 14(8), p.4758.
11. Irfan, M., Razzaq, A., Sharif, A., and Yang, X., 2022. Influence mechanism between green finance and green innovation: Exploring regional policy intervention effects in China. Technological Forecasting and Social Change, 182(November 2021), p.121882.
12. Jirakraisiri, J., Badir, Y. F., Frank, B., and Salam, A. (2018). Green strategic intent and green process innovation performance: the role of intellectual capital. Aca
13. Joghee, S., Alzoubi, H.M., and Alshurideh, M., 2021. The Role of Business Intelligence Systems on Green Supply Chain Management : Empirical Analysis of FMCG in the UAE. In pringer International Publishing, pp. 539–552.
14. Kara, E., Akbaba, M., Yakut, E., Çetinel, M.H., and Pasli, M.M., 2023. The Mediating Effect of Green Human Resources Management on the Relationship between Organizational Sustainability and Innovative Behavior: An Application in Turkey. Sustainability (Switzerland).
15. Maldonado-Guzmán, G., and Pinzón-Castro, S.Y., 2022. Financial resources, eco-innovation and sustainability performance in the automotive industry. Tec Empresarial.
16. Moslehpour, M., Chau, K.Y., Tu, Y. Te, Nguyen, K.L., Barry, M., and Reddy, K.D., 2022. Impact of corporate sustainable practices, government initiative, technology usage, and organizational culture on automobile industry sustainable performance. Environmental Science and Pollution Research.
17. Munodawafa, R.T., and Johl, S.K., 2022. Measurement development for eco-innovation capabilities of Malaysian oil and gas firms. International Journal of Productivity and Performance Management, 71(8), pp.3443–3465.
18. Munodawafa, R.T., and Johl, S.K., 2022. Measurement development for eco-innovation capabilities of Malaysian oil and gas firms. International Journal of Productivity and Performance Management, 71(8), pp.3443–3465.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue IV April 2025

19. Nirino, N., Ferraris, A., Miglietta, N., and Invernizzi, A.C., 2022. Intellectual capital: the missing link in the corporate social responsibility–financial performance relationship. Journal of Intellectual Capital, 23(2), pp.420–438.
20. Quynh, M.P., Van, M.H., Le-dinh, T., Thai, T., and Nguyen, H., 2022. The role of climate fnance in achieving Cop26 goals: evidence from N-11 countries. Cuadernos De Economía, 45(128), pp.1–12.
21. Rennings, K., 2000. Redefining innovation — eco-innovation research and the contribution from ecological economics. Ecological Economics, 32(2), pp.319–332.
22. Subramaniam, M., and Youndt, M. A. (2005). The influence of intellectual capital on the types of innovative capabilities. Acad. Manag. J. 48, 450–463. d. Manag. Annu. Meet. Proc. 1:15825.
23. Waqar, A., Othman, I., Shafiq, N., and Mansoor, M.S., 2023. Applications of AI in oil and gas projects towards sustainable development: a systematic literature review. Artificial Intelligence Review.
24. Yong, J.Y., Yusliza, M.Y., Ramayah, T., and Fawehinmi, O., 2019. Nexus between green intellectual capital and green human resource management. Journal of Cleaner Production, 215, pp.364–374.
25. Zhang, Y.Q., Li, L., Sadiq, M., and Chien, F.S., 2023. The impact of non-renewable energy production and energy usage on carbon emissions: Evidence from China. Energy and Environment.
26. Zhao, L., Chau, K.Y., Tran, T.K., Sadiq, M., Xuyen, N.T.M., and Phan, T.T.H., 2022. Enhancing green economic recovery through green bonds financing and energy efficiency investments. Economic Analysis and Policy.