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Research

Educational paradigm shift: assessing the prospects of a master's course in green energy transition

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Abstract
This study examines the integration of emerging engineering technologies into STEM education with a focus on the green energy transition. Using a mixed-methods approach, including an international student survey conducted via Google Forms, the research identifies key factors influencing the demand for an innovative Master's program in Green Energy. Quantitative analysis through JASP software reveals a significant positive correlation between student interest in renewable energy related MSc courses and the perception of improved job opportunities in the green energy sector. Furthermore, the survey results indicate that students prioritize the inclusion of Mechanical, Electrical, and IT skills in the curriculum. Qualitative feedback highlights the critical need for practical skills in new research areas such as nanotechnology, quantum chemistry, Carbon capture, and Solar/Wind-based energy sources to meet the evolving demands of the green energy industry. These findings suggest that academic programs must be restructured to align more closely with the skills required for sustainable energy systems, thereby bridging the gap between academic preparation and market readiness.

Keywords Energy transition · Higher education · International students · Job opportunities · Renewable energy

1 Introduction

Since the twentieth century, the perception of executive education programmes has changed, with an emphasis on executive master's in business administration (EMBA) programs—the first of which was founded at Harvard in 1908—being the main focus. Specialized master's programmes that target fields like the Management of Technology (MoT), Technology Management (TM), and Engineering Management (EM) have been more popular over the past ten years in an effort to close the gap between business and technology [1]. There has been a notable upsurge in the creation of cutting-edge master's programmes outside the fields of traditional business and technology that are intended to address urgent global concerns, particularly those related to energy and sustainability. The need to give professionals the tools they need to deal with the complexity of energy transition and sustainability is highlighted by programmes like the Masters of Energy and Sustainability [2] and the partnership between the University of APEC (UNAPEC) and the University of Puerto Rico-Mayagüez (UPRM) for a Master's Programme on Sustainable Energy [3]. The necessity for a paradigm shift in educational offerings becomes increasingly apparent when considering the rapid growth of the renewable energy

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sector, catalyzed by the advent of Industry 4.0. As smart technologies, including artificial intelligence, Big Data, the Internet of Things, and augmented reality [4] become integral to the renewable energy landscape, there is a burgeoning need for educational programs that prepare individuals to harness these technologies effectively [5]. Furthermore, the intersection of industrial symbiosis (IS), energy efficiency (EE), and green economy policies within energy-intensive industries (EIIs) emphasizes the crucial connection between policy objectives and the skills needed for green jobs. This linkage, as proposed by [6], stresses the importance of aligning educational programs with evolving market demands, ensuring a skilled workforce capable of driving investment [7], technical innovation [8], economic diversification, and job creation. In their analysis of active learning for postgraduate students via online platforms, Lamon et al. discovered that deep learning requires careful scaffolding of online learning and that the effect of switching to online learning on commitment and performance should be taken into account, particularly when targeting less experienced students [9]. The learning materials and methods used in curricula and lectures must be modified to better convey knowledge to students in light of ever-changing circumstances, such as current business concerns and course content [10] for development of analytical thinking [11].

These days, a lot of students find mathematical modelling to be a difficult and complex assignment and struggle with its complexities. To solve energy engineering challenges metacognition is important. Hidayat et al. evaluated if the many sub-dimensions of metacognition can predict the sub-constructs of a student's true modelling ability [12]. The transformative nature of education in response to these challenges is underscored by the emergence of digitally connected and renewables-based energy systems, often referred to as 'Smart Local Energy Systems' [13] highlight the imperative to generate, supply, manage, and balance energy across all vectors, while concurrently delivering social, environmental, and economic benefits to local communities. Mechanical engineering is at the centre of the seismic shift towards renewable energy technologies. This discipline is essential since it leads innovation and plays a key role in creating a sustainable future. Mechanical engineering is at forefront in leading the way for the world's shift to renewable energy, as the information supplied makes clear. It is using its clout to maximise the possibilities of wind, solar, hydro, geothermal, and other renewable resources. In the context of the green energy transition, mechanical engineering's dedication to pushing the limits of design innovation is one of its main advantages. Optimization techniques, a cornerstone of mechanical engineering, further enhance the impact of this discipline in the realm of renewable energy. The importance of mechanical engineering is growing as the need for sustainable energy solutions around the world increases. It is not only a wise strategic choice, but also an absolute must to fund educational and training initiatives that provide participants with not only mechanical engineering but renewable energy fundamentals-based skills and knowledge for Industry 4.0. The development of a workforce capable of navigating the complex green energy transition environment and advancing global sustainability and resilience will be greatly aided by such programmes [14].

A recent study by Habek et al. [14] combined three prestigious universities in Europe to determine the sustainability-related subjects incorporated into mechanical engineering curricula. There is still an opportunity for improvement because not all Master's students from the three universities who completed their mechanical engineering degrees were exposed to sustainability subjects in one or more required courses. A retrospective evaluation of the course design for students enrolled in the new graduate-level course "Local Renewable Energy Policy Course" was carried out by researchers at the University of Michigan [15]. According to the findings, training students to lead on climate change requires more than just understanding why the climate is changing; it also entails giving them a thorough understanding of the complex and useful skill sets that graduates will likely need to fill in the types of leadership roles that will likely arise in the future. For graduate students, this begs the question of what technologies and skills the Next Wave of Energy Innovation will demand [16]. And, who else can write their opinions on such curriculum developments more effectively than they themselves?

There comes a point at which it becomes clear that a Master's Course in Green Energy Transition is necessary in the light of this changing educational landscape. Henceforth, this article aims to evaluate the program's prospects from the viewpoint of international students, assessing its capacity to address the multidimensional challenges posed by the global transition to sustainable and renewable energy sources. Undertaking a survey study is imperative for the initiation of a pioneering Master's level course focused on "Green Energy Transition". This investigative approach is grounded in the necessity to discern and respond to the diverse expectations, preferences, and academic needs of the prospective international student cohort. By engaging in a meticulous survey, authors endeavor to tailor the curriculum suggestions to the specific interests and career aspirations of the diverse demographic, thereby ensuring its direct relevance to their professional trajectory. The global perspective brought by international students is invaluable, with their varied cultural and educational backgrounds poised to enrich the discourse on green energy transition. In addition to assessing any perceived deficits in skills on the part of the students, the purpose of this survey is to optimize educational methods in order to create an inclusive pedagogical approach that caters to the varied learning preferences of the cohort. Information obtained from the survey will not just shape the program's design, but also strategically direct marketing strategies to appeal to a varied and skilled group of students. In its basic form, this survey acts as a compass to steer the development of a state-of-the-art academic programme that fulfils the demands of foreign students while also adding to the global conversation on creative and sustainable approaches in the field of green energy transition. The prime objectives of the study are:

- To Evaluate the level of interest among international students in enrolling in a Master's course specializing in green energy transition through statistical analysis.
- Identify and analyze potential emerging engineering technologies or interdisciplinary fields that will significantly influence the future of green energy transition.
- Gather insights that inform curriculum development by exploring the student's mindset and suggestions which could be crucial for mastering in green energy transition.

In pursuit of these objectives, the survey aims to establish a comprehensive understanding of international students' perspectives, enabling the Faculty of Mechanical Engineering and Informatics at the University of Miskolc to design and implement a master's program in green energy transition that not only meets but exceeds the expectations of its diverse and globally-oriented student body.

2 Overview of green energy in engineering education

The evolution of energy transition concepts within engineering curricula has been integral to preparing the future of engineering pedagogy and their contrivances presented by the shift towards sustainable and renewable energy sources [17] provides a comprehensive analysis of technological transitions, including energy transitions, from an evolutionary and reconfiguration perspective, highlighting the multi-level changes involving technology, user practices, regulation, industrial networks, infrastructure, and culture. This framework is critical for understanding how engineering education must adapt to incorporate these multidimensional aspects of energy transitions. In preparing a national-level representative questionnaire survey for Hungary, [18] looked at a variety of topics, including self-reported and actual knowledge, correlations between various energy sources, typical energy attitudes of different social groups, and characteristic stereotypes. There was an exceptional level of understanding regarding wind, solar, and hydropower, as well as a strong correlation between them. A consistent rise in engineering education for sustainability was found in a review study. The literature revealed four main conceptual themes: curriculum assessment and benchmarks, curriculum reform, engineering competencies, pedagogy, and curriculum, and sustainable technologies [19]. The review emphasizes how curricular reform must be ongoing in order to properly move engineering education towards sustainability [20].

Furthermore, the study by [21] on optimizing the complementarity between small hydropower plants and solar PV systems introduces engineering students to innovative approaches in renewable energy system design, emphasizing the importance of integrating various renewable resources for sustainable energy production and related skills. These concepts have become increasingly relevant in engineering curricula, reflecting the industry's move towards more diversified and sustainable energy solutions. This means that in order to educate engineering graduates about the fresh challenges they will face as practicing engineers, educators must update their courses and curriculum [22].

2.1 Global trends in green energy pedagogy at universities

Global trends and activities in green energy education at universities have been strongly impacted by the growing importance of renewable energy sources as a means of addressing the interrelated problems of climate change, energy poverty, and sustainable development. In order to equip the upcoming generation of professionals to address these intricate difficulties, there is now a greater emphasis on integrating renewable energy into academic curricula and research agendas as a result of this shift in focus. [23] highlight the critical role that renewable energy plays in the global energy transition in a seminal work that clarifies the technical and economic aspects of a faster energy transition and the interdependent relationships between renewable energy and energy efficiency. Measurements of the knowledge and awareness of Indonesian VHS (Vocational High School) students were conducted by Muslim et al. [24]. Based on factors including gender, parents, the island, public versus private schools, and the VHS's areas of specialisation, the knowledge and awareness level of the children is thoroughly examined. The findings indicate that VHS students now have awareness levels in the "fair" category and a knowledge level in the "good" category regarding renewable energy. In another attempt at the university level, [25] conducted a comparison of various Canadian programmes, such as the Energy Programme at the University of Toronto, the Sustainable and Renewable Energy Engineering Degree at Carleton University, the Electrical Energy Systems Option at the University of British Columbia, and the Energy and Environment Specialisation at the University of Calgary. to assess each program's contribution to the development of the "T-shaped" engineer using a multicriteria framework intended to gauge learning objectives. The programme comparison demonstrates that there is a great deal of opportunity and design flexibility when it comes to incorporating sustainable energy systems thinking into energy engineering education, despite the enormous constraints placed on active curriculum development, such as accreditation requirements, budgets, and faculty availability. According to a Polish study by I. Ocetkiewicz et al., [26] very few Polish instructors were able to include lessons on green energy in their curriculum. It's unclear how and to what degree educators wish to incorporate sustainable consumption issues into their curricula. While it is important for the future of the global energy economy concerns, the study draws attention to these challenges in the curricula. It is also suggested that teachers be informed about the appropriate work methods and formats, software for knowledge, and ways to incorporate the subject matter into the curricula.

However, it's not as adequately reflected in the discussions on the transformation of the traditional curricula in the pedagogy of engineering that such discussions and research, reflect the increasing emphasis on renewable energy topics within engineering and are coherent with the policies supporting the United Nations (UN) sustainable development goals which are critical in shaping future jobs for Industry 4.0. Moreover, the global renewable energy development analysis by [27] sheds light on the political, technical, economic, and social perspectives influencing renewable energy policy and development across different regions. Such analyses are crucial for educational institutions aiming to prepare students for the global energy market's complexities, emphasizing the need for a comprehensive understanding of the factors driving renewable energy adoption. To equip students with skills that govern future industrial innovation and growth. The integration of green energy topics into engineering pedagogy is nothing but a response to the energy sector's dynamic evolution, driven by technological advancements, policy shifts, and the global push for sustainability. Engineering curricula are increasingly incorporating these multidisciplinary aspects, preparing graduates to contribute effectively to the energy transition. The subsequent section discusses the local developments in Europe.

2.2 Initiatives in Europe

The European Commission urges EU member states to prioritize education for the green transition and sustainable development and supports the teaching of renewable energy at European institutions. In addition to publishing the European Competence Framework on Sustainability (GreenComp) (https://green-comp.eu/), which outlines the knowledge, abilities, and attitudes that students of all ages must develop in order to make the transition to a greener economy, the Commission maintains a specialized working group on sustainability in education. The EU's Erasmus +, Horizon Europe, and other financing programmes offer financial support. For elementary and secondary schools, the Commission also offers free educational resources on energy, the environment, and climate change as listed in Table 1**.** On the other hand, no precise information about the European Commission's position on renewable energy education in European universities is available [28].

The European Union has initiated several programs and frameworks to foster the integration of sustainability and environmental consciousness into the educational landscape. Among these, the Education for Climate Coalition stands out as a growing network comprising educators, students, and organizations dedicated to environmental sustainability and climate change. This coalition plays a pivotal role in networking [29], allowing for the exchange of ideas, resources, and best practices among its participants. Complementing this, the Council Recommendation on learning for the "Green Transition" and sustainable development assists educational entities to weave sustainability into their curricula, emphasizing training [30] as a core component. This recommendation underscores the necessity for educators to develop and implement sustainability-focused training and education programs.

The European sustainability competence framework delineates the necessary mindsets, expertise, and skills for learners of all ages, aiming at competence development [31]. It is a guide for educational institutions to mold individuals who can contribute effectively to the green economy. Meanwhile, the working group on vocational education and training and the green transition (VET) focuses on generating valuable communications and inputs for policy formation, targeting higher education and vocational training [32]. It addresses sustainability and green transition as critical components of vocational education and training. The Erasmus + and European Solidarity Corps program bolsters these efforts by

Table 1 European initiatives to promote the transition of green education

EU initiatives	Framework	Role	References
Education for Climate Coalition	This is an expanding network of educators, students, and organisations working on environmental sustainability and climate change	Networking	[29]
Council Recommendation on learning for the green transition and sustainable development	This organisation helps its members incorporate sustainability into their training and education programmes	Training	[30]
European sustainability competence framework	This framework lays forth the mindsets, expertise, and skills that students of all ages must develop in order to make the shift to a greener economy	Competence development	[31]
Working Group on vocational education and training and the green transition (VET)	Important communications and input documents are regularly produced by this body. Sustainability and the green transition are other topics covered by the working groups on adult learning, higher education, and vocational education and training	Higher education and vocational training	[32]
Erasmus + and European Solidarity Corps	It supports a range of efforts pertaining to sustainability in training and education, such as staff and student exchanges, research, and volunteer work	Staff, student exchange and mobility	[33]
Invest-EU programme	This body makes it possible for Member States to obtain funds for skill development and sustainable educational infrastructure	Funding	[34]
Researchers at Schools initiative	Facilitates the discussion of climate change and sustainable development among educators and students and young researchers	Research activities	[35]
Erasmus + DiscoverEU Green route	They inspire young people to plan and discover Europe in a sustainable way	Exploration	[36]
EU Learning Corner	It offers primary and secondary schools instructional materials on climate change, sustainability, and environmental crises	Primary learning	[37]

supporting a variety of initiatives related to sustainability in training and education. This includes staff and student exchanges, research, and volunteer work, thereby enhancing staff, student exchange, and mobility [33]. To facilitate the financial aspects of these educational reforms, the Invest-EU programme provides a funding mechanism [34] that enables Member States to secure funds for skill development and to build sustainable educational infrastructures. The "Researchers at Schools" initiative opens up avenues for research activities [35], where discussions on climate change and sustainable development can take place directly in the educational setting, involving educators, students, and young researchers in the conversation. The Erasmus + Discover-EU Green route aims to inspire young individuals to explore [36] and plan their travels with a consciousness towards sustainability, thereby promoting a greener way to discover Europe. Lastly, the EU Learning Corner offers primary and secondary schools a repository of instructional materials on climate change, sustainability, and environmental crises, targeting primary learning [37].

Assessing these initiatives, it is evident that the EU is taking a comprehensive approach to integrate green education across various levels and sectors. These programs collectively establish a robust framework for educators and learners to engage with sustainability and environmental issues. These EU initiatives collectively provide a rich ecosystem of resources, frameworks, and opportunities that can be leveraged by universities and engineering departments to develop comprehensive and cutting-edge courses on green energy transition, equipping students with the necessary knowledge and skills for the sustainable energy sector.

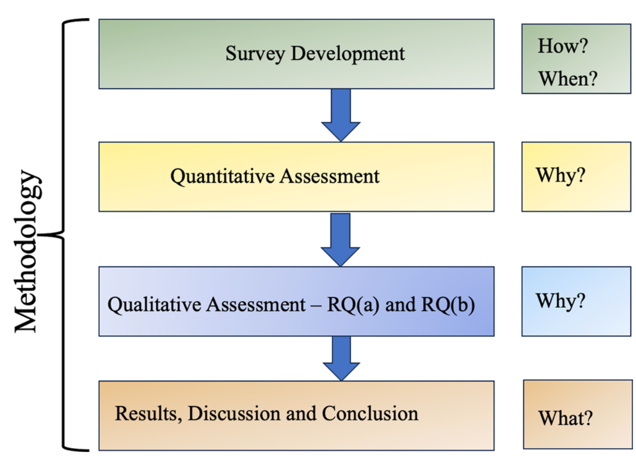
3 Methodology

The Fig. 1 illustrates the methodological framework employed in the study, structured as a logical flowchart that delineates the sequence and rationale of the research survey process. At the top, "Survey Development" is the initial phase where the research instruments are designed. The queries "How?" and "When?" adjacent to this phase suggest that this section details the procedural and temporal aspects of the survey—how the survey was created and when it was distributed.

Following this, the "Quantitative Assessment" phase likely involves statistical analysis of the collected data, with the question "Why?" indicating a need to justify the use of quantitative methods. This could mean explaining the rationale for the selection of certain statistical tests or metrics used in evaluating the survey data. The subsequent phase, "Qualitative Assessment – RQ(a) and RQ(b)," implies a deeper analysis of open-ended survey responses pertaining to two specific research questions (a and b). The accompanying "Why?" suggests this section elaborates on the reasons for employing qualitative analysis, possibly to understand the context and nuances behind the quantitative data or to explore themes that numbers alone cannot elucidate.

At the bottom, "Results, Discussion, and Conclusion" is the final phase where the outcomes of both assessments are presented, and their implications are discussed. The "What?" question indicates that this section should summarize the findings (what the study found), discuss their significance, and provide a concluding synthesis that encapsulates the entire research process and its contributions to the field.

Fig. 1 Methodology adopted for the study



3.1 Survey development and rationale

In addition to collecting helpful feedback for improving a proposed Master's course in green energy transition, the survey instrument was painstakingly designed to capture a wide range of insights on emerging engineering technologies and interdisciplinary fields that are expected to significantly influence the future of green energy transition. Recognizing the pivotal role of diverse perspectives in shaping comprehensive and inclusive educational programs, the survey was developed using Google Forms for its accessibility, ease of use, and widespread acceptance, ensuring a user-friendly interface for participants across the globe. Comprising 17 carefully crafted questions, the survey was structured to assess a variety of dimensions, including demographic diversity, educational backgrounds, and specific insights related to the green energy sector around 107 students took part. The questions were framed to gather detailed information on the participants' home country, gender, level of education, and field of study. The purpose of gathering this demographic data was to guarantee that a diverse range of international students were represented, adding a wealth of viewpoints and experiences to the data. The survey data collection was done in January 2024 with one month time period, to allow ample time for participants to provide thoughtful and reflective responses.

The awareness that the switch to green energy is a worldwide challenge requiring creative solutions and interdisciplinary methods forms the basis for the survey's development. The survey seeks to identify new pedagogical approaches, technology, and trends that are applicable to various geographical locations and educational situations by leveraging the perspectives of foreign students. This method promotes inclusivity while guaranteeing that the course material stays up to date with educational and technological developments in the sphere of the transition to green energy.

3.2 Quantitative assessment

Surveys that consider Likert-based questions generally are considered as ordinal data, hence, for our survey quantitative assessment, it was adequate to use non-parametric tests such as Spearman's rho or Kendall's tau for correlation analysis. JASP software (https://jasp-stats.org/) offers both frequentist and Bayesian inference on the same statistical models, including descriptive, T-Tests, ANOVA, Mixed Models, Regression, Frequencies, Factors, and many others. Therefore, for Likert survey results, non-parametric tests such as Spearman's rho or Kendall's tau can be used in JASP for correlation analysis. In this assessment, we evaluated the Correlation coefficients using Pearson's r, Spearman's rho, and Kendall's Tau B, along with their associated p-values.

The survey questions were coded to enable statistical analysis by categorizing responses into quantifiable data. Each question and its corresponding options were assigned numerical values or labels. For instance, Likert scale responses ("Strongly Disagree" to "Strongly Agree") were coded from 1 to 5. Multiple-choice questions with categorical responses were also numerically coded ("One Year" = 1, "Two Year" = 2). These codings facilitated the use of statistical software (JASP) for quantitative analysis, allowing us to compute correlations, descriptive statistics, and other analyses to interpret the data effectively.

Table 2**.** presents a structured overview of survey questions and their corresponding answer options designed to gather data on perceptions of the green energy transition and related educational programs. It includes questions on the importance of emerging technologies for future careers, interest in Master's programs in Green Energy, preferred program duration, crucial skills for the green energy industry, preferred learning approaches, influencing factors for pursuing advanced education, potential barriers, and the relevance of different engineering fields. The coded responses facilitate quantitative analysis, allowing for the extraction of meaningful insights through statistical software. This enables the assessment of trends, correlations, and overall attitudes towards the green energy sector among international students.

In this study, we tested the relationships between several variables related to students' perceptions of new Master's courses in green energy. To do this, we employed statistical correlation analyses, which involve assessing whether there is a significant relationship between these variables. The foundation of this analysis is the null hypothesis, which posits that there is no significant correlation between the variables—in other words, that any observed relationships are due to random chance rather than a true underlying association.

The relevance of the null hypothesis in this study is crucial. By comparing the observed correlation coefficients to this null hypothesis, we can determine whether the relationships we observe in the data are statistically significant.

Table 2 A structured overview of survey questions related to quantitative analyses and their corresponding options

Dimensions	Question	Options
Future career	The transition from conventional energy to renewable energy technology will change the future career prospects for engineering graduates. What is your opinion?	- Strongly Disagree—Disagree—Neutral—Agree—Strongly Agree
Job opportunity	An exclusive master-level diploma in the green energy transition will be really helpful for job seekers in the energy sector. your opinion?	- Strongly Disagree—Disagree—Neutral—Agree—Strongly Agree
Importance	What should be the ideal duration of an executive master's program for international students?	- One Year—Two Year
Interest	How interested are you in pursuing an Executive Master's course in Green Energy Transition?	- Not Interested at All—1—2—3—4—5—Extremely Interested
Job opportunity	Which of the following skills do you believe are crucial for professionals in the field of green energy industry?	- Knowledge of Mechanical and Electrical energy optimization—Engineering Designing and Simulation—Project Management—Computer programming knowledge—Basic physics and chemistry involved in renewable energy generation
Interest	For the executive master's program, Do you prefer a theoretical or practical approach to learning?	- Classroom learning—Project-based practical learning
Future career	What factors might influence the decision to pursue a Master's course in Green Energy Transition for international students?	- Program Reputation—Course Content—Faculty Expertise—Career Opportunities
Future career	What potential barriers do you foresee in pursuing a Master's course in Green Energy Transition?	- Financial Constraints—Lack of Previous Knowledge—Language Barriers—Other…
Interest	In your opinion, which engineering field do you believe holds the highest relevance to the successful implementation of the green energy transition?	- Knowledge of Mechanical/Electrical/IT Engineering—Knowledge of Materials—Knowledge of Biology and Ecology—Knowledge of Mining
Importance	How important do you think Mechanical/Electrical/Computer science engineering is in ensuring the successful implementation of green energy transition projects across different engineering fields?	- Not important at all—1—2—3—4—5—6—7—8—9—10—Very important
Importance	Given a chance, would you consider having training on subjects from the green energy transition course as part of your master's program course? If yes, What percentage of the coursework should be from energy technology course?	- 20%—40%—60%—Not at all

A lower p-value indicates stronger evidence against the null hypothesis, suggesting that the correlations we observe are unlikely to have occurred by chance and are more likely indicative of real, meaningful relationships. Testing against the null hypothesis thus allows us to validate our findings and draw more reliable conclusions about the factors influencing student interest in green energy education.

3.3 Qualitative assessment

Emerging developments like carbon capture and storage, floating offshore wind farms, decentralised energy systems, nanotechnology, etc., bode well for the future of renewable energy technologies [38]. Review studies indicate that the engineering community must comprehend the developments in renewable technology. But it wouldn't be feasible without considering what today's students think and suggest about these developing fields. A few case studies that have been conducted on students from a variety of areas to get their view on the adoption of renewable energy courses while taking students' suggestions into consideration have inspired the study's second research topic. Students from backgrounds in agriculture (Iran)[39], economies (Poland)[40], vocational education (Indonesia) [41], etc. are some examples. Giving us justification to take this point of view into account in our evaluation. Henceforth, the survey consisted of two open-ended questions to encourage detailed, qualitative responses, allowing participants to express their views freely on the subjects of emerging technologies and course improvements. These questions were:

RQ(a): Are there any emerging engineering technologies or interdisciplinary fields that you believe will significantly influence the future of green energy transition?

RQ(b): Any suggestions for improving the proposed Master's course in Green Energy Transition?

The approach used to examine the answers to these open-ended questions is based on thematic analysis, a versatile technique for finding, examining, and summarising patterns (themes) in the survey data that has been gathered. The authors chose the Thematic analysis for its feasibility in exploring the perspectives of international students across a diverse dataset, allowing for the in-depth exploration of participants' thoughts and opinions on emerging technologies and educational improvements.

The qualitative analysis commenced with a comprehensive review of all survey responses, ensuring a deep understanding of the participants' insights into emerging engineering technologies and course improvement suggestions. This initial familiarization phase was crucial for grasping the responses' depth and complexity. Following this, the coding process involved meticulously labeling segments of text to highlight relevant information, with the codes refined through an iterative process as new patterns emerged. These codes were then organized into themes that accurately reflected the data's core aspects, with specific technologies and interdisciplinary fields identified for RQ(a), and pedagogical suggestions for RQ(b). A thorough review of these themes ensured their validity and alignment with the dataset. Each theme was carefully defined and named to encapsulate the data's essence succinctly. The final phase involved synthesizing the findings into a coherent analysis, linking the identified themes to the research questions, and situating them within the broader scientific literature. This streamlined approach allowed for a focused and efficient analysis, yielding meaningful insights into the subjects at hand.

This methodology provides a structured yet flexible approach to qualitative analysis, enabling a deep dive into the perspectives of individuals within the STEM community on crucial topics. By systematically organizing and interpreting the survey responses, this approach facilitates a comprehensive understanding of the collective vision for the future of green energy transition and education.

4 Results

4.1 Background information

The survey attracted predominantly male participants with a strong representation of engineering and earth sciences, hailing from diverse geographic locations. The academic level of the participants span from bachelor's degree to doctoral degree level, indicating a breadth of academic engagement in the topic of green energy transition. A total of 107 students filled the survey coming from various faculties with a response rate of 53.5%.

Figure 2 presents a graphical summary of the demographic and academic background of participants in a survey designed to gauge student perspectives on master's level courses in the field of green energy transition. The survey results are depicted through four distinct parts labelled (a) through (d).

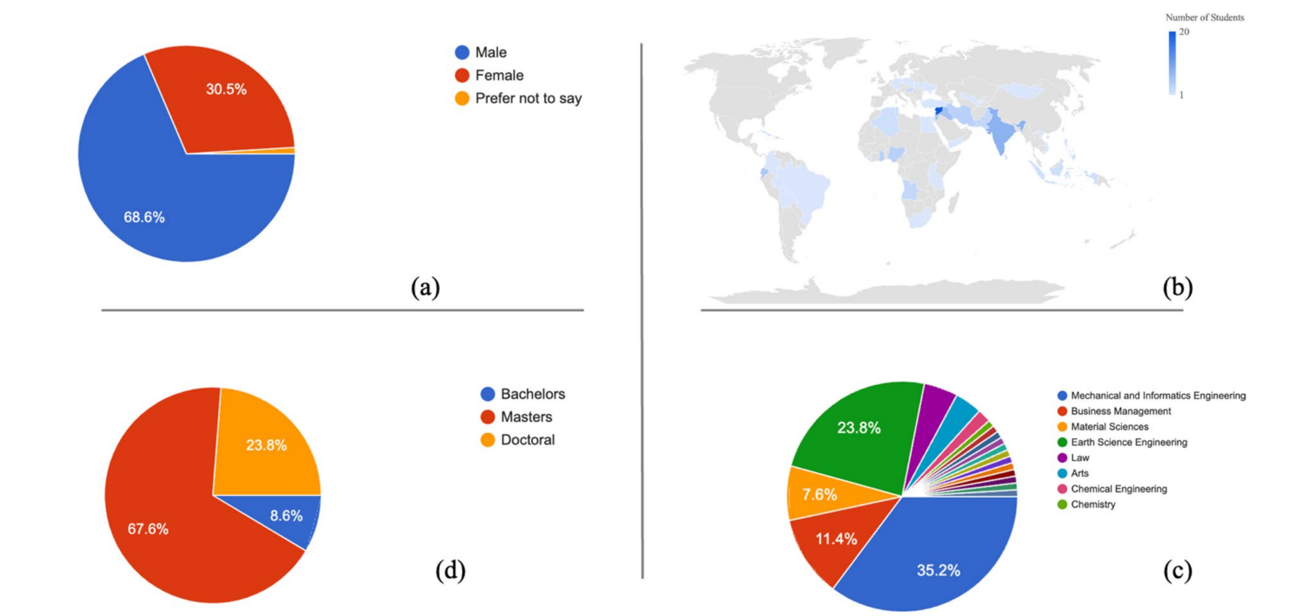


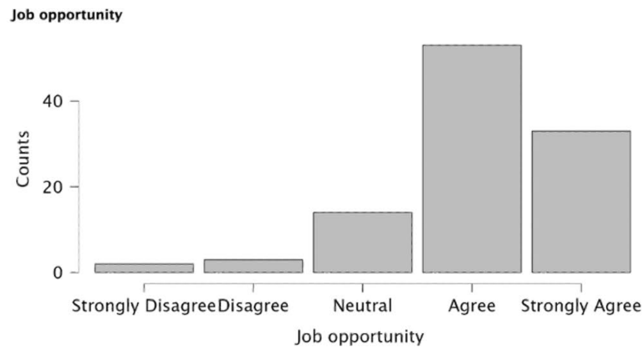
Fig. 2 Representation of demographic diversification of student respondents

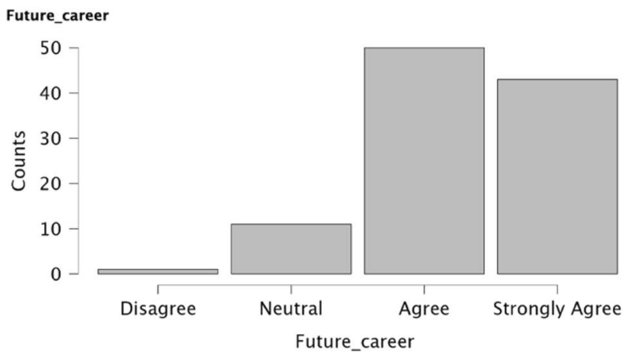
(a) The first chart is a pie chart indicating the gender distribution of the survey respondents. The majority, at 68.6%, are male, followed by 30.5% female, and a small fraction, 1%, choosing not to disclose their gender.
(b) Next to this pie chart is a world map, indicating the global distribution of the participants, with varying shades of blue representing the concentration of students from different regions. With the highest participation from Middle Eastern countries followed by South Asia.
(c) The third element of Fig. 2 is a multi-colored pie chart detailing the academic disciplines of the respondents. A significant portion of the respondents, 35.2%, come from the field of Mechanical and Informatics Engineering, which is likely relevant due to the mechanical aspects of energy systems. Earth Science students make up 23.9%, indicating a strong representation from a field directly concerned with the environmental impact of energy production. Other fields include Business Management (11.4%), Material science (7.6%), and smaller percentages from fields such as Law, Chemical Engineering, and Chemistry. This diverse disciplinary representation suggests a comprehensive interest in green energy across various sectors of academia.
(d) The last chart is another pie chart displaying the highest degree obtained by the respondents. The majority, 67.6%, are from a Master's degree program, while 23.6% are pursuing a Doctoral degree, and 8.6% are from a Bachelor's level of studies. This distribution underscores the involvement of both early-career and advanced scholars in the green energy transition topic, reflecting a range of insights and experiences pertinent to master's level education.

4.2 Quantitative findings

4.2.1 Future career prospects and job expectations

The amount of higher education courses offered in comparison to the industry's strong demand for practical training indicates that there is a mismatch between the given education and the demand for competent people in general [42]. The quantitative assessment of the survey responses, focusing on "Future Career" prospects and "Job Opportunities," provides insightful data on the participants' perceptions regarding their educational experience and potential employability post-graduation. The data is depicted through histogram graphs and is complemented by descriptive statistics and frequency distributions. The histogram presented in Fig. 3. for "Future Career" indicates that the majority of participants feel positively about their career prospects after completing their education. With the responses of participants falling in the 'Agree' category and a significant number in 'Strongly Agree', it is evident that the sentiment is generally optimistic. The descriptive statistics support this, showing a high mean score of 8.571 out of 10, which signifies a strong positive perception. The standard deviation of 1.379 suggests that responses are relatively consistent and there is limited variability in the participants' confidence regarding their future career prospects.





Descriptive Statistics

	Future_career	Job opportunity
Valid	105	105
Missing	0	0
Mean	8.571	8.133
Std. Deviation	1.379	1.716
Minimum	4.000	2.000
Maximum	10.000	10.000

Frequencies for Future_career

Future_career	Frequency	Percent	Valid Percent	Cumulative Percent
Disagree	1	0.952	0.952	0.952
Neutral	11	10.476	10.476	11.429
Agree	50	47.619	47.619	59.048
Strongly Agree	43	40.952	40.952	100.000
Missing	0	0.000		
Total	105	100.000		

Frequencies for Job opportunity

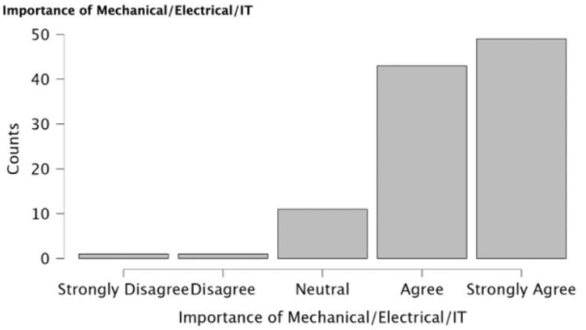
Job opportunity	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly Disagree	2	1.905	1.905	1.905
Disagree	3	2.857	2.857	4.762
Neutral	14	13.333	13.333	18.095
Agree	53	50.476	50.476	68.571
Strongly Agree	33	31.429	31.429	100.000
Missing	0	0.000		
Total	105	100.000		

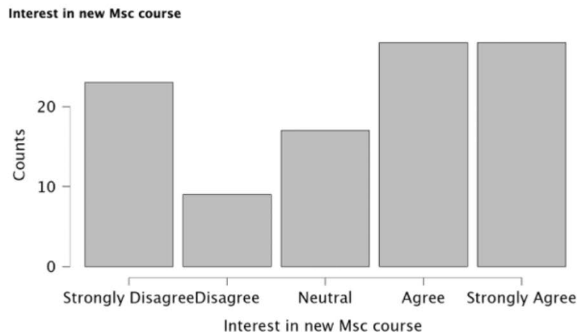
Fig. 3 Student's opinion on future career prospects and job expectations in context with the master's course

In the "Job Opportunities" category, the histogram reveals a similar positive trend, with the majority of participants agreeing or strongly agreeing that their education will yield job opportunities. The mean score here is slightly lower at 8.133, with a higher standard deviation of 1.716, which indicates a somewhat wider spread of opinions compared to the "Future Career" prospects. This wider spread suggests that while optimism is prevalent, there is more variation in participants' certainty regarding the direct translation of their education into job opportunities. A comparative analysis of the two histograms shows that students are slightly more confident in their general "Future Career" prospects than in the specific "Job Opportunities" available to them post-graduation. This distinction could reflect an understanding that while career opportunities in their field may be abundant, the immediate availability of jobs post-study may not be as certain. The frequency distributions provide additional context to the histograms, with "Future Career" showing a strong concentration of responses in the 'Agree' and 'Strongly Agree' categories, accounting for over 90% of the responses. "Job Opportunities" displays a similar pattern, with these positive categories comprising approximately 85% of responses. It is noteworthy that very few respondents disagreed or strongly disagreed with the positive statements about their future career and job prospects, indicating a general consensus of positive outcomes from their education.

4.2.2 Importance and interest in engineering aspects

The quantitative assessment further explores students' opinions on the significance of Mechanical, Electrical, and IT (Information Technology) subjects in a Master's course and their overall interest in a new MSc (Master of Science) program. The histogram depicted in Fig. 4 the "Importance of Mechanical/Electrical/IT" shows a substantial number of participants recognizing the importance of these subjects, with a dominant number of respondents in the 'Strongly Agree' category. This indicates a significant acknowledgment of the relevance of Mechanical, Electrical, and IT disciplines within the Master's curriculum. The descriptive statistics corroborate this with a high mean value of 8.952 out of 10, which signals a strong positive acknowledgment of these disciplines' importance. The relatively low standard deviation of 0.774 points to a consistent agreement among participants regarding this view. Regarding the "Interest in New MSc Course," the histogram displays a more evenly distributed set of student's responses, with the majority of participants agreeing or strongly agreeing, yet with a notable number of neutral responses. This suggests that while there is a general interest in the new MSc course, there is also a significant level of uncertainty or ambivalence among the students. The mean score





Descriptive Statistics

	Interest in new Msc course	Importance of Mechanical/Electrical/IT
Valid	105	105
Missing	0	0
Mean	6.552	4.314
Std. Deviation	2.994	0.776
Minimum	2.000	1.000
Maximum	10.000	5.000

Frequencies for Interest in new Msc course

Interest in new Msc course	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly Disagree	23	21.905	21.905	21.905
Disagree	9	8.571	8.571	30.476
Neutral	17	16.190	16.190	46.667
Agree	28	26.667	26.667	73.333
Strongly Agree	28	26.667	26.667	100.000
Missing	0	0.000		
Total	105	100.000		

Frequencies for Importance of Mechanical/Electrical/IT

Importance of Mechanical/Electrical/IT	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly Disagree	1	0.952	0.952	0.952
Disagree	1	0.952	0.952	1.905
Neutral	11	10.476	10.476	12.381
Agree	43	40.952	40.952	53.333
Strongly Agree	49	46.667	46.667	100.000
Missing	0	0.000		
Total	105	100.000		

Fig. 4 Student's opinion on the importance of Mechanical/Electrical/IT in the master's course and their general interest in the course

of 6.952 indicates a moderate level of interest, with a relatively higher standard deviation of 2.594 suggesting greater variability in participants' interest levels compared to their views on the importance of Mechanical/Electrical/IT subjects.

Comparing the two histograms, it is evident that students show a stronger consensus on the importance of Mechanical, Electrical, and IT subjects in the Master's course than their interest in the new MSc course. This could reflect a scenario where students recognize the value of these subjects but may need additional information or motivation to commit to a new MSc program. The frequency distributions for both parameters further detail these perceptions. For the "Importance of Mechanical/Electrical/IT," the distribution is heavily skewed towards agreement, with approximately 94% of participants rating this as 'Agree' or 'Strongly Agree.' In contrast, the "Interest in New MSc Course" responses are more varied, with 'Agree' and 'Strongly Agree' making up about 73% of the responses, but with a substantial proportion of participants remaining neutral.

4.3 Correlation study

The provided correlation is in Fig. 5 summarizes the results of a survey investigating students' opinions on new master's level courses in green energy. It looks at the relationships between four different variables: future career, job opportunity, interest in the new MSc course, and the importance of Mechanical/Electrical/IT. The use of Spearman's rho, Kendall's Tau B, and Pearson's r together, despite similar coefficients, is justified by their distinct purposes and underlying assumptions. Pearson's r measures linear relationships between variables assuming normally distributed data. In contrast, Spearman's rho and Kendall's Tau B assess monotonic relationships, suitable for ordinal data or non-parametric distributions. Including all three metrics provides a comprehensive view, ensuring robustness and validity in various data conditions, thereby enhancing the reliability and interpretability of the results. This triangulation approach helps to confirm findings across different statistical assumptions and methodologies.

- From the results of the assessment as shown in the Fig. 5 we infer that:
- Future career: There are no correlation values present in this row because it has been used as a reference or control variable.
- Job opportunity: According to Pearson's $r = 0.341$, $p < 0.001$, the first parameter, which represents students' perceptions of job opportunities after completing the new master's course, has a moderately positive correlation with the interest in new MSc courses. This suggests that as perceived job opportunities rise, so does interest in new MSc courses. This

Variable		Future_career	Job opportunity	Interest in new Msc course	Importance of Mechanical/Electrical/IT
1. Future_career	Pearson's r	—			
	p-value	—			
	Spearman's rho	—			
	p-value	—			
	Kendall's Tau B	—			
	p-value	—			
2. Job opportunity	Pearson's r	0.341	—		
	p-value	< .001	—		
	Spearman's rho	0.374	—		
	p-value	< .001	—		
	Kendall's Tau B	0.347	—		
	p-value	< .001	—		
3. Interest in new Msc course	Pearson's r	0.268	0.495	—	
	p-value	0.006	< .001	—	
	Spearman's rho	0.261	0.492	—	
	p-value	0.007	< .001	—	
	Kendall's Tau B	0.230	0.438	—	
	p-value	0.007	< .001	—	
4. Importance of Mechanical/Electrical/IT	Pearson's r	0.010	0.156	0.107	—
	p-value	0.917	0.112	0.279	—
	Spearman's rho	−0.002	0.137	0.061	—
	p-value	0.982	0.165	0.535	—
	Kendall's Tau B	−0.002	0.125	0.056	—
	p-value	0.979	0.157	0.507	—

Fig. 5 Correlation coefficients are calculated using Pearson's r, Spearman's rho, and Kendall's Tau B, along with their associated p-values

holds true for both Kendall's Tau B and Spearman's rho, and all p-values are significant ($p < 0.001$), indicating a strong association.

- Interest in new MSc course:Shows a moderate positive correlation with job opportunity (Pearson's $r = 0.495$, $p < 0.001$), which is the strongest observed correlation in this table. This suggests a strong relationship where an increased interest in new MSc courses is associated with the perception of better job opportunities. There's also a positive correlation with the importance of Mechanical/Electrical/IT (Pearson's $r = 0.268$, $p = 0.006$), indicating that students who find these fields important are more likely to be interested in new MSc courses related to green energy.
- Importance of Mechanical/Electrical/IT: It does not show significant correlations with future career, job opportunity, or interest in new MSc course as per Pearson's r and Kendall's Tau B, except for a very weak correlation with interest in new MSc course which is statistically significant (Kendall's Tau $B = 0.230$, $p = 0.007$). However, these low correlation values, coupled with non-significant p-values in Pearson's r, suggest that there is no strong evidence to claim a meaningful relationship between these fields' importance and the other variables. The p-values show that these results are statistically significant and unlikely to be the result of chance because they are all below the standard alpha threshold of 0.05. It's crucial to remember that correlation does not indicate causation, thus these findings should be understood as demonstrating relationships as opposed to direct impacts.

The correlation plot is a matrix of scatter plots where each cell represents the relationship between two variables. The diagonal histograms show the distribution of each variable. Above the diagonal in Fig. 6, the Pearson's r correlation coefficient is provided along with its significance level, while below the diagonal, there's information on the correlation's p-value and t-test result based on analysis in JASP software heat map plot. The significance values indicate how likely it is that the observed correlation occurred by chance, with a lower p-value indicating a shred of stronger evidence against the null hypothesis of no correlation.

Figure 6 provides a heatmap that visually represents the strength and direction of these correlations. In this heatmap, color intensity indicates the strength of the relationship: darker colors represent stronger correlations, while lighter colors indicate weaker ones. The heatmap also shows whether the correlations are positive (blue) or negative (red). This visual representation helps to quickly identify which relationships are most significant.

4.4 Qualitative findings

The results are assessed through the lens of their relevance to the research questions, the coherence of the identified themes, and their implications for the future of STEM education and the green energy transition. The analysis not only highlights the specific technologies and interdisciplinary fields seen as pivotal by the STEM community but also provides actionable insights into how a Master's course in Green Energy Transition can be improved to meet the evolving needs of

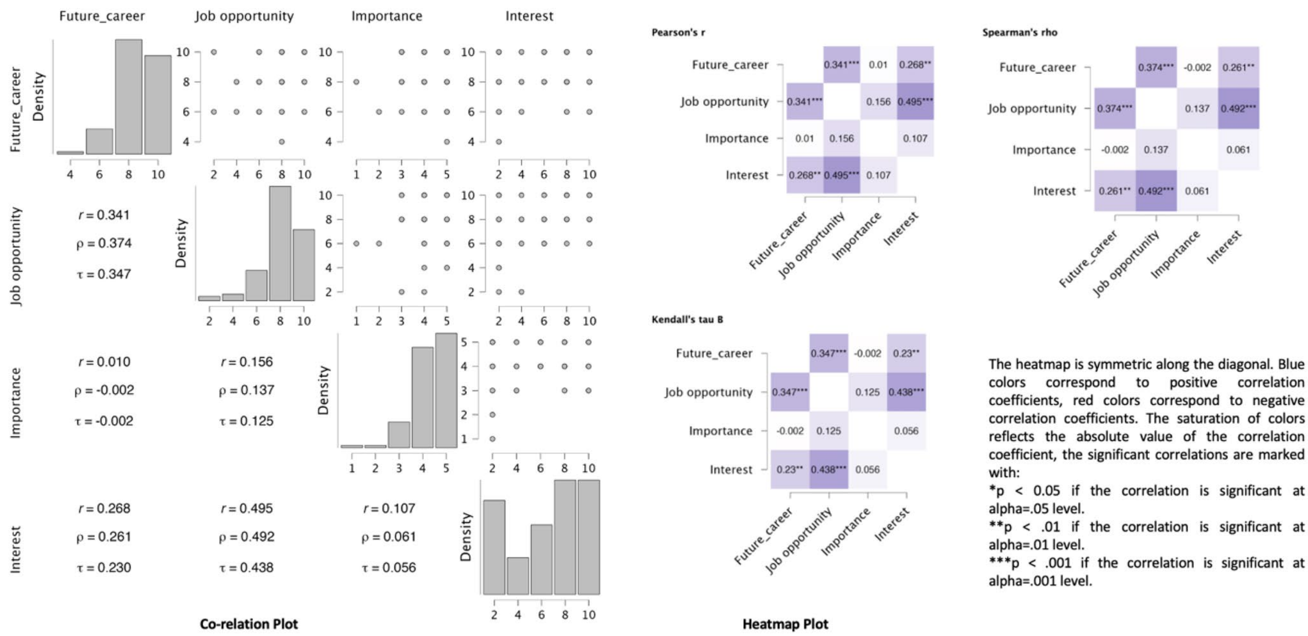


Fig. 6 Co-relation and heat map plots of the data

the sector. The qualitative analysis of the survey data, focusing on emerging engineering technologies and interdisciplinary fields expected to influence the future of green energy transition, alongside suggestions for improving a proposed Master's course in Green Energy Transition, reveals insightful patterns and themes. This analysis follows the thematic analysis methodology outlined earlier, emphasizing an in-depth understanding of the STEM community's perspectives.

4.4.1 Emerging technologies and fields RQ(a)

The responses to the first research question highlighted several key technologies and fields:

- Nanotechnology: Mentioned multiple times, nanotechnology is perceived as a crucial driver for the future of green energy, pointing to its potential to enhance materials efficiency and energy storage solutions.
- Quantum chemistry: Highlighted alongside nanotechnology, quantum chemistry is seen as instrumental in understanding and developing new materials and their mechanics for energy production and storage.
- Offshore eolic (Wind) energy: This suggests a growing interest in expanding renewable energy sources, specifically the potential of offshore wind farms to contribute significantly to green energy transition.
- Carbon capture, utilization, and storage (CCUS): Identified by its acronym and variations (like "C capturing"), CCUS is recognized for its potential to mitigate greenhouse gas emissions from existing and future energy systems.

These technologies and fields underscore a significant inclination toward innovation in material science, renewable energy sources, and carbon management, reflecting a broader vision for a sustainable energy future.

4.4.2 Suggestions for Master's course improvement RQ(b)

The suggestions for improving the proposed Master's course in Green Energy Transition, though fewer, offer valuable insights into curriculum development:

- Comprehensive infrastructure focus: One response emphasized the importance of including infrastructure design and management within the course, suggesting a "*blueprint*" for urban green cities. This indicates a demand for practical, application-oriented learning that prepares students for the infrastructural challenges of green energy transition.

- Mechanical background: Highlighting the importance of strong foundational knowledge in mechanical, this suggestion points to the interdisciplinary nature of green energy studies, where material science, mechanical modelling, software modelling and simulations plays a critical role.

The lack of responses in some entries suggests either satisfaction with the proposed course as is or a hesitation to suggest improvements without more information. However, the feedback provided stresses the importance of a curriculum that is both comprehensive and interdisciplinary, equipping students with the theoretical knowledge and practical skills needed for the green energy sector.

5 Discussion

We refer to similar studies to provide context and validate our findings. A recent study at Democritus University of Thrace in Greece demonstrated that students support renewables and recognize the need for a green transition in curricula, particularly among final-year students [43]. Additionally, a comparative study involving Canadian, Romanian, and Turkish students found similar levels of awareness and understanding regarding the environmental impact of renewable and nuclear power plants, with response percentages generally within 10% of each other [44]. These findings align closely with our results, reinforcing the importance of integrating green energy topics into educational programs globally. This consistency across diverse geographical contexts underscores the widespread recognition of the significance of renewable energy education in preparing students for future careers in the green energy sector.

5.1 Comparative analysis and implications

The findings from our survey on emerging engineering technologies and the suggestions for improving a Master's course in "Green Energy Transition" offer significant insights when compared with existing literature. In sustainable energy education, it is often highlighted in literature the significance of incorporating interdisciplinary methods and implementing the latest technologies in curriculum development. Similar to our findings, studies have highlighted nanotechnology, renewable energy sources such as wind energy, and carbon capture and storage (CCUS) as pivotal areas for the future of green energy [45, 46].

This comparative analysis confirms the relevance of our survey findings and underscores the alignment between current educational demands and the broader academic and industrial trends in green energy transition.

5.1.1 Impact on curriculum development

The insights gathered from the survey underscore the necessity for curriculum developers to incorporate a blend of theoretical knowledge and practical skills in green energy programs. By highlighting specific areas such as nanotechnology, quantum chemistry, and CCUS, the findings direct educational institutions to focus on these emerging fields, ensuring that students are equipped with the knowledge and skills needed to navigate and contribute to the green energy transition. Additionally, the call for an interdisciplinary approach, combining engineering with environmental science, policy studies, and material science, suggests a shift towards a more holistic educational framework that mirrors the multifaceted nature of sustainability challenges.

5.1.2 Contribution to the Broader discourse on sustainability education

The study adds empirical support to the ongoing conversation about sustainability education by highlighting how crucial it is to incorporate interdisciplinary studies and emerging technologies into green energy curricula. This is consistent with the increasing acknowledgment that sustainability education is pivotal in propelling society's shift towards sustainable practices. By involving international students in this discussion, the study adds a richer perspective to the debate and emphasizes the importance of inclusive educational practices as well as the global nature of sustainability issues.

5.2 Inference from correlation study

The heatmap and correlation plots collectively suggest that while students' perceptions of future careers and job opportunities are related, the perceived importance of certain subjects does not strongly correlate with these variables. The strongest relationship is between "Job Opportunity" and "Interest", indicating that practical outcomes like job prospects are a significant factor in students' interest in the MSc course. The lack of significant correlation between Importance and other variables might indicate that while students acknowledge the significance of Mechanical/Electrical/IT, this recognition does not necessarily impact their career optimism or interest in the course as strongly as job opportunities do. This finding is important for curriculum developers to consider when designing course content and marketing educational programs to potential students.

5.3 Limitations and Future Research

While the study provides valuable insights into the future of green energy transition and education, it is not without limitations. The reliance on a self-selected group of international students may introduce bias, as participants who are already interested or involved in sustainability issues may be more likely to respond. Furthermore, the survey's scope, limited to participants' perceptions and suggestions, may not fully capture the complexities of integrating emerging technologies into curriculum development. Recognizing these limitations is crucial for interpreting the findings within the appropriate context and for guiding future research efforts. To have a more thorough grasp of the requirements and difficulties in sustainability education, future studies may look at expanding the participant base to include a larger range of stakeholders, such as educators, business experts, and legislators. Additionally, ongoing studies may shed light on how new technologies and multidisciplinary teaching methods are incorporated into green energy curricula over time, as well as how this influences students' professional choices and contributions to the green energy industry. Additionally, research concentrating on the execution and results of the proposed curriculum modifications would be extremely beneficial, providing proof of how well these innovations work to improve student's educational experiences and readiness for the shift to green energy.

6 Conclusion

This study concludes with a critical examination of emerging engineering technologies and interdisciplinary fields anticipated to significantly influence the green energy transition, alongside eliciting suggestions for enhancing a proposed master's course in Green Energy Transition. Through a methodical survey leveraging Google Forms, we engaged international students to provide a mosaic of insights reflective of diverse global perspectives. As educators, there is a responsibility to bridge the gap between academic offerings and the professional and personal aspirations of students, ensuring that educational pathways in green energy transition are accessible, relevant, and appealing to a broad spectrum of students. The most significant finding is the positive relationship between the opinion on job opportunities and the interest of students in the discussed master's course on green transition. This suggests that students may be motivated to pursue further education if they believe it will enhance their job prospects, particularly in the field of green energy in the fast-developing green Industry 4.0. There seems to be a minor association between the importance of technical fields and interest in new courses, but this link is weaker and may require further investigation to understand its implications. The qualitative analysis of survey responses provides valuable insights into the technologies and interdisciplinary fields viewed as pivotal to the green energy transition, along with constructive feedback on improving a master's course tailored to this transition. Aligning educational programs with these emerging trends and incorporating practical, interdisciplinary approaches to learning will be key in preparing the next generation of leaders in green energy.

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Data availability The full data of the survey in an Excel file is available from the corresponding author on request.

Code availability Not applicable.

Declarations

Consent for publication Informed consent was obtained from all individual participants included in the study.

Competing interests The authors declare no competing interests.

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