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Green Technology for the Landscape Architecture TVET Curriculum: A Triangulated Analysis using ATLAS.ti



Abstract: - Green technology has increasingly been practised across various industries in line with the global aim of achieving the Sustainable Development Goals (SDGs). However, Technical and Vocational Education and Training (TVET) institutions are seen to be lagging in applying green technology elements into the curriculum of the programs offered due to the lack of industry-required knowledge about green technology. Therefore, this research aims to identify the green technology knowledge that should be integrated into the TVET curriculum from the industry's perspective, focusing on the landscape industry in Malaysia. Methodologically, this study involves qualitative, non-experimental research oriented with triangulation approach, involving three main methods: interviews with landscape industry experts, literature review, and document analysis. Analysis with ATLAS.ti 24 software indicates that the green technology curriculum for landscape architecture programs in TVET institutions should include six main topics: Introduction to Green Technology Concepts, Importance of Green Technology, Types of Green Technology, Applications of Green Technology, Green Technology Handling Skills, and Green Practices. The findings of this study are not only relevant for landscape architecture programs but also suggest that other related TVET programs should incorporate green technology into their curricula. This integration aims to produce a skilled workforce capable of meeting industry needs.

Keywords: Green Technology, Landscape Architecture, Sustainability, TVET.

I. INTRODUCTION

Green technology, also known as environmental technology, plays a critical role in ensuring a sustainable future for our society. The primary importance of green technology lies in the effort to develop technology that does not harm or deplete Earth's natural resources [1]. Introducing the concept of green technology in the TVET context is crucial for fostering environmental awareness and sustainability among students from an early stage. Integrating green technology into the TVET curriculum can be achieved through a multifaceted approach that promotes hands-on learning experiences. An effective method is to build a learning communication model that introduces green technology to enhance students' green ethos. Studies have shown that providing comprehensive materials on green technology systems can raise awareness and encourage participation in environmental conservation activities [2].

Educational programs from kindergarten to higher education need to focus on developing skills, knowledge, values, and perceptions related to sustainability, in line with the United Nations' sustainable development education goals [3]. Incorporating indigenous technology into the curriculum also provides suitable solutions for environmental, social, and economic issues, helping students develop creative solutions for sustainable development [4]. Universities and higher education institutions can promote an environmentally conscious campus culture by integrating sustainable practices into their operational strategies and engaging the community in achieving full sustainability [5]. Interactive teaching kits that allow students to build green technology systems can facilitate a deeper understanding of fundamental principles and connect conceptual ideas with physical systems in a meaningful way [6].

Furthermore, introducing the concept of green technology in the TVET curriculum can train students to incorporate environmental sustainability into their professional practices [7]. In Malaysia, efforts to green ICT in the education system have been recognized as essential for reducing carbon dioxide emissions and minimizing the adverse effects of technology on the environment. However, more efforts are needed to support green technology practices in teaching and learning environments [8]. By integrating these diverse approaches, educators can effectively introduce the concept of green technology. This will cultivate a generation of environmentally conscious individuals

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equipped with the knowledge and skills to contribute to a sustainable future. The triangulated approach using ATLAS.ti in this study will ensure that the collected data is holistic and comprehensive, thereby enhancing the effectiveness of green technology teaching in the TVET curriculum for landscape architecture.

II. LITERATURE REVIEW

1.1 *Introduction to Green Technology*

Green technology, or clean technology, encompasses the development and application of solutions designed to conserve the environment and natural resources while minimizing the negative impacts of human activities. Its core objective is to create sustainable solutions that enhance operational performance while being economically viable, reducing energy consumption, and generating minimal or zero waste [9]. This technology includes innovations such as renewable energy sources, energy-efficient devices, and pollution control mechanisms [10]. The overarching aim of green technology is to mitigate the adverse effects of industrial and technological advancements on the environment, thus fostering a resilient global society [11]. By addressing current environmental challenges and repairing past damages, green technology supports the goal of ensuring a healthier planet for future generations.

1.2 *Green Technology in the Landscape Industry*

The landscape industry has increasingly integrated green technology to enhance environmental sustainability and aesthetic value. Notable advancements include the use of computer-based three-dimensional simulation technology for urban landscape design. This technology facilitates the creation of accurate and visually appealing 3D models, optimizing spatial layouts and enhancing design efficiency [12]. Similarly, 3D laser scanning technology has improved urban green space planning by providing high-precision terrain simulations, achieving up to 98% accuracy in terrain modelling [13]. Green roof technology offers benefits such as improved thermal insulation, waterproofing, and ecological value, supporting activities like sports and pedestrian pathways while maintaining economic viability due to low operational costs [14].

The integration of artificial intelligence (AI) in landscape design has further advanced the field, with AI algorithms creating visualization systems that streamline design and planning processes. These systems, operating both online and offline, provide real-time updates and reduce delays [15]. Additionally, the application of green building technology in projects like the entrance area of Tianlu Lake Forest Park showcases how site analysis, planning, and design can be tailored to natural terrain, incorporating features such as permeable soils and ecological corridors to enhance environmental quality [16]. Furthermore, digital technologies such as BP neural networks and the Grey Wolf algorithm have been employed in environmental art design to improve user satisfaction and integrate landscape art with ecological considerations [17]. The continued adoption of these technologies is crucial for developing sustainable, efficient, and aesthetically pleasing urban environments.

1.3 *TVET and Green Technology Curriculum*

Incorporating green technology into Technical and Vocational Education and Training (TVET) curricula is vital for preparing a workforce capable of supporting sustainable development. Practical skills in green technology are essential, yet there is a moderate level of readiness among TVET teacher trainees, indicating a need for enhanced training [18]. Mobile technologies, including smartphones, laptops, and tablets, are effective tools for developing green skills among TVET students by promoting continuous practice in energy efficiency [19]. However, many vocational educators still need to gain adequate knowledge of green technology despite recognizing its importance for environmental protection and industry transformation [20].

UNESCO highlights the role of TVET in promoting lifelong learning, youth employment, gender equality, and a transition to a green economy, which necessitates the integration of green skills into TVET programs [21]. Employability skills related to the green economy—such as understanding green growth, interpreting environmental laws, and enhancing energy and resource efficiency—are crucial for all job sectors [22]. In Malaysia, incorporating green technology into vocational college curricula is driven by industry demands and educational reform needs [23]. Evidence suggests that online pedagogy can be as effective as traditional methods in delivering practical skills training, thus broadening access to green technology education [24]. In the Philippines, the slow adoption of Green IT awareness among TVET students underscores the need for dedicated curricula to educate future professionals on sustainable practices [25]. Therefore, networking and reflection have shown a positive

correlation with learning for sustainable development, highlighting the importance of collaborative and reflective practices in developing green competencies among TVET trainees [18].

The integration of green technology into both the landscape architecture industry and the TVET curriculum is crucial for advancing sustainable development. This review emphasizes the need for strategic curriculum enhancements to address the varying levels of technological preparedness among educators and students. Recognizing critical green technologies and collaborating with experts is essential to align educational programs with industry requirements. The upcoming methodology section will detail the triangulation strategy used for data collection and analysis, aimed at developing a practical manual for TVET institutions in Malaysia.

III. PROBLEM STATEMENT

The lack of integration of green technology elements in the TVET curriculum for landscape architecture is a multifaceted issue influenced by several factors. One significant challenge is the need for more knowledge and understanding of green technology among vocational education teachers. Studies indicate that 68% of these teachers need more expertise to effectively integrate these elements into their teaching [20]. This knowledge gap is further compounded by the generally low levels of awareness and skills related to sustainable development among TVET teachers, hindering the effective teaching of green skills [26]. Current TVET policies and implementations also need more focus on sustainable practices, which are essential for reducing environmental impact and meeting labour market needs [27]. In Malaysia, for instance, there is a recognized need to incorporate green technology into the TVET curriculum to align with industry demands. However, this integration still needs to be viewed as a necessity rather than an imperative, indicating a pressing deficiency in educational reforms [23]. In the Philippines, awareness and implementation of Green Information Technology in TVET schools could be faster. Student awareness remains unidentified, highlighting a critical gap in the curriculum that needs to be addressed to ensure future professionals are equipped with the necessary knowledge to sustain the environment [25]. A previous study by Kaliappan and Hamid (2022) examined the levels of knowledge, attitudes, and practices related to green technology among students at four vocational colleges in Johor, Malaysia. The study found that the knowledge of green technology among Vocational College students was moderate. They emphasized the importance of integrating a green technology curriculum that meets the needs of Vocational College students. There needs to be more exposure to the importance of green technology and the need to address environmental issues and solutions among students. Collectively, this study emphasizes the need for a more robust and integrated approach to incorporating green technology education into the TVET curriculum for landscape architecture programs. It should involve collaboration with the industry, enhanced teacher training, and a shift in policy focus towards sustainable development.

IV. RESEARCH OBJECTIVES

- 1) To identify the green technologies required in the landscape architecture curriculum at Malaysian TVET institutions.
- 2) To employ a triangulation approach that includes interviews with academic and industry experts, literature review, and document analysis to gather data related to green technology.
- 3) To develop a practical guide for Malaysian TVET institutions in designing a curriculum that aligns the green technology needs of the industry with the requirements of landscape architecture graduates.

V. RESEARCH METHODOLOGY

This study employs a qualitative approach, encompassing expert interviews, a literature review, and document analysis to identify the green technology requirements for the landscape architecture curriculum at Malaysian TVET institutions. Following the recommendations of previous researchers such as Kaliappan & Hamid (2022), the researcher engaged with stakeholders to integrate green technology into the curriculum in alignment with industry needs. Consequently, experts from the landscape architecture industry were involved in providing comprehensive insights into gathering data related to green technology education.

5.1 *Data Collection Approach*

5.1.1 *Interviews with Academic and Industry Experts*

Interviews were conducted with academic and industry experts in the field of landscape architecture to obtain direct insights from those involved in both education and the landscape industry, as well as to identify essential green technologies for graduates. Semi-structured interviews were utilized to engage in detailed discussions with seven landscape industry stakeholders in Malaysia. In this study, the concept of saturation was adopted to ascertain the requisite sample size for qualitative research. Saturation occurs when additional data fails to introduce novel insights [28]. The interview sessions ranged from 30 to 40 minutes and were duly recorded with the participant's consent.

5.1.2 Literature Review

A literature review was conducted to gather information related to the green technology requirements in the field of landscape architecture. The literature review included journal articles, books, research reports, and other relevant sources. A critical analysis was performed on the selected literature to identify patterns and trends in green technology requirements. By using features such as co-occurrence codes and query tools in ATLAS. ti software, the researcher could integrate various forms of data into a single Hermeneutic Unit, enhancing the depth and breadth of analysis [29].

Table I: Triangulation of Green Technology Themes

Theme	Document Analysis	Literature Review	Interview	Total Quotations
Introduction to the Concept of Green Technology	3	10	3	16
Importance of Green Technology	3	25	2	30
Types of Green Technology	3	20	8	31
Applications of Green Technology	2	11	7	20
Skills in Handling Green Technology	2	10	2	14
Green Practices	0	11	2	13

5.1.3 Document Analysis

Document analysis was performed on official documents such as study program curricula and industry guidelines for landscape architecture programs at Malaysian TVET institutions. These documents provided clear insights into the green technologies integrated into the curriculum and the industry requirements. Document analysis involved examining specific details related to the green technologies taught and expected by the industry. The versatility of ATLAS.ti software in handling varied data formats empowered the researcher to navigate extensive datasets and facilitate the dissemination of findings across researchers from diverse backgrounds [30].

The combination of these three methods enables this study to obtain a holistic and in-depth understanding of the green technology requirements for landscape architecture graduates at Malaysian TVET institutions. The data obtained from various sources were then analyzed using ATLAS. ti software to gain a detailed and structured understanding of the green technologies that are crucial to consider in the curriculum and industry training.

5.2 Data Analysis Procedure

The collected data were analyzed using thematic analysis procedures using ATLAS.ti 24 software. This thematic analysis revealed themes that could be used to address the research objectives. Additionally, the weighting of each theme and category source was visualized using a Sankey Diagram and Code-Document Table in ATLAS.ti. By utilizing features such as co-occurrence codes and query tools in ATLAS.ti, the researcher could systematically compare data, ensuring a continuous and iterative verification process [30].

5.3 Validity and Reliability

The study's validity is ensured through a triangulation approach involving three primary methods: interviews with academic and industry experts, a literature review, and document analysis. Each method provides unique and comprehensive insights into gathering data related to the green technologies required by landscape architecture graduates. By converting raw qualitative data into coded categories, ATLAS.ti enables the researcher to achieve accurate content representation, thereby enhancing the validity of the research findings [31].

This approach enables the study to offer comprehensive insights into the incorporation of green technology into the TVET curriculum for landscape architecture programs, alongside relevant recommendations for enhancing the curriculum to align with industry requirements, as detailed in the subsequent findings section.

VI. RESEARCH FINDINGS

Based on the data analysis using ATLAS.ti software, several key themes related to green technology in the TVET curriculum for landscape architecture were identified. Table 1 presents the number of quotations recorded for each category within six main themes. A total of 124 quotation segments related to green technology were recorded, with the category "Types of Green Technology" dominating with 31 quotations. This dominance indicates that the types of green technology are the most frequently discussed topic in the research sources. The findings are presented in Table 1.

6.1 Thematic Analysis and Data Visualization

The use of ATLAS.ti software enabled the generation of a Sankey diagram that displays the triangulation of data across all identified themes from the three research sources. This Sankey diagram aids in visualizing the flow of data and the relationships between the main themes, highlighting how contributions from various data sources support each theme.

These findings can assist in developing a more relevant and effective curriculum to equip graduates with the practical technologies needed for a sustainable future. The six themes developed in this section will be discussed in the following Discussion section to provide recommendations on how they can be embedded in the existing curriculum.

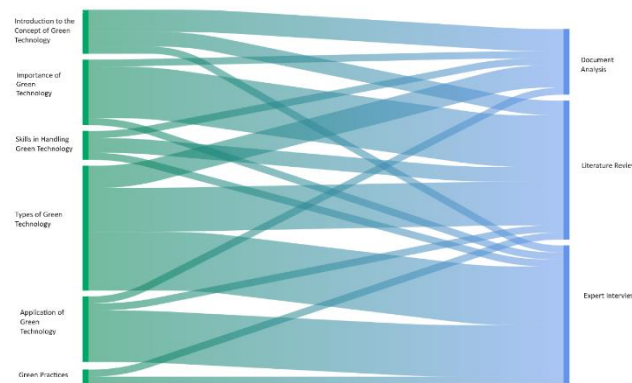


Fig.1. Sankey Diagram of Six Main Green Technology Themes

VII. DISCUSSION

7.1 Theme 1: Introduction to Green Technology Concepts

Green technology refers to the application of scientific and technological knowledge to develop environmentally friendly products and processes, with the primary goal of reducing negative impacts on the environment. The basic principles of green technology include enhancing energy resource efficiency and preserving biodiversity. In the context of TVET education for landscape architecture, knowledge of green technology is crucial. It provides a solid foundation before students are exposed to more in-depth applications in the industry. As the foundation of TVET education, students need to understand the basics of green technology, which not only helps them grasp its importance but also prepares them to face industry challenges. Expert 7 supports this view by stating, "This (green technology) is essential because we consider it basic knowledge. Once you enter the industry, you will receive broader exposure." This statement highlights the critical role that an understanding of green technology plays in

shaping the necessary skills for students in the industry. The use of green technology in landscape architecture is not only important for the environment but also provides educational benefits. Innovative teaching methods such as problem-based learning and work-integrated learning incorporate green skills, enabling students to develop the competencies needed in an increasingly complex global environment [32]. Integrating green technology into the curriculum not only enhances the employability of TVET graduates but also ensures they can bridge the skills gap between the classroom and the industry [33].

7.2 *Theme 2: The Importance of Green Technology*

Students must understand the use of green technology in landscape architecture, as it not only helps achieve environmental sustainability but also plays a role in reducing negative environmental impacts and enhancing the comfort and quality of life for residents. Green technology, which aims to reduce human impact on the natural environment, is vital for reversing the harmful effects of human activities and ensuring long-term sustainability [34]. Energy savings, as one of the key aspects of green technology, significantly impact the environment. Expert 5 noted that energy savings contribute not only to the environment but also to the landscape, which is part of that environment: "If we talk about energy saving, its impact is on the environment... its contribution to the environment... and the environment is part of the landscape." This statement highlights the importance of students recognizing and understanding the role of green technology in environmental preservation, particularly in the context of landscapes.

In addition to environmental benefits, green technology also offers significant social and economic advantages in landscape architecture. The increased access to technology has allowed designers in this field to benefit from the enhanced computational power for better visualization and conceptualization of designs [35]. Furthermore, rapid technological advancements have facilitated access to global information, which is crucial for achieving sustainable development goals in landscape architecture [36]. The use of green technology also brings satisfaction to students, especially in terms of visualization, helping them complete projects and assignments more effectively [35]. With the growing recognition of the importance of green technology education, government mandates and industry transformations now aim to enhance student employability while fostering citizens who are aware of their environmental responsibilities [20]. This awareness reinforces the need to integrate green technology into the TVET curriculum. Students must be equipped with relevant knowledge and skills to face current environmental challenges while leveraging green technology to promote sustainable development and environmental conservation.

7.3 *Theme 3: Types of Green Technology*

In landscape architecture, the application of green technology is critical for ensuring environmental sustainability and improving the effectiveness of landscape design. Commonly used green technologies include renewable energy technologies such as solar power, wind energy, and waste management technologies. A deep understanding of these technologies is essential for TVET students who will work in this industry, where they need to master the skills to identify and update relevant green technologies. According to Expert 1, basic knowledge of solar energy use is one of the key skills students must master because technology is constantly evolving and needs to be updated: "Technology is something that keeps improving. Therefore, it needs to be updated. Solar lighting, all that." This emphasis indicates that students need exposure to emerging technologies, such as solar lighting, to ensure they are prepared to adapt to changes in the industry. Expert 3 also emphasized the importance of identifying relevant green technologies in the industry: "Green technology is very important. Maybe this one is closer. How to identify the technology that can be applied." This evident shows that students must not only understand the green technologies currently in use but also keep up with developments in potential future technologies.

The use of renewable energy sources such as solar, battery, wind, and hydro at the local level is an example of practical and relevant green technology applications [37]. These technologies allow students to explore more advanced design techniques and strengthen their foundational knowledge of green technology. On a broader scale, the landscape architecture industry is increasingly integrating green technology to address long-term sustainability and environmental challenges. A significant advancement is the optimization of energy systems using renewable energy sources, such as wind and photovoltaic power, which have proven effective in reducing carbon emissions and increasing energy efficiency in landscape architecture projects [38]. The integration of artificial intelligence (AI) in green landscape design also brings innovations, allowing the creation of more sophisticated visualization systems to improve the planning and implementation of sustainable landscapes. These innovations not only reduce

operational delays but also enhance overall project efficiency [15]. The types of green technology applied in landscape architecture have a profound impact on project sustainability and efficiency. Therefore, TVET graduates must remain attentive to the latest developments in green technology and be prepared to adapt their knowledge to meet the growing demands of the industry. This is essential not only to ensure their employability in the industry but also to promote sustainable and environmentally friendly design practices.

7.4 *Theme 4: Applications of Green Technology*

The application of green technology in landscape architecture encompasses various aspects such as the use of smart irrigation systems, eco-friendly construction materials, and efficient waste management systems. In this context, the utilization of green technology not only positively impacts the environment but also enhances the effectiveness and comfort of landscape design. According to Expert 2, "Certain skills, such as green technology, drones, and so on, need to be taught at a fundamental level so that students have the basic skills to operate these devices, machines, or whatever." This statement suggests that students need to know how to apply basic skills in green technology, such as solar energy and drones, to better prepare them for real industrial applications. Moreover, the application of green technology in designs that utilize natural ventilation and thermal comfort has also been emphasized. Expert 5 stated, "How to design using natural ventilation, thermal comfort—that is green technology." This highlights that the understanding of green technology is not limited to energy aspects but also involves design approaches that utilize natural resources to create more comfortable and sustainable environments.

Engaging students in solving sustainability-related issues within their environment can help them gain a deeper understanding of green technology applications in their professional context. For instance, the approach used in the United Kingdom involves secondary and high school students in reducing energy usage at their schools through data collection, monitoring energy consumption, and planning and implementing relevant projects. After a few cost-free projects were implemented, the school's electricity usage decreased by an average of 35% [39]. This approach aligns with the experience shared by Expert 5, who recommended teaching and learning methods that start by addressing minor issues within the campus environment as a foundation for achieving a sustainable campus. He noted, "So, I give the assessment; you need to know how energy-saving applications work on your campus to achieve a green campus. Very small issue, very small action." Such involvement demonstrates that active involvement in green technology applications can help students comprehend the practical impact that can be achieved. Furthermore, modern technological solutions are also used to preserve historic green spaces while introducing new functions that highlight their cultural significance [40]. This evidence shows that green technology is not limited to modern applications but can also be used to preserve cultural and environmental heritage.

7.5 *Theme 5: Green Technology Handling Skills*

Practical skills in handling green technology, including installation, maintenance, and adaptation to current landscape and environmental needs, are essential. Expert 3 emphasized, "We aim to produce technical workers who can handle machines and so on. The system and machines—that's the target within TVET." This highlights the importance of hands-on training for students, which goes beyond theoretical knowledge. Expert 5 further supported this view by stating, "Exposure to theory alone is not sufficient; they need to know how to install, operate, and maintain the technology." This insight underscores the necessity of equipping TVET students with practical skills that are directly applicable in real-world settings, ensuring they are well-prepared to meet industry demands. The significance of green technology for TVET students lies in enhancing the professional skill sets of future graduates, enabling them to meet industry needs effectively [23]. This aligns with the industry's expectation that students familiarize themselves with green technology used in other countries, preparing them to stay relevant as technological advancements accelerate. Moreover, policies and the implementation of TVET must focus on sustainable practices to reduce environmental impact while aligning with labor market demands, thereby fostering a workforce that is not only technically skilled but also ethically committed to sustainability principles [27]. As such, teaching and learning methods need to keep pace with these technological advancements, allowing students to bring landscape designs to life and experience them in real time, thus gaining a clearer understanding of their design proposals [41]. This comprehensive approach to green technology education will ensure that TVET graduates are not only competent in theory but also proficient in the practical application of green technologies, making them valuable assets in the evolving landscape architecture industry.

7.6 *Theme 6: Green Practices*

Appreciating the concept of green practices in the context of landscape architecture is crucial for waste reduction, efficient resource use, biodiversity conservation, and promoting green practices within the community. Expert 5 highlighted the importance of integrating these practices into everyday actions, stating, "When we talk about green technology globally, the application is like I mentioned earlier—energy-saving, turning off the air conditioning, that's already green technology." This perspective suggests that understanding and appreciating green practices can start with simple yet impactful actions that foster a culture of sustainability among students. Students can develop a deeper appreciation for green practices and sustainable ethics in landscape architecture through a combination of practical, theoretical, and innovative educational approaches. Integrating ideological and political education into landscape architecture projects, such as community greening and ecological education, helps students cultivate correct social values and environmental awareness, fostering a sense of social responsibility and commitment to sustainable development [42]. This approach aligns with the idea that educators need to emphasize core values and ethics necessary for a green culture, ensuring that students are prepared to create and sustain green practices in their future workplaces [43]. By embedding green practices into the educational framework of landscape architecture, students not only gain the technical skills required for sustainable development but also develop the ethical and social awareness necessary to implement and advocate for these practices in their professional lives.

VIII. CONCLUSION

This study offers explicit guidance on integrating green technology into the TVET curriculum and its application in the landscape architecture industry. The findings indicate that the incorporation of green technology into the TVET curriculum is crucial to producing graduates who are proficient and ready to address industry requirements. Through the utilization of a triangulation method and ATLAS.ti software, the researchers were able to pinpoint pertinent themes and primary categories, presenting a comprehensive direction for formulating a curriculum centred on green technology in landscape architecture.

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