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TEACHERS' PERCEPTIONS OF INTEGRATING SUSTAINABILITY INTO MALAYSIAN MATRICULATION CHEMISTRY EDUCATION: A QUALITATIVE NEEDS ANALYSIS

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ABSTRACT

Sustainability has become a central priority in global education reform in response to escalating environmental, social, and economic challenges. Although Education for Sustainable Development has been widely promoted internationally, its integration within Malaysian pre-university education remains limited. In particular, sustainability is not explicitly prioritised within the Malaysian National Education Blueprint (2015–2025), resulting in fragmented implementation at the matriculation level. This study investigates matriculation chemistry lecturers' perceptions, challenges, and instructional needs regarding the integration of sustainability dimensions into chemistry education. A qualitative needs analysis was conducted using semi-structured interviews with eight experienced matriculation chemistry lecturers. The data were analysed through thematic analysis, generating 46 initial codes that were consolidated into 12 categories and synthesised into three overarching themes: (1) repositioning chemistry through sustainability, (2) conceptual and structural barriers, and (3) instructional and structural supports. Findings reveal a perceived tension between examination-oriented curriculum structures and the transformative aspirations of sustainability-oriented instruction. Lecturers recognised sustainability integration as a means of enhancing chemistry's relevance, promoting responsible citizenship, and fostering higher-order competencies. However, limited conceptual clarity, curriculum ambiguity, and structural constraints restrict systematic implementation. Participants emphasised the need for structured pedagogical guidance, professional development, inquiry-based instructional strategies, and authentic assessment approaches aligned with sustainability competencies. This study contributes context-specific evidence to inform curriculum reform and the development of a sustainability-integrated chemistry pedagogical module within examination-driven education systems.

Keywords: *Sustainability, chemistry education, needs analysis, thematic analysis, matriculation teacher.*

INTRODUCTION

Contemporary societies face complex and interrelated global challenges, including climate change, environmental degradation, socioeconomic inequality, resource depletion, and recurring natural disasters. In response, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has identified education as a critical mechanism for advancing sustainable development. International initiatives such as the Decade of Education for Sustainable Development (2005–2014), the Rio+20 Conference (2012), the Sustainable Development Goals (SDGs), particularly Target 4.7, and the ESD 2030 Roadmap (UNESCO, 2020) have emphasised the need for transformative education that equips learners with sustainability competencies necessary for responsible action.

Sustainability is conceptualised as the balanced integration of environmental, social, and economic dimensions to ensure present and future well-being. Within this framework, chemistry occupies a central role due to its extensive applications across industry, health, agriculture, and environmental systems. UNESCO and the International Union of Pure and Applied Chemistry (IUPAC) have repeatedly highlighted chemistry as a key discipline for promoting sustainable development. A growing body of scholarship similarly argues that chemistry education can serve as a powerful platform for developing sustainability awareness and socio-scientific reasoning (Burmeister et al., 2012; Herranen et al., 2021; Jegstad & Sinnes, 2015).

Despite this recognition, the integration of ESD within chemistry education remains inconsistent. International research indicates that sustainability is often marginalised within secondary and tertiary chemistry curricula, where content coverage and examination performance dominate instructional priorities (Tal et al., 2021; Tomas et al., 2020). Teachers frequently report limited time, insufficient pedagogical guidance, and structural curriculum constraints that restrict meaningful sustainability integration (Aubrecht et al., 2019; Gibbons et al., 2021; Orgill et al., 2019). Even when sustainability issues appear in textbooks, they are typically fragmented and predominantly environmental in focus, with limited attention to social and economic dimensions (Brown et al., 2018).

In the Malaysian context, the integration of sustainability within chemistry education remains limited and uneven. Existing research has primarily focused on green chemistry practices rather than broader sustainability frameworks (Karpudewan & Kulandaisamy, 2018; Taha et al., 2019). Clear, structured guidance for embedding environmental, social, and economic dimensions within chemistry curricula is largely absent. Consequently, teachers are often required to interpret and implement ESD independently, resulting in fragmented and inconsistent practice. These patterns suggest a persistent gap between sustainability aspirations and classroom implementation, particularly within high-stakes, examination-oriented systems.

While international studies have explored ESD integration in secondary and tertiary chemistry education, empirical research focusing specifically on pre-university or matriculation-level chemistry remains limited. The Malaysian matriculation programme occupies a critical transitional stage between secondary and tertiary education. It is characterised by compressed academic timelines, strong examination orientation, and cognitively mature learners capable of engaging with complex socio-scientific issues. Despite this strategic position, sustainability integration at this level has received minimal scholarly attention. Furthermore, systematic needs analyses grounded in lecturers' lived experiences are lacking, limiting evidence-based curriculum innovation.

This study addresses this gap by examining matriculation chemistry lecturers' perceptions, challenges, and instructional needs regarding sustainability integration in Malaysia. Grounded in teachers' professional experiences, the study aims to provide an empirical foundation for the development of a sustainability-oriented pedagogical module.

Specifically, the study aims to:

1. Examine matriculation chemistry lecturers' perceptions of integrating sustainability into chemistry education in Malaysia.
2. Identify challenges encountered in implementing sustainability dimensions within the matriculation chemistry curriculum.
3. Determine instructional and structural supports required to facilitate effective sustainability integration.

The corresponding research questions are:

1. How do matriculation chemistry lecturers perceive the integration of sustainability into chemistry education?
2. What challenges do lecturers encounter in integrating sustainability dimensions?

3. What instructional supports are needed to facilitate systematic implementation?

The study is theoretically grounded in UNESCO's ESD 2030 framework (UNESCO, 2020), which emphasises transformative learning and the development of sustainability competencies, including systems thinking, anticipatory, normative, strategic, and interpersonal competencies (Remington-Doucette & Musgrove, 2015; Wiek et al., 2011). Within chemistry education, sustainability integration aligns with systems-thinking approaches that connect chemical concepts to environmental, social, and economic contexts (Orgill et al., 2019; Sjöström & Talanquer, 2018; Wissinger et al., 2021). Such alignment corresponds with international recommendations advocating inquiry-driven and contextualised science education as vehicles for sustainability learning (Ariza et al., 2021; Hofstein & Mamlok-Naaman, 2021; Jegstad, 2024). The study also draws on Taba's (1962) curriculum development model, which positions needs analysis as a Sustainability integration requires not only pedagogical innovation but structural curriculum alignment foundational stage in systematic curriculum design. By integrating ESD competency frameworks with curriculum theory, this research situates sustainability integration within a structured pedagogical and policy-oriented framework rather than treating it as an isolated instructional addition.

To support effective implementation, the study further explores the potential of incorporating low-tech virtual reality (VR) as an instructional tool to enhance contextualised and immersive sustainability-oriented learning experiences. Grounded in lecturers' perspectives, the findings provide a needs-analysis foundation for the systematic design and development of a sustainability-integrated chemistry pedagogical module at the matriculation level.

METHODOLOGY

Data for the needs analysis were collected using semi-structured interviews and analysed through thematic analysis. The interview transcripts were analysed using Braun and Clarke's (2006) six-phase thematic analysis, as in Figure 1. Initial open coding was conducted to identify meaningful units related to perceptions, challenges, and instructional needs. Codes were then grouped into conceptual categories through axial coding. Finally, categories were synthesised into three overarching themes reflecting teachers' perceptions of sustainability integration.

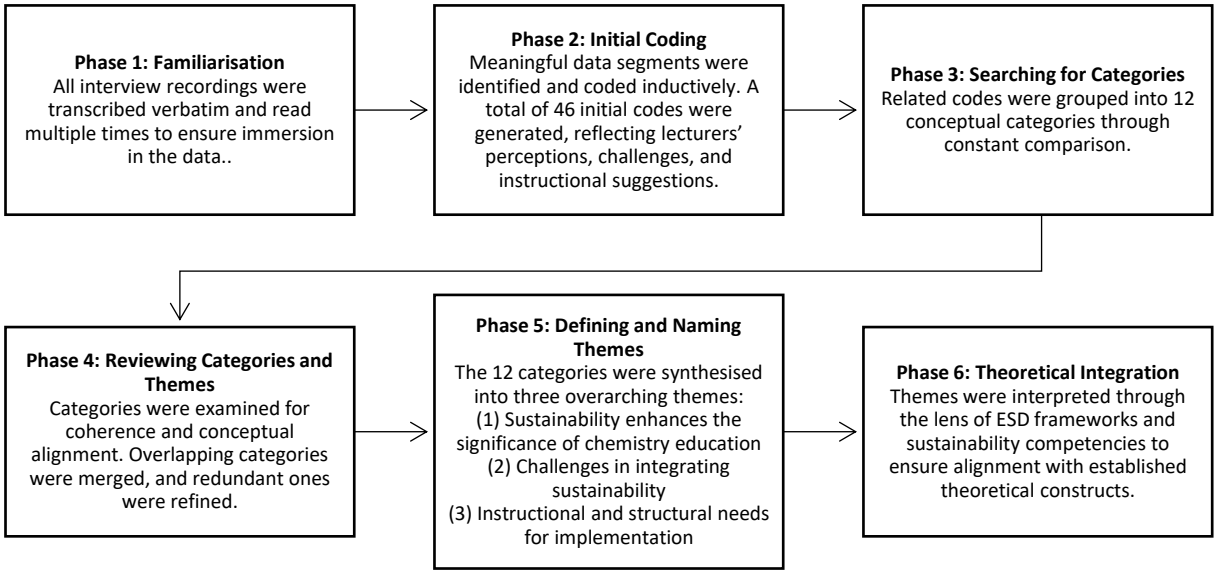

Figure 1. *Process of Thematic Analysis*

To ensure credibility, member checking was conducted by sharing thematic summaries with selected participants to verify the accuracy of interpretations. Reflexivity was maintained through analytic memo-writing, whereby the researcher systematically documented assumptions, decisions, and reflections throughout the coding process to minimise interpretive bias and enhance transparency and confirmability. The sample of interview questions includes: How do you understand sustainability in the context of chemistry teaching? What challenges do you encounter when integrating sustainability into your lessons, and what forms of instructional support would facilitate sustainability integration? Below is the example of the coding, category, and theme that have been analysed (Table 1).

Table 1. *Coding, Category and Theme Analysis*

Raw Data Excerpt	Initial code	Category	Theme
"We are content-oriented and focus on exams."	Exam-oriented instruction	Structural curriculum constraint	Challenges in integrating sustainability

Interviews were conducted with eight chemistry lecturers either face-to-face at the participants' workplaces or online via the Google Meet platform, depending on accessibility and preference. Five participants specialised in pure chemistry, while three specialised in applied chemistry, particularly in chemical industries and chemical engineering. All participants had served as Matriculation Examination Markers, with three also having experience as Matriculation Examination Assessors. One participant was directly involved in the development and revision of the matriculation chemistry curriculum, while two others actively contributed to the Matriculation STEM activities programme. In addition, all participants had engaged in action research related to chemistry teaching and learning at the matriculation level, and several were involved in innovation initiatives at both college and national levels. The majority of the participants had more than eighteen years of teaching experience as matriculation chemistry educators, and all had taught the same chemistry matriculation curriculum for a minimum of ten years. Their professional grades ranged from DG44 to DG52. Collectively, the participants' extensive teaching experience, professional roles, and diverse expertise provided a rich and credible foundation for generating meaningful insights into the current practices, challenges, and needs associated with integrating sustainability into matriculation-level chemistry education. Ethical approval was obtained before data collection, and informed consent was secured from all participants, with anonymity and confidentiality assured throughout the study.

FINDINGS

The thematic analysis yielded three overarching themes: (1) repositioning chemistry through sustainability, (2) conceptual and structural barriers, and (3) instructional and structural supports.

Theme 1: Repositioning Chemistry Through Sustainability

Participants consistently indicated that integrating sustainability can strengthen students' sense of purpose in learning chemistry. Current instruction was described as predominantly content-driven and examination-oriented, prioritising syllabus completion over contextual application. While this approach supports assessment performance, it was perceived to limit students' understanding of chemistry's broader relevance, particularly for those not pursuing careers related to chemistry. Lecturers noted that limited real-world integration contributes to students viewing chemistry as abstract and disconnected from daily life. Sustainability was therefore positioned as a meaningful pedagogical entry point. Embedding environmental, social, and economic dimensions into chemistry topics was seen as a way to connect abstract concepts to authentic societal issues and enhance perceived relevance. As one lecturer stated:

> Students will recognise the value of their learning, which strengthens their sense of responsibility and enhances their capacity to make informed decisions for themselves and others. (CL4)

Participants further linked the integration of sustainability to the development of higher-order competencies, including critical thinking, anticipatory reasoning, evaluation, and problem-solving. Overall, sustainability was framed not as additional content, but as a means of recontextualising chemistry toward broader societal relevance.

Theme 2: Conceptual and Structural Barriers

Two major challenges were identified. Firstly, lecturers reported a limited conceptual understanding of sustainability and its multidimensional nature. Most associate sustainability primarily with environmental protection, with minimal reference to social and economic dimensions. This narrow interpretation was attributed to the absence of explicit sustainability requirements within matriculation chemistry standards. Because sustainability is not clearly articulated in learning objectives or topic specifications, it was often perceived as non-compulsory and secondary to examination preparation. As one participant explained:

> We are largely content-oriented; therefore, our primary focus is on content knowledge, which is essential for preparing students for examinations. Other aspects, such as real-life applications, are addressed only when additional time is available. (CL4)

Even when curriculum documents encourage real-world application, unclear wording and limited guidance were reported to hinder systematic implementation. As a result, sustainability remains peripheral rather than embedded in formal planning.

The second challenge relates to practical constraints. Participants emphasised the need for clear instructional guidelines, professional development, quality teaching resources, and administrative support to prevent sustainability integration from becoming an additional burden. While sustainability-related practices occur informally, particularly in laboratory waste management, these efforts remain largely environmentally-focused and lack systematic integration of social and economic dimensions.

Theme 3: Instructional and Structural Supports

Participants identified several supports necessary for effective integration. Inquiry-based pedagogies particularly project-based learning (PjBL) and problem-based learning (PBL)were viewed as suitable strategies for connecting chemistry concepts to socio-scientific issues and promoting higher-order thinking. Collaborative approaches, including discussions and group tasks, were also recommended. However, feasibility concerns were prominent. Time constraints and extensive syllabus coverage were reported to limit student-centred instruction, often reinforcing teacher-led approaches. As one lecturer noted:

> I am attempting to shift towards a student-centred approach; however, time constraints remain a significant limitation. (CL1)

Participants therefore stressed the importance of structured instructional guidance and curriculum alignment to ensure sustainability integration is manageable. Views differed regarding curriculum placement: some favoured integration within organic chemistry due to its everyday relevance, while others supported cross-topic integration. These variations suggest the need for flexible, context-sensitive implementation within the matriculation framework.

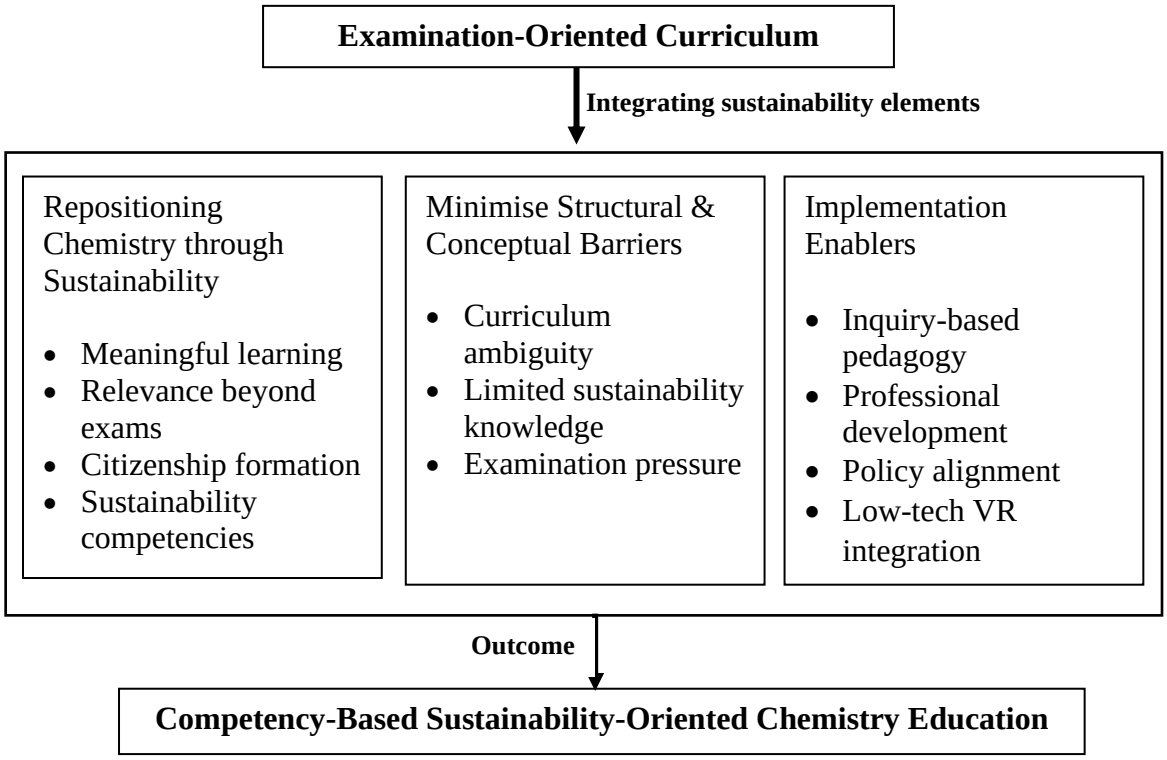

Figure 2. *Conceptual Framework of Sustainability Integration in Malaysian Matriculation Chemistry*

Figure 2 illustrates the relationships among the three overarching themes identified through thematic analysis. Sustainability integration in matriculation chemistry is shaped by the interaction between (1) the perceived pedagogical value of sustainability, (2) structural and conceptual barriers within the curriculum, and (3) required instructional and institutional supports. These interacting dimensions collectively inform the development of a sustainability-oriented pedagogical module aligned with the examination-driven matriculation context. The framework synthesises participants' perspectives into a coherent model that links contextual constraints, pedagogical strategies, and competency-based outcomes.

Table 2. *Summary of Themes and Subthemes*

Theme	Subthemes	Description
Repositioning Chemistry through Sustainability	Meaningful learning; Relevance beyond examinations; Citizenship formation; Sustainability competencies	Sustainability reframes chemistry as socially relevant and competency-oriented
Conceptual and Structural Barriers	Curriculum ambiguity; Limited sustainability knowledge; Examination pressure	Systemic and conceptual constraints limiting integration
Instructional and Structural Supports	Inquiry-based pedagogy (PBL/PjBL); Professional development; Curriculum alignment; Low-tech VR integration	Enablers required for feasible and systematic implementation

The thematic structure presented in Table 2 and synthesised in Figure 2 provides the empirical foundation for the following discussion, which interprets these findings in relation to ESD theory and international scholarship.

DISCUSSION

The findings of this study reveal a structural tension between the examination-oriented culture of the Malaysian matriculation chemistry curriculum and the transformative aspirations of Education for Sustainable Development (ESD). While participants expressed strong support for integrating sustainability dimensions into chemistry instruction, implementation remains constrained by curriculum structures that prioritise content coverage and examination performance. This misalignment reflects what has been described in international ESD scholarship as an "implementation gap," whereby sustainability is acknowledged conceptually but insufficiently operationalised within classroom practice (Tal et al., 2021; Tomas et al., 2020).

Participants perceived sustainability integration as a means of repositioning chemistry from a predominantly examination-driven subject toward a socially meaningful and contextually relevant discipline. This perception aligns with UNESCO's (2020) ESD 2030 framework, which emphasises transformative learning and the development of sustainability competencies beyond content acquisition. In this study, lecturers consistently linked sustainability-oriented instruction with enhanced student relevance, responsibility, and decision-making capacity. Importantly, participants identified competencies such as critical thinking, anticipatory reasoning, evaluation, and problem-solving as central outcomes of sustainability integration. These competencies correspond closely to internationally recognised sustainability competencies, including systems thinking, anticipatory, normative, strategic, and interpersonal dimensions (Remington-Doucette & Musgrove, 2015). The findings therefore suggest that lecturers intuitively recognise the need for competency-based transformation, even when structural curriculum constraints limit systematic implementation.

From a chemistry education perspective, this repositioning reflects broader calls for contextualised and socio-scientific approaches that connect abstract chemical concepts to real-world issues (Sjöström & Talanquer, 2018). International research indicates that when chemistry is taught in isolation from societal contexts, students often struggle to perceive its relevance (Rahmawati et al., 2021). By embedding sustainability issues within chemistry topics, lecturers perceive that students are better able to connect conceptual knowledge with environmental, social, and economic realities. However, it is important to emphasise that these conclusions are based on lecturers' perceptions rather than direct measures of student outcomes. The findings indicate perceived potential rather than empirically tested impact.

Despite recognising the pedagogical value of sustainability integration, participants identified significant structural barriers. Chief among these was the content-heavy, examination-oriented nature of the matriculation curriculum. Sustainability was described as insufficiently articulated within official standards, with limited guidance regarding objectives, instructional strategies, or assessment expectations. As a result, sustainability integration was often treated as peripheral rather than embedded within formal lesson planning. This finding is consistent with prior research indicating that when sustainability is not explicitly operationalised within curriculum documents, teachers are less likely to prioritise it systematically (Holst, 2023). In the Malaysian context, previous analyses have similarly noted limited coherence in national ESD implementation strategies (Balakrishnan, 2021; Kanapathy et al., 2021). The present study extends this understanding to the matriculation level, highlighting the particular constraints of compressed academic timelines and high-stakes assessment environments.

From a curriculum theory perspective (Taba, 1962). The absence of clearly defined sustainability objectives inhibits systematic instructional design. Without explicit articulation of intended competencies, teachers default to established content-driven practices. The findings, therefore, suggest that this recommendation reflects broader shifts toward a competency-based education model. Sustainability integration requires not only pedagogical innovation but also structural curriculum alignment and institutional commitment, consistent with broader findings on sustainability integration in higher education systems (Leal Filho et al., 2021). Moreover, participants strongly endorsed inquiry-based pedagogies, particularly project-based learning and problem-based learning, as appropriate strategies for embedding sustainability within chemistry education. These approaches were perceived

as facilitating authentic engagement with socio-scientific issues and supporting higher-order cognitive development (Zou et al., 2024). Such alignment corresponds with international recommendations advocating inquiry-driven and contextualised science education as vehicles for sustainability learning (Singha & Singha, 2024).

However, feasibility concerns were equally prominent. Time constraints, syllabus coverage requirements, and assessment pressures were described as limiting sustained student-centred implementation (Aubrecht et al., 2019; Gibbons et al., 2021; Orgill et al., 2019). This tension underscores the need for structured instructional guidance and ready-to-use modules that reduce teacher workload while maintaining curricular alignment (Widyantoro et al., 2025). Participants' recommendations regarding curriculum organisation further illustrate the importance of flexibility. While some favoured embedding sustainability within organic chemistry due to its everyday relevance, others argued for cross-topic integration. These differing perspectives suggest that sustainability integration must remain adaptable to local teaching contexts and institutional expectations (Weiss et al., 2021).

Assessment practices also emerged as a critical dimension. Participants advocated for more authentic assessment approaches capable of evaluating both conceptual understanding and sustainability-related competencies. This recommendation reflects broader shifts toward competence-based ESD implementation models, where assessment extends beyond factual recall to include systems thinking, collaborative reasoning, and applied problem-solving (Demssie et al., 2023; Rauch et al., 2022; Rieckmann & Barth, 2022). Nevertheless, participants acknowledged that examinations remain central within the matriculation system, indicating the need for balanced and hybrid assessment frameworks.

The study also identified strong participant support for the integration of VR as a tool for enhancing sustainability-oriented chemistry learning. Lecturers perceived VR as beneficial for visualising abstract chemical processes and contextualising real-world issues. These perceptions are consistent with research demonstrating the potential of immersive technologies to enhance spatial reasoning and conceptual understanding (Rahmawati et al., 2021). At the same time, practical limitations related to cost and infrastructure were emphasised. The proposed use of low-tech, mobile-based VR solutions, therefore, represents a pragmatic compromise between innovation and feasibility. Rather than advocating high-cost technological transformation, the findings support scalable and resource-sensitive approaches tailored to institutional realities. It is important to note that this study does not evaluate the effectiveness of VR implementation, but rather documents lecturers' perceived openness to such innovation. Future research should empirically assess its impact on learning outcomes.

Beyond the Malaysian context, this study contributes to ongoing international debates concerning the operationalisation of ESD within high-stakes educational systems. Similar tensions between sustainability aspirations and assessment-driven curricula have been documented globally (Tal et al., 2021; Tomas et al., 2020). By situating evidence within a Southeast Asian pre-university context, this research extends comparative ESD literature and highlights systemic barriers common to examination-oriented systems. Unlike prior Malaysian studies that focus predominantly on green chemistry implementation at the secondary level, this study provides a structured qualitative needs analysis at the matriculation level, an underexplored pre-university context in sustainability-oriented chemistry education. It contributes to existing literature by explicitly connecting lecturers' perceptions with established sustainability competency frameworks and curriculum development theory. In doing so, the study bridges theoretical ESD frameworks with practical curriculum design considerations, offering empirically grounded insights to inform sustainability integration within pre-university chemistry education.

IMPLICATIONS FOR PRACTICE AND POLICY

The findings suggest that integrating sustainability into matriculation chemistry requires a shift from examination-driven instruction toward learning that emphasises contextual relevance and socio-scientific engagement. Effective implementation depends on structured institutional support, including curriculum-aligned modules, clear guidelines, and sustained professional development in sustainability-

oriented and inquiry-based pedagogy. Without such systemic alignment, integration is likely to remain inconsistent and teacher-dependent.

Inquiry-based approaches such as problem-based and project-based learning offer practical pathways for embedding sustainability; however, structured resources are essential given time and syllabus constraints. Assessment practices should also extend beyond traditional examinations to include authentic methods that evaluate sustainability-related competencies, including systems thinking and critical reasoning. At the policy level, explicit incorporation of sustainability learning outcomes within matriculation curriculum standards is necessary to ensure coherence across objectives, pedagogy, and assessment. Finally, while VR presents promising instructional potential, scalable and low-cost solutions are more appropriate to ensure feasible and sustainable adoption.

CONCLUSION

This study provides empirical insight into how sustainability integration is perceived within the Malaysian matriculation chemistry context. While lecturers demonstrated limited conceptual clarity regarding the multidimensional nature of sustainability, they expressed clear willingness to embed sustainability principles into chemistry instruction. The findings reveal a central tension between examination-oriented curriculum structures and the transformative aspirations of Education for Sustainable Development (ESD), highlighting a systemic rather than individual-level challenge.

By foregrounding lecturers' lived experiences, this research identifies key areas requiring structural attention, namely curriculum clarity, competency articulation, instructional guidance, and professional learning support. Rather than positioning sustainability as an additional content layer, participants conceptualised it as a means of recontextualising chemistry education toward relevance, responsibility, and higher-order competency development. However, meaningful implementation depends on institutional alignment and explicit policy articulation.

This study contributes to sustainability-oriented chemistry education by offering a structured qualitative needs analysis at the matriculation level in an underexplored pre-university context. By linking teacher perceptions with sustainability competency frameworks and curriculum development theory, the research bridges ESD theory with practical curriculum design considerations in high-stakes transitional education systems. Ultimately, the findings underscore that sustainable transformation in chemistry education requires systemic coherence across curriculum standards, pedagogy, assessment, and institutional support. Future research should move beyond needs analysis to evaluate the design and impact of sustainability-integrated pedagogical models within the matriculation setting.

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