Operationalising the SDGs in Hospitality Education: A KAP-Based Quasi-Experiment in a University Restaurant Laboratory

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ABSTRACT

This study evaluates an SDGs-embedded pedagogy for hospitality education using a Knowledge–Attitude–Practice (KAP) lens in a university restaurant laboratory. Nineteen second-year students completed a one-group pretest–posttest intervention supported by process evidence (observations, reflections, focus groups, and customer feedback). The design integrated industry co-teaching, structured brainstorming, two operational service cycles, and green cleaning/resource-circulation routines. Paired-sample tests indicated significant pre-post gains in SDGs knowledge (8.32→9.63), attitudes (4.41→4.80), and practices (3.60→4.44), all $p < .001$, with large within-group effects ($d \approx 1.09$-1.31). Given the single-group design and partially self-reported measures, findings are interpreted as feasibility and directional change rather than definitive causal effects. Thematic analysis suggests that expert demonstration, proceduralized workflows, whole-food utilization, energy-efficient cooking, traceable sourcing, and guest-facing sustainability communication helped translate concepts into role-specific routines, consistent with dynamic links among K, A and P. The study offers an adaptable course architecture mapping SDGs indicators to culinary roles and identifies implementation conditions for resource-constrained programmes.

Keywords: SDGs literacy, KAP model, Hospitality education, Restaurant laboratory, Sustainable culinary skills, Quasi-experimental design

1. Introduction

Taiwanese higher education has accelerated efforts to embed environmental protection, carbon reduction, and eco-friendly practices into institutional policy and curricula, extending "green" concepts into campus operations and daily life to cultivate students' sustainability literacy. As universities shift from single-discipline instruction to interdisciplinary teaching and research, sustainability education, especially around the United Nations' (UN) Sustainable Development Goals (SDGs), increasingly emphasises cross-domain integration and hands-on application [1]. Yet

classroom observations in hospitality programs indicate that, prior to entering university restaurant laboratories (on-campus training restaurants), many students lack foundational knowledge of sustainable foodservice. Recurring issues such as food and energy waste and weak implementation of the "three Rs" (reduce, reuse, recycle) highlight the need for pedagogy that is teachable, learnable, and assessable, translating SDGs from abstract ideals into concrete behaviours and professional competencies aligned with institutional development plans [2].

The course examined here targets SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), and SDG 12 (Responsible Consumption and Production). Through industry co-teaching and practice-based tasks, it integrates low-carbon menu design, energy-efficient cooking, food upcycling, and local/traceable sourcing into routine restaurant operations. This instructional design avoids treating sustainability education as mere conceptual advocacy or isolated skill training, instead positioning sustainability as an integral part of everyday managerial decision-making and service workflows. Such an approach responds to growing scholarly calls that education for sustainable development must be embedded within professional practice systems rather than delivered as a "bolt-on" or supplementary module [1], [3], [4]. By adopting team-based task allocation and a learning-by-doing pedagogy, the course further enhances students' applied understanding of how the SDGs can be operationalized within restaurant contexts, strengthening both their practical competencies and sustainability-oriented professional capacity.

To address the instructional gap, we adopt the Knowledge–Attitude–Practice (KAP) model as the organising framework for pedagogy and assessment. Rather than treating KAP as a strictly linear evaluative sequence, we use it as a lens to examine how sustainability learning unfolds in vocational settings. Although cognitive–affective–behavior perspectives often assume that knowledge and attitudes lead to behavioral change, research on the knowledge-action (and attitude–behaviour) gap shows that these links are contingent and frequently non-linear [5].

Recent work in professional training contexts proposes a "practice primacy" mechanism, whereby repeated enactment of sustainability routines, supported by feedback and accountability, can strengthen attitudes and deepen knowledge, creating reciprocal links among K, A, and P [6]. The restaurant laboratory provides an appropriate setting to examine this possibility because it combines authentic operational constraints with expert modelling and timely feedback. This design allows us to explore whether situated practice can translate SDGs concepts into role-specific competencies more effectively than classroom-only instruction.

Accordingly, this study pursues three aims: (1) to operationalise SDGs literacy through a KAP-informed, practice-based restaurant-laboratory intervention; (2) to assess pre–post changes in K, A, and P; and (3) to integrate quantitative outcomes with process evidence to clarify how enacted practice interacts with knowledge and attitudes during learning [4]. In doing so, the study evaluates both outcome patterns and explanatory mechanisms linking course design features (e.g., industry co-teaching, structured tasks, live service cycles) to observable sustainability routines.

Although the study is conducted in Taiwan, the pedagogical architecture and KAP-based assessment logic are designed to be adaptable across hospitality education contexts internationally [1]. Conceptually, it renders SDGs literacy empirically assessable by treating KAP as a contingent learning system rather than a purely evaluative sequence [6]. Pedagogically, it offers a structured

restaurant-laboratory model that maps SDG indicators to role-specific tasks and integrates process evidence for instructional evaluation. Empirically, it triangulates pre-post outcomes with behavioural evidence to link course mechanisms to sustainable culinary capabilities including whole-food utilisation, energy-efficient workflows, local sourcing, and customer-facing sustainability communication, thus translating abstract SDGs into executable professional actions.

2. Literature Review

2.1 KAP Model in Higher Education and the SDGs Context

The UNs' SDGs provide a global blueprint for integrated progress across economic, social, and environmental dimensions [7]. Comprising 17 goals, 169 targets, and 232 indicators, the SDGs framework seeks to catalyse systemic transformation toward a more sustainable future [8]. The goals are deeply interdependent, often involving feedback loops and cross-domain trade-offs. Meaningful progress toward the 2030 Agenda therefore requires coordinated and complementary actions that minimize trade-offs while maximizing synergies among targets [9].

Within this context, higher education institutions (HEIs) have been widely recognised as key actors in advancing the SDGs agenda not only through developing professional talent but also by embedding sustainability into institutional governance, curricular innovation, and community engagement [10], [2]. Among the 17 goals, SDG 4 (Quality Education) is frequently viewed as a foundational enabler for progress on the others [11]. However, the challenge lies not merely in incorporating sustainability-related content, but in translating the SDGs, given their highly interconnected and interdisciplinary nature, into learning outcomes that are teachable, learnable, and assessable [12].

Despite growing scholarly attention to sustainability competencies and literacy, empirical research remains limited regarding what students actually learn and how such learning can be reliably assessed [13]. Many HEIs struggle to integrate the SDGs systematically into curricula due to the absence of operational frameworks and concrete assessment tools [14]. Consequently, sustainability education risks remaining declarative or fragmented rather than embedded within professional practice. Addressing this gap requires pedagogical models that enable SDGs to be operationalized into measurable learning designs, thereby avoiding symbolic or "bolt-on" educational approaches.

The hospitality sector, given its material intensity and public visibility, is considered a high-priority arena for sustainability action. Early work by Diamantis and Ladkin [15] underscored the need to "green" hospitality education to build resilience in tourism and foodservice operations. Contemporary studies further link hospitality practices with SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), focusing on energy and water conservation, sustainable sourcing, waste reduction, and sustainability communication with guests [16], [17]. Compared to more general sustainability courses, the restaurant laboratory offers a quasi-authentic learning environment in which students can engage with sustainability through role-specific, hands-on procedures. Within such settings, students operationalize sustainability through menu development, standardized energy-efficient cooking techniques, local and traceable procurement, waste reduction and upcycling practices, and green communication in front-of-house service. These highly contextualized environments allow

sustainability principles to be translated into routinized operational decisions, making campus-based practice spaces effective testbeds for innovative pedagogies [14]. Importantly, hospitality operations involve behaviors such as cutting techniques, cooking methods, and portion control that directly influence food waste outcomes and are observable and manageable in practice-based contexts [18]. This observability is critical, as prior research consistently demonstrates a gap between students' sustainability awareness and their actual behaviors [19].

In this context, the KAP model provides a structured lens for tracing how sustainability literacy progresses from awareness to action. While KAP is often used as an evaluative sequence, we treat it here as a mid-range learning theory whose links are contingent on practice conditions, enabling both process-level explanation and assessment of observable behavioural outcomes. KAP is commonly represented as a K–A–P pathway, in which knowledge relates to attitudes and both are associated with practice [20]. Empirical studies frequent report relationships among these domains; for example, Afroz and Ilham [20] identified significant links between attitudes and practice among Malaysian university students, though they noted the gap between knowledge and action. Similarly, Serwah et al. [22] reported that hotel staff in Ghana exhibited significant alignment across the three domains when engaging with indigenous culinary sustainability.

However, the literature cautions that the K–A–P relationship is neither automatic nor strictly linear. Knowledge acquisition alone is often insufficient to produce sustained behavioral change, and positive attitudes do not necessarily translate into action [5]. Recent work further suggests that practice may sometimes precede and shape cognition: a "practice primacy" mechanism process posits that enacted habits and resource investment can be stronger predictors of pro-environmental behavior than attitude alone, potentially generating feedback loops in which practice reinforces knowledge and attitudes [6]. Accordingly, the strength and occasionally the direction of K, A, and P linkages may vary by learning design and implementation context, particularly in authentic service settings characterised by visibility, accountability, and rapid feedback.

This persistent attitude–behavior gap highlights the need for pedagogical interventions that support the translation of sustainability understanding into situated professional practice. Research suggests that such translation requires robust instructional scaffolding, including expert modeling and immediate feedback to bridge the theory-practice divide [23], as well as real-world simulations, peer collaboration, and structured reflection to deepen critical engagement [1], [4].

Accordingly, the value of the KAP framework extends beyond its use as a pre- and post-assessment tool. It also functions as a pedagogical logic for examining how educational design facilitates behavioral change. In hospitality education, particularly within restaurant laboratory settings, the KAP model enables SDGs to be transformed from abstract sustainability ideals into measurable, comparable, and transferable competencies, linking curriculum design directly to observable professional practice and sustainability capability development.

2.2 Industry Co-Teaching and Situated Practice in Hospitality Education

Recent developments in hospitality education have moved toward industry-embedded co-teaching and experiential projects and toward design-thinking and collaborative learning approaches that structure ideation and inquiry [24], [25]. Industry co-teaching enables the infusion of current operational protocols, workplace standards, and sustainability practices directly into the learning

environment, effectively narrowing the theory–practice divide through expert modelling, hands-on exercises, and formative feedback loops [26]. Simultaneously, collaborative learning formats, particularly brainstorming-based ideation, encourage cross-role engagement and cultivate creative thinking, both of which are essential for menu innovation, workflow design, and real-time problem-solving within restaurant operations [25], [30].

A growing body of empirical research confirms that co-teaching and closely aligned formative, process-oriented feedback can enhance students' learning strategies, motivation, and self-efficacy, particularly when feedback is actionable and iterative [27], [28], [29]. These instructional scaffolds support the cognitive and affective transitions required for knowledge to translate into sustained practice, aligning directly with the KAP model. Brainstorming, in particular, has been shown to stimulate idea generation, creativity, and collaborative engagement in higher education settings [30], consistent with SDG 4's emphasis on active, participatory, and competency-oriented learning [31]. Within the context of a restaurant laboratory, such pedagogical approaches can therefore be understood as learning accelerators that facilitate the K → A → P progression by embedding sustainability into authentic task performance.

The urgency of integrating such approaches is amplified by global sustainability imperatives. According to the United Nations Environment Programme (UNEP), approximately one billion tonnes of food were wasted globally in 2019, contributing to 8–10% of global greenhouse gas emissions [32]. In response, SDG 12 (Responsible Consumption and Production) calls for halving per capita global food waste by 2030 at both retail and consumer level [7].

In the hospitality domain, this mandate translates into a range of actionable touchpoints, including traceable sourcing, inventory and waste optimisation, whole-food utilisation, upcycled leftovers, energy-efficient cooking methods, and sustainability communication with guests [33], [16]. These domains serve not only as teaching content, but as observable performance anchors, allowing instructors to assess students' progression from knowledge and attitude to demonstrable professional behaviours. By situating SDGs-related competencies within real-world kitchen and service settings, including featuring rotating roles, menu execution, and direct customer interaction, students are more likely to internalise sustainability not as abstract moral positioning, but as an embodied, repeatable professional routine (Yang et al., 2025).

2.3 Synthesis and Hypotheses

Building upon the preceding discussions, hospitality higher education requires an instructional and evaluative framework that can capture students' development in sustainability knowledge, attitudes, and practice in ways that are meaningful for professional work. At the same time, treating KAP as a strictly linear K→A→P sequence risks underestimating the knowledge-action gap, whereby awareness and favourable attitudes do not reliably translate into sustained behavior [5]. Accordingly, we conceptualise KAP as a contingent learning system and examine a "practice primacy" possibility: In practice-based training, repeated enactment of sustainability routines, supported by feedback and accountability may catalyse and consolidate learning, potentially generating reciprocal links in which practice reinforces attitudes and knowledge [6].

To test this perspective in a quasi-authentic learning environment, we designed a restaurant laboratory intervention that embeds SDGs-aligned routines, including low carbon menu design,

traceable procurement, whole-ingredient utilization, and energy-efficient cooking, into role-specific culinary tasks, supported by expert modelling and real-time feedback [23]. The intervention was evaluated using pre–post change in KAP outcomes.

Guided by this synthesis, we propose:

• H1 (Knowledge): Students' SDGs-related knowledge will increase following the intervention.

• H2 (Attitude): Students' sustainability attitudes will improve following the intervention.

• H3 (Practice): Students' sustainable foodservice behaviors will improve following the intervention.

By linking SDG indicators to role-specific tasks and evaluating outcomes in an authentic service context, this study responds to calls to move beyond attitudinal advocacy toward observable, measurable sustainability competencies in hospitality education.

3. Research Design

3.1 Context and Course Setting

This study was situated within a second-year compulsory undergraduate course, Restaurant Management Practice, offered by the Department of Culinary Management at a university in Taiwan. The course carries four credits and comprises eight instructional hours per week. Practical components are delivered through the restaurant laboratory, Ju Xuan Ting, where students rotate between Front-of-House (FOH) and Back-of-House (BOH) roles during themed restaurant operations.

Prior to participating in this course, students had completed prerequisite modules in Chinese culinary arts, baking, hospitality service management, and menu design. Building upon this foundational knowledge, the Restaurant Management Practice course was designed to integrate sustainability literacy, explicitly aligned with four SDGs: SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), and SDG 12 (Responsible Consumption and Production). Through industry co-teaching, the course embedded core sustainability competencies into students' day-to-day culinary and service responsibilities [23], [26].

In addition to technical instruction, students participated in structured brainstorming activities to collaboratively design sustainable menus [30], [38]. These were subsequently implemented in the restaurant laboratory under real-time conditions. Changes in performance and professional behavior were assessed through direct observation and triangulated with pre- and post-intervention KAP survey instruments. This research design enabled the pedagogical alignment of conceptual knowledge and value formation with observable actions in an authentic learning environment, facilitating experiential and reflective learning through situated practice [4], [28].

3.2 Design and Conceptual Framework

This study employed a single-group pretest–posttest design anchored in the KAP framework. Given the authentic educational setting and the intensive nature of the restaurant laboratory intervention, we adopted an exploratory action research orientation. We acknowledge that the absence of a control group constrains causal inferences regarding the intervention's isolated effects [34]. Accordingly, the primary objective was to evaluate feasibility and examine preliminary outcome patterns rather than to establish definitive causal relationships.

Consistent with this aim, the study focused on theory-informed instructional evaluation. To

reduce common validity threats in single-group designs, we triangulated quantitative pre–post shifts with qualitative and process evidence to contextualize learning outcomes and strengthen interpretive credibility [4]. Specifically, we assessed changes in students' SDGs-related knowledge (K), attitudes (A), and sustainable foodservice practices (P), and explored whether linkages among K, A, and P reflected a strictly sequential pathway or a practice-driven feedback process in which enacted routines reinforce attitudes and knowledge [6].

The study involved 19 participants and no comparison group, which also introduces statistical constraints associated with small samples. However, in course-based instructional intervention research, developmental phase studies commonly employ small, non-randomized designs to examine feasibility and preliminary effectiveness [4], [34]. While such designs are not intended to generate generalizable causal models, they are useful for identifying directional change patterns and surfacing process-level insights that inform subsequent confirmatory research with larger and more diverse samples [35].

As depicted in Figure 1, the intervention was driven by two complementary pedagogical engines. First, industry co-teaching brought current operational standards and sustainability practices into the learning environment through expert demonstration, guided rehearsal, and formative feedback s [26], [23]. Second, design-based collaborative learning (e.g., structured brainstorming) scaffolded menu co-creation and operational problem-solving [25], [30]. Students completed two full operational cycles in the restaurant laboratory, rotating across kitchen and service roles while enacting SDGs-aligned tasks, such as local/traceable sourcing, whole-food utilisation, food-waste upcycling, energy-efficient cooking, guest-facing sustainability communication.

Outcomes were assessed with the KAP instrument at Week 1 (pretest) and Week 18 (posttest) [21]. In parallel, process evidence, instructor observations, reflective journals, feedback sheets, and focus-group interviews, were gathered across both operational runs to illuminate change mechanisms [4], [35]. In Figure 1, arrows indicate both measurement points and the hypothesised linkages among K, A, and P, supporting integration of quantitative gains with a qualitative account of how students internalised SDGs content and translated it into observable, role-specific behaviours [6].

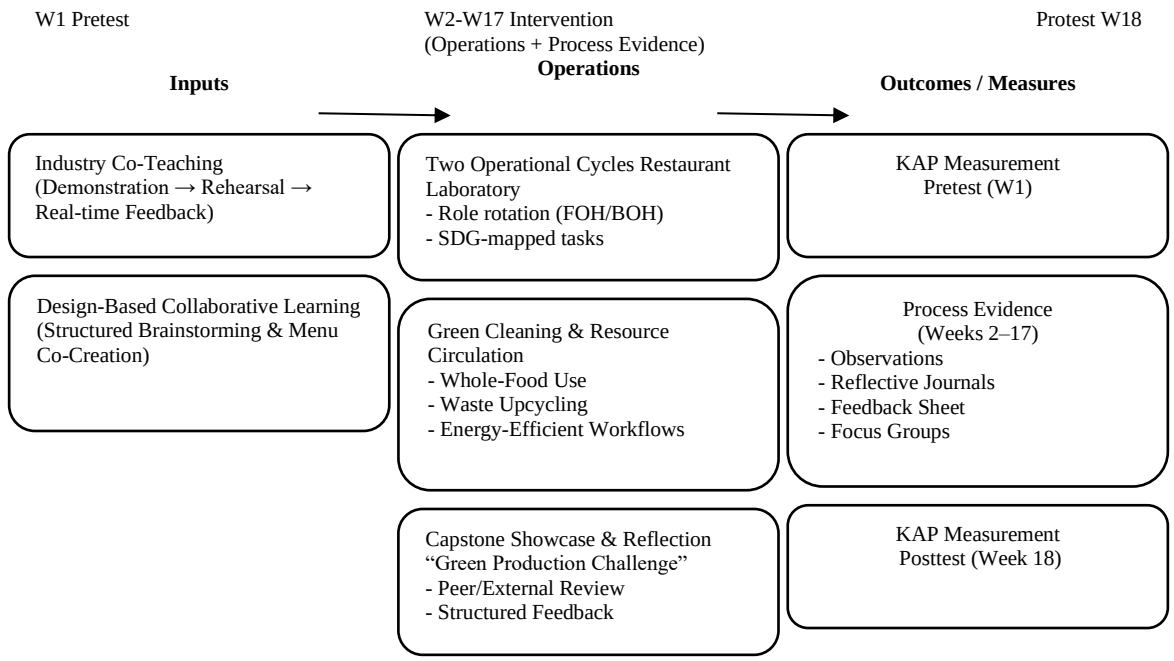

Figure 1. Conceptual framework and measurement timeline
Source: By the authors

3.3 Intervention Timeline and Data Collection

The intervention was implemented as planned, with all scheduled sessions and contact hours completed in full. The study followed a fixed timeline: study briefing and informed consent → pretest (Week 1) → instructional/intervention period (Weeks 2–17) → posttest (Week 18). Figure 1 visualises measurement timing and data flow; Table 1 maps course units to their corresponding SDGs indicators, providing a transparent link between instructional content and assessed competencies.

Table 1. Mapping of SDG indicators to course units (Weeks 1–18)

Week(s)	Unit / Theme	Content	Notes (What is strengthened)	SDGs Indicators
1	Course Orientation & SDGs Introduction	SDGs concepts; low-carbon ingredients and "imperfect/ugly" produce; course briefing and team formation; **KAP pre-test**; class LINE group set-up	★ Promote SDGs literacy; establish communication and baseline	
2, 4, 9	Education Intervention - Industry Co-Teaching	Demonstrations: (i) low-carbon global cuisine; (ii) energy-efficient cooking; (iii) food upcycling	★ Skills advancement; ★ Embedding SDGs literacy in operations	
2, 9	Education Intervention - Brainstorming Application	Head-chef team menu workshops; structured brainstorming; traceable sourcing & procurement planning	★ Output of creative low-carbon/energy-saving menus; ★ Traceability planning	

Week(s)	Unit / Theme	Content	Notes (What is strengthened)	SDGs Indicators
3, 10	· Low-Carbon Menu Piloting & Clean Production	Pilot tests; cost control & review; natural cleaner making; clean production & sustainable economy concepts	★ Reflect–revise menus; ★ Execute traceable sourcing; ★ Make natural cleaning agents; ★ Costing practice	
5 - 8	· Operational Run 1 - Rotating Themed Service	Thai / Japanese / Cantonese / French service weeks	★ Execute traceable sourcing; ★ Apply SDGs literacy; ★ Green marketing; ★ Customer satisfaction survey & analysis	 + FOH green communication
11 - 15	· Operational Run 2 - Fixed Menu Service	Fixed menu: Southeast Asian / Hakka / Korean / Italian	★ Execute traceable sourcing; ★ Apply SDGs literacy; ★ Green marketing; ★ Customer satisfaction survey & analysis	 + service process optimisation
16	· Showcase & Qualitative Evidence Collection	Capstone showcase & competition "Green Production Champions"; corporate SDG sharing talk	★ Public presentation; ★ External/peer evaluation; ★ SDGs literacy in outcomes	 (practice consolidation)
17	· End-of-Term Clean-Up & Inventory	Classroom deep clean; equipment inventory; satisfaction check on natural cleaners	★ Green cleaning routines; ★ Asset stewardship	 (waste / chemicals reduction)
18	· Learning Outcomes Assessment	Final report submission; **KAP post-test**	★ Evaluate learning effectiveness (pre–post)	KAP (K–A–P change)

Source: Authors' course documentation and mapping to SDGs indicators.

3.4 Participants

The study involved second-year undergraduate students enrolled in the required course Restaurant Operations Management I & II. After excluding students who did not complete the full intervention protocol, the final analytical sample comprised 19 students. Participant demographics, including gender, academic level, and course retake status are detailed in Table 2. As enrollment was determined by course requirements, the study employed a convenience sampling approach. Considerations regarding generalizability and external validity are addressed in the Methods and Limitations section.

At the course orientation, students were briefed on the purpose of the study, data collection procedures, anonymization measures, and their right to withdraw at any time. Informed consent was obtained from all participants. All feedback forms and interview transcripts were de-identified, and only aggregated findings or anonymized quotations were used in reporting. The study adhered to institutional research ethics guidelines throughout.

Table 2. Participant demographics

Category	Option	N		%	
		1st Semester	2nd Semester	1st Semester	2nd Semester

Gender	Male	11	10	52.38%	52.63%
	Female	10	9	47.62%	47.37%
Academic Year	Year 2	19	19	90.48%	100%
	Year 3	1	0	4.76%	0%
	Extended Study	1	0	4.76%	0%
Retaking Course	Yes	2	0	9.52%	0%
	No	19	19	90.48%	100%

Source: By the authors.

3.5 Measurement and Instrumentation

In addition to demographic information, this study used three quantitative instruments to assess student outcomes: (1) Course Learning Outcomes, (2) Core Competencies, and (3) a SDGs-related KAP scale. To mitigate limitations of self-report, especially for Practice (P), survey measures were complemented by behavioural evidence derived from course artefacts and operational records.

1. Course Learning Outcomes: A seven-items scale assessed competencies in restaurant operations, including menu design, procurement, food preparation, FOH service, operations management, marketing, and SDGs-aligned practices.
2. Core Competencies: A ten items instrument assessed six professional competencies and four transferable skills (e.g., communication, teamwork, innovation), derived from the programme curriculum map and institutional standards. Both Course Learning Outcomes and Core Competencies used a five-point Likert scale and were administered at Week 1 (pre-test) and Week 18 (post-test).
3. SDGs-related KAP scale: Adapted from Afroz and Ilham [21], the KAP instrument contained 38 items; Knowledge (K) comprised 10 dichotomous items (Yes = 1; No = 0; range 0–10); Attitude (A) comprised 14 items on a five-point agreement scale; and Practice (P) comprised 14 items on a five-point frequency scale. Items were reviewed by domain experts and piloted for clarity and contextual fit. To enhance behavioral objectivity, instructor grading rubrics were retrospectively mapped to Ko and Hong's [16]. "food waste avoidance behavior indicators" (e.g., removing excessive edible parts, water flow control). Objective operational artifacts (e.g., traceable receipts, menu cost-control logs) were also examined to corroborate the self-reported Practice scores.
4. Behavioural evidence protocol: Practice (P) was further operationalised using coded behavioural evidence from (a) weekly reflective journals/homework, (b) instructor observation notes during restaurant operations/co-teaching, (c) customer feedback forms, and (d) end-of-course focus-group transcripts. Additional artefacts (e.g., task checklists/learning sheets, procurement receipts, cost-control logs) supported corroboration. Extracts were indexed to an audit trail (source type, week/cycle, participant/group ID). Coding was directed by SDGs task mapping and restaurant performance anchors, focusing on enacted practices: (i) whole-ingredient utilisation/upcycling, (ii) energy-efficient cooking, (iii) traceable/local sourcing, (iv) green cleaning/resource circulation, (v) waste measurement/cost control, and (vi) guest-facing sustainability communication. Given the single-instructor delivery context, IRR statistics were not computed; credibility was supported through a codebook/audit trail

and iterative recoding with cross-source convergence checks. Code-occurrence summaries were compiled descriptively by data source and operational cycle (Cycle 1 vs. Cycle 2).

3.6 Intervention Components

The pedagogical intervention was designed in alignment with relevant literature and course-specific learning objectives, comprising two instructional modules and four structured, practice-based components. This design aims to systematically translate sustainability competencies into observable professional behaviors within an authentic learning environment.

The first instructional module involved co-teaching with industry experts, who delivered sessions based on three core themes: low-carbon global cuisine, energy-efficient cooking techniques, and food upcycling practices. Each session followed a structured progression of demonstration, role-rotated practice, and real-time feedback, enabling students to internalize sustainability standards and operationalize them through hands-on procedures. This approach sought to narrow the theory–practice gap by embedding professional norms directly into the student restaurant context.

The second instructional module introduced structured brainstorming as a collaborative problem-solving tool. Under the leadership of rotating student "Head Chefs," teams co-developed low-carbon, energy-saving menus, conducted cost analysis, and designed service workflows supported by local sourcing plans, traceability checklists, and inventory control strategies. This module promoted creative autonomy while providing scaffolding for sustainability-driven menu design and operations planning.

Four core practice components were embedded to reinforce learning in real-world contexts:

1. Two-cycle restaurant operations (Weeks 5–8 and Weeks 11–15) featured both rotating themed menus (e.g., Thai, Japanese, Cantonese, French) and fixed menu service formats (e.g., Southeast Asian, Hakka, Korean, Italian). Students rotated through BOH and FOH roles, applying sustainability principles such as traceable sourcing, green menu storytelling, and sustainability communication with guests. Customer feedback was collected through satisfaction surveys to monitor student performance and inform real-time adjustments.
2. The green cleaning and resource circulation module provided experiential exposure to environmental hygiene and waste reduction. Students produced natural cleaning agents, managed food waste upcycling (e.g., using imperfect ingredients or transforming scraps into flavored water or jam), and optimized kitchen workflows for energy-efficient operations. These actions were directly linked to SDG 12 (Responsible Consumption and Production) and evaluated as observable behavioral indicators.
3. A final presentation and internal competition was held in Week 16 under the theme "Sustainable Production Champions." Teams showcased their outcomes to peers and a panel of external industry judges. Presentations were assessed for both process quality and output deliverables. Structured feedback from judges was used as a formative assessment and reflective learning tool.
4. The closing phase (Weeks 17–18) involved equipment audits, environmental cleanup, and submission of individual reflective learning reports. During this phase, the post-intervention KAP survey was also administered to measure overall program effectiveness.

A full alignment of the instructional modules, operational tasks, and associated SDGs indicators

is provided in Table 1, illustrating how conceptual learning was embedded across all stages of the intervention.

3.7 Data Analysis

This study employed a paired-sample mixed-methods design. Quantitative, two-tailed paired-sample t-tests assess pre–post differences in KAP, course learning outcomes, and core competencies. Effect sizes were calculated as Cohen's d ($d = t/\sqrt{n}$), and 95% confidence intervals were reported. Given the small sample (N = 19) and single-group design, results are interpreted as feasibility and directional change rather than definitive causal effects [34]. To enhance robustness and mitigate threats to internal validity, such as maturation or testing effects, these quantitative findings were rigorously triangulated with qualitative process evidence and behavioural artefacts to examine convergence with students' enacted practices [4]. Missing data below 5%, were handled with pairwise deletion. Assumptions were checked using standard diagnostics on change scores; sensitivity checks were conducted where applicable.

Qualitatively, behavioural evidence protocol operationalised Practice (P) beyond self-report using thematic procedures (open coding, theme development, and iterative refinement) directed by the SDG task-aligned practice-code scheme. Instances were defined as explicit descriptions or observations of actions taken, workflow steps/tools used, or operational decisions made, and extracts were indexed to an audit trail (source type, week/cycle, participant/group ID). To enhance behavioral objectivity, relevant observational evidence was mapped to Ko and Hong's [16] "food waste avoidance behavior indicators". Coding was conducted by the course lecturer/instructor; a second researcher reviewed a subset of coded excerpts (~20% stratified by data source and operational cycle) and disagreements were resolved through discussion and codebook refinement. Because only a limited subset was double-coded and the primary coding was course-embedded, IRR coefficients were not computed [35]. Code-occurrence summaries were compiled descriptively by data source and operational cycle.

Qualitative findings functioned as coded behavioural evidence to corroborate quantitative outcomes to identify mechanisms linking instructional components (e.g., co-teaching, structured brainstorming, dual-cycle operations) with shifts in self-efficacy, value alignment, and enacted sustainability routines. A triangulated interpretation synthesized quantitative and qualitative evidence to strengthen explanatory coherence and overall credibility.

4. Results and Discussion

4.1 Teaching Outcomes

This study sought to cultivate students' professional competencies in energy-efficient cooking and sustainable food production, underpinned by SDGs literacy and practical application. Central to the intervention were principles of whole-food utilization, waste minimization, and energy-efficient culinary practices, which collectively aimed to reduce the environmental footprint of foodservice operations. Many students entered the course with limited prior exposure to sustainability-related concepts; however, the course fostered not only substantial knowledge acquisition but also a shift in mindset, as students expressed greater motivation and willingness to adopt sustainable behaviors in both professional and personal contexts.

The curriculum design featured a multi-modal learning structure that blended theoretical foundations with experiential practice. Across the semester, students participated in two industry-led seminars on sustainable hospitality, eight hands-on co-teaching sessions, and a culminating presentation showcase. Student feedback consistently reflected high satisfaction, with many highlighting the emotional fulfilment of contributing to planetary wellbeing through food choices and service practices.

4.1.1 Evaluation of teaching activities and self-reported learning

The co-teaching model encompassed a diverse set of learning activities, including sous-vide cooking, food upcycling, plating aesthetics, and a French pastry workshop, each designed to illustrate sustainability through both technique and presentation. These were complemented by thematic lectures on sustainable restaurant operations and the practical implications of SDGs-aligned management. A highlight of the semester was the integrative instructional unit titled "Theory–Practice Synergy in Sustainability", designed by the lead instructor to bridge abstract SDGs concepts with tangible practices during live restaurant service.

As shown in Table 3, the French pastry workshop was rated highest in terms of visual engagement (45.5%) and enjoyment (36.4%) yet was also ranked among the most challenging activities (30.0%)—underscoring the pedagogical value of high-engagement, high-complexity learning moments. Meanwhile, the "Theory–Practice Synergy" module received the highest rating for sustainability relevance (54.5%), indicating that students perceived the integration of conceptual frameworks with hands-on application as both meaningful and effective.

In sum, these findings suggest that combining cognitive insight with embodied practice not only enhances student engagement and motivation but also facilitates the development of a sustainability-oriented professional identity. Through repeated exposure to sustainability principles in real-time restaurant contexts, students demonstrated greater confidence and intentionality in aligning culinary decisions with environmental responsibility.

Table 3. Student evaluation of sdgs-integrated teaching activities

Activity / Component	Easiest (%)	Most Enjoyable (%)	Favorite (%)	Most Inspiring (%)	Most Rewarding (%)	Most Eye-Catching (%)	Most Sustainable (%)	Most Difficult (%)	Least Enjoyable (%)	Worth Repeating (%)
Low-temp sous-vide cooking	**63.6**	18.2	9.1	**27.3**	**18.2**	9.1	**18.2**	20.0	20.0	9.1
Food upcycling /with industry co-teaching	18.2	9.1	9.1	0.0	9.1	0.0	9.1	0.0	10.0	9.1
Plating and presentation skills	9.1	**27.3**	9.1	**27.3**	**18.2**	18.2	9.1	10.0	20.0	27.3
French pastry workshop /with industry co-teaching	9.1	18.2	**36.4**	0.0	9.1	**45.5**	0.0	**30.0**	10.0	**36.4**
Creative global cuisine /with industry co-teaching	0.0	9.1	**18.2**	9.1	18.2	9.1	0.0	10.0	0.0	0.0
Sustainable hospitality management lecture	0.0	0.0	9.1	18.2	9.1	9.1	9.1	0.0	**30.0**	9.1
"Theory–Practice Synergy in	0.0	18.2	9.1	18.2	**18.2**	9.1	**54.5**	**30.0**	10.0	9.1

Sustainability" module										

Source: Authors' dataset, based on student post-course evaluations (N=19).

4.1.2 Evaluation of the "green production challenge" showcase

The course's experiential learning design significantly enhanced students' engagement with both culinary techniques and sustainability themes. Serving as a capstone assessment, the "Green Production Challenge" was designed to consolidate the pedagogical elements introduced throughout the semester which included low-carbon menu planning, sustainable procurement, energy-efficient cooking, and FOH sustainability communication into a single integrated event.

As shown in Table 4, student feedback was overwhelmingly positive across all measured dimensions. Specifically, 81.8% of participants expressed overall satisfaction with the challenge, while 90.9% reported increased learning motivation and 81.8% indicated enhanced understanding of low-carbon culinary innovation. Importantly, 100% of respondents agreed that the activity was well-conceived and recommended its inclusion in future iterations of the course.

These outcomes reinforce the central theoretical proposition of this study: that experiential learning when combined with expert demonstration and real-world practice functions as a pedagogical accelerator for the K → A → P transformation. By operationalising SDGs concepts within the context of team-based culinary execution and peer/expert evaluation, the challenge enabled students to translate abstract knowledge and attitudinal commitment into observable sustainable practices. The integration of formative feedback, reflective learning, and public presentation further contributed to students' sense of professional identity and agency in sustainability-oriented foodservice.

Table 4. Student perceptions of the "green production challenge" capstone showcase

Items	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)
I was satisfied with the experience.	54.5	27.3	18.2	0.0
I found the activity interesting.	45.5	36.4	18.2	0.0
It increased my motivation to learn.	**63.6**	**27.3**	9.1	0.0
It enhanced my professional knowledge in low-carbon innovation.	54.5	27.3	18.2	0.0
The concept is meaningful and should be continued in future courses.	**63.6**	**36.4**	0.0	0.0

Source: Authors' dataset, based on post-activity student feedback (N=19).

4.1.3 Achievement of course objectives and core competencies

As summarised in Table 5 and Figure 2, students' self-assessment data indicate high levels of perceived achievement across the course's intended learning outcomes. With the exception of "marketing planning," all competency areas received agreement or strong agreement from over 80% of respondents. The highest-rated objective was "SDGs literacy and action competence" (M = 4.63), followed by "restaurant service competence" (M = 4.58) and "operational and managerial capability" (M = 4.53).

Table 5. Achievement of course objectives

Course Objective	Mean	SD	Rank	Strongly Agree (%)	Agree (%)	Neutral (%)
1. Menu design competence	4.21	0.77	**6**	42.1	42.1	15.8
2. Ingredient procurement competence	4.42	0.59	**4**	47.4	47.4	5.3
3. Food preparation competence	4.37	0.67	**5**	47.4	42.1	10.5
4. Restaurant service competence	4.58	0.49	**2**	**57.9**	**42.1**	0.0
5. Restaurant operation and management competence	4.53	0.50	**3**	**52.6**	**47.4**	0.0
6. Restaurant marketing planning competence	4.00	0.92	**7**	42.1	15.8	42.1
7. SDGs literacy and actionable sustainability competence	4.63	0.48	**1**	**36.8**	**63.2**	0.00

Source: Authors' analysis based on post-course survey results (N=19).

These findings underscore the value of embedding SDGs-focused content within vocational culinary education. Rather than competing with core professional skills, sustainability themes were integrated in a way that reinforced and enriched students' development of both technical and managerial competencies. The course design enabled students to approach restaurant operations through a dual lens, applying rigorous professional standards while simultaneously advancing sustainability goals. This dual alignment supports the proposition that SDGs literacy and professional competence are not mutually exclusive but can be mutually reinforcing when aligned through experiential, role-specific, and reflective pedagogy.

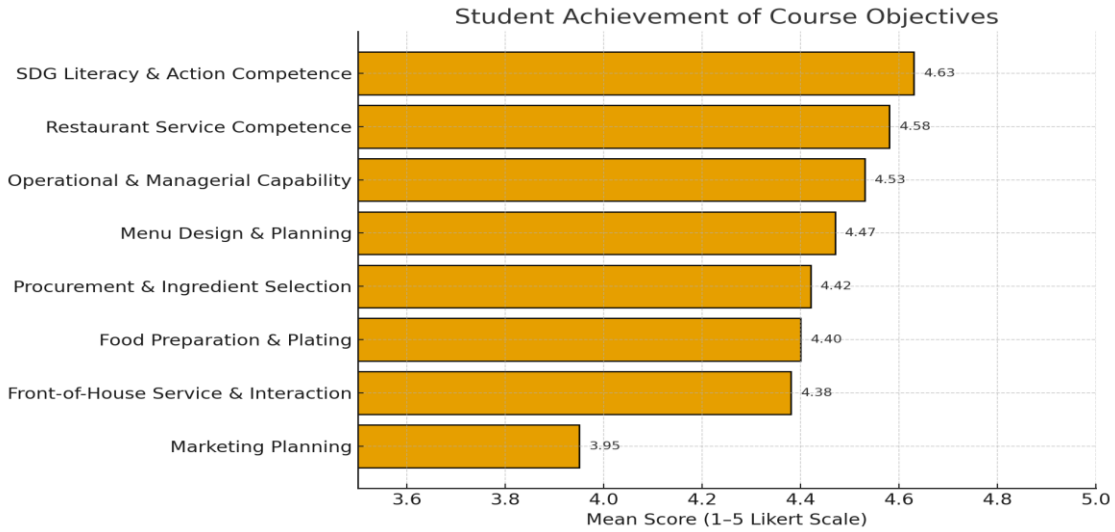

Figure 2. The bar-chart of student achievement scores of course objects

Table 6 and Figure 3, Figure 4 presents students' self-assessed progress in both professional and general core competencies across two semesters. The results indicate substantial improvement following the course intervention. In terms of professional competencies, both semesters recorded significant gains, suggesting that the curriculum effectively deepened students' technical knowledge and operational expertise over time. Notably, "Culinary production" was rated highest in the first semester (M = 4.31), while "Restaurant operation and sanitation self-management" emerged as the top-rated item in the second semester (M = 4.79). These findings demonstrate that students acquired

hands-on proficiency in both food production and restaurant operations.

Table 6. Professional and general core competencies development before and after intervention

Professional Core Competencies	1st Semester			2nd Semester		
	Mean	SD	Rank	Mean	SD	Rank
1. Restaurant Operation & Sanitation Self-management	4.11	0.49	4	4.79	0.52	**1**
2. Service Management Competency	4.15	0.40	**3**	4.58	0.49	**2**
3. Culinary Production Competency	4.31	0.55	**1**	4.53	0.50	**3**
4. Beverage Production Competency	4.20	0.49	**2**	4.21	0.52	5
5. Professional Foreign Language Communication	3.70	0.75	5	3.88	0.86	6
6. Information Application in F&B	3.63	0.63	6	4.42	0.59	4
General Core Competencies	**1st Semester**			**2nd Semester**		
	Mean	SD	Rank	Mean	SD	Rank
1. Responsibility and Teamwork Competence	4.20	0.52	**1**	4.58	0.49	**2**
2. Interpersonal and Communication Competence	4.11	0.48	**3**	4.84	0.36	**1**
3. Cultural Literacy and Multicultural Perspective Understanding	4.05	0.71	**4**	4.47	0.60	**4**
4. Innovation and Interdisciplinary Learning Competence	4.13	0.59	**2**	4.58	0.49	**2**

Source: By authors.

For general (transferable) competencies, marked improvements were observed in the second semester, particularly in interpersonal communication and teamwork. These gains reflect the course's strong emphasis on soft skills development. "Responsibility and teamwork" received the highest score in the first semester (M = 4.20), whereas "Interpersonal interaction and communication skills" showed the greatest growth and highest rating in the second semester (M = 4.84). This suggests that repeated participation in collaborative restaurant operations, co-teaching activities, and public presentations contributed meaningfully to students' personal and professional growth.

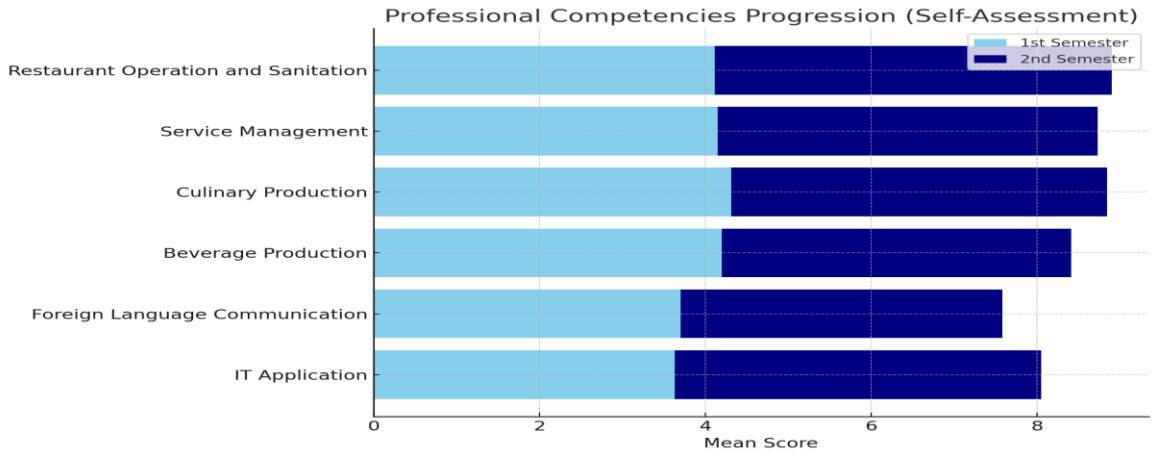

Figure 3. The bar-chart of professional competencies progression scores

Taken together, the results underscore the dual impact of the course design: simultaneously

promoting sustainability literacy and advancing core employability competencies. By integrating the KAP-based SDGs framework with practice-based industry co-teaching, the intervention yielded both domain-specific and transferable learning outcomes aligning with the holistic competency requirements of the modern hospitality industry.

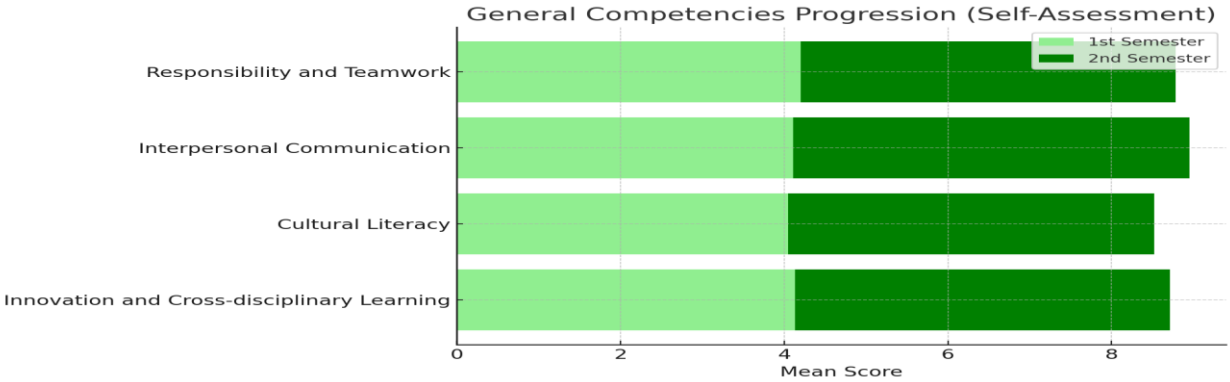

Figure 4. The bar-chart of general competencies progression scores

4.2 Key Outcomes: Changes in SDGs Knowledge (K), Attitudes (A), and Practices (P)

To evaluate the impact of the pedagogical intervention, paired-sample t-tests were conducted to examine differences in students' SDGs-related knowledge (K), attitudes (A), and practices (P) before and after the course (see Table 7). The results revealed statistically significant improvements across all three domains: knowledge increased from 8.32 to 9.63, attitudes from 4.41 to 4.80, and practices from 3.60 to 4.44 (all $p < .001$).

To assess the practical significance of these gains, Cohen's d was calculated using the formula $d = t/\sqrt{n}$ (where $n = 19$). All three outcomes demonstrated large effect sizes: Knowledge ($d \approx 1.09$), Attitude ($d \approx 1.23$), and Practice ($d \approx 1.31$). These values indicate substantial learning effects aligned with the intervention.

Importantly, the greatest improvement was observed in Practice (P), reflecting the course's emphasis on processual and operationalised sustainability. Key elements contributing to this outcome included menu co-design, whole-food utilisation, energy-saving cooking techniques, traceable procurement, food waste upcycling, and guest-facing sustainability communication. These findings affirm the study's central hypothesis: that increases in knowledge and attitudinal alignment were successfully translated into observable, domain-relevant behaviors.

Table 7. Paired-sample t-test results for sdgs knowledge, attitude, and practice (two-tailed)

Variable	**Pre, *M* (SD)**	**Post, *M* (SD)**	**Mean Diff**	***t***	**df**	***p***	***d***	**95% CI for Diff**
Knowledge	8.32 (1.34)	9.63 (0.58)	1.32	4.76	18	< .001	1.09	[0.74, 1.90]
Attitude	4.41 (0.53)	4.80 (0.48)	0.39	5.35	18	< .001	1.23	[0.23, 0.53]
Practice	3.60 (0.69)	4.44 (0.36)	0.84	5.72	18	< .001	1.31	[0.53, 1.15]

Note. Two-tailed paired t-tests. Cohen's d = t/√n; CIs are for the mean difference (Post–Pre).

4.3 Qualitative Insights: Mechanisms Linking K, A and P in Practice -Based Learning

Embedding SDGs literacy within the Restaurant Operations Management course enabled students to apply sustainability concepts through authentic service practice. Students reported increased competence and development across knowledge (K), attitude (A), and practice (P). To reduce reliance on self-report, qualitative analysis treated multiple artefacts as behavioural evidence, including reflective journals, focus-group transcripts, instructor observation notes from restaurant operations, and customer feedback forms.

Using a directed practice-code scheme aligned with SDGs task anchors, we coded enacted practices and assessed convergence across sources (e.g., whether a practice described in reflections was also evidenced in observation notes or customer feedback). Descriptive code-occurrence summaries indicated that whole-ingredient utilisation/upcycling and energy-efficient cooking recurred most consistently, whereas traceable sourcing and guest-facing sustainability communication were more concentrated in live-service episodes, suggesting context-dependent enactment.

Thematic analysis identified four mechanisms that translated SDGs concepts into role-specific routines. First, industry co-teaching functioned as a catalyst, expert demonstrations (e.g. low-temperature sous-vide cooking) clarified how sustainability can improve quality and efficiency, strengthening and making abstract principles actionable. Second, whole-ingredient utilisation and upcycling shifted attention from waste reduction to resource regeneration through practices such as using cosmetically imperfect produce, repurposing food scraps, and creating DIY eco-cleaning agents, reinforcing cost awareness and sustainable habits. Third, local and traceable sourcing, reinforced through field visits to producers, deepened students' understanding of supply chain transparency, community-based food system, and procurement decisions. Fourth, guest-facing green communication reinforced sustainability identity through interactions and explanations activities positioned students as advocates and strengthened role internalisation.

Taken together, these mechanisms suggest a dynamic relationship among K, A, and P rather than a strictly linear K→A→P sequence. Enacted routines, supported by visibility and feedback, appeared to reinforce attitudes and deepen knowledge [6]. Knowledge was continuously elaborated through expert modelling [4], attitudes were strengthened through authentic tasks and iterative feedback [23], and practice functioned both as an outcome and a catalyst—consistent with a "practice primacy" dynamic in which doing consolidated commitment [6]. Overall, the course operated as a structured learning laboratory that supported internalisation, routinisation, and transferability of sustainability-oriented behaviours and strengthened professional readiness.

5. Conclusions and Recommendations

This study operationalised an SDGs-aligned pedagogy through the KAP model in a university restaurant laboratory. The intervention—combining industry co-teaching, structured brainstorming, two operational service cycles, green cleaning and resource-circulation routines, a capstone showcase, and guided reflection demonstrated that sustainability literacy can be translated into observable, role-specific behaviours. Quantitative analyses indicated significant pre–post gains in knowledge, attitudes, and practices, each with large effect sizes. Qualitative process evidence illuminated the

mechanisms underpinning these effects: expert demonstration enhanced perceived feasibility and self-efficacy; the proceduralisation of menus and workflows supported consistent behavioural enactment; and local/traceable sourcing and guest interaction deepened sustainability identity and intrinsic motivation.

Taken together, these findings yield an adaptable course-and-assessment architecture for embedding SDGs competencies in authentic hospitality settings. The results affirm that SDGs are not only teachable and measurable in higher education but are also transferable to practice, producing synergistic growth in domain-specific (technical/operational) and transferable (employability) competencies. In this respect, the KAP-based design functions as both an evaluative framework and a pedagogical logic, aligning conceptual learning with situated performance.

Implementation experience offers several recommendations. First, sustainability learning benefits from being anchored to concrete behavioural anchors, such as whole-food utilisation, energy-efficient cooking, food waste upcycling, traceable procurement, and green communication, embedded across rotational roles and weekly tasks. Second, co-teaching is most effective when sequenced as demonstration, rehearsal, real-time feedback, and re-performance, thereby reducing the theory–practice gap and strengthening self-efficacy. Third, the cultivation and use of herbs at the restaurant entrance, the adoption of low-emission with local/seasonal ingredients, and the systematic use of "ugly" produce illustrate how small, visible practices can normalise low-carbon habits and make the "farm-to-table" principle tangible for students and diners alike. Fourth, structured brainstorming and other CPS techniques should recur across the term to scaffold creative autonomy; while initial hesitation is common, iterative facilitation and peer dialogue can convert reluctance into proactive problem-solving and innovation.

The behavioural spillovers observed students purchasing imperfect produce, transforming unused household ingredients into desserts, and repackaging surplus food for redistribution suggest that the intervention moved learners from conceptual awareness to embodied practice. This supports a view of SDGs not as static endpoints but as a dynamic, cyclical process that requires repeated design–implementation–reflection loops. Instructors play a pivotal modelling role: demonstrating sustainable production (e.g., jam, fruit leather, flavoured water, natural cleaners), using reusable materials in service, and sharing personal market and household practices helps students extend classroom learning into everyday life. At the institutional level, program coherence can be strengthened by aligning course objectives with core competency rubrics, documenting effect sizes semester-to-semester, and sustaining partnerships with local suppliers and social enterprises to secure traceability, upcycling pathways, and internship pipelines. These strategies enhance implementation fidelity and support scalability across courses and campuses.

Although implemented within a specific institutional setting, the course design principles and KAP-based indicators proposed in this study offer an adaptable framework that can be adapted to hospitality programmes in diverse cultural and regulatory contexts. In sum, the "SDGs x restaurant laboratory" model offers credible evidence that sustainability competencies can be intentionally taught, rigorously assessed, and reliably operationalised in real service contexts. By integrating authentic tasks with expert modelling, iterative feedback, and reflective practice, hospitality programs can cultivate graduates who not only understand sustainability but also practice it consistently, visibly,

and professionally.

5.1 Implications and Transferability

5.1.1 Theoretical implications and boundary conditions

Responding to critiques of linear K→A→P assumptions, our findings indicate that KAP can operate as a dynamic learning system in practice-based hospitality education: feedback from enacted routines may reshape attitudes and deepen knowledge [6]. Importantly, these inferences are supported not only by pre–post surveys but also by coded behavioural evidence (reflective artefacts, instructor observations, operational records, and customer feedback), which linked course mechanisms to observable sustainability routines [4], [16], [35].

We therefore advance four boundary-condition propositions specifying when KAP is more likely to function recursively rather than sequentially in sustainability training:

- **Proposition 1 (Practice primacy).** When sustainability is proceduralized into routinized tasks and enacted under authentic service conditions, practice can precede and strengthen attitudes and knowledge through repetition, reflection, and performance feedback .
- **Proposition 2 (Role specificity).** K–A–P linkages strengthen when SDG concepts are translated into role-specific behavioural anchors, reducing abstraction and increasing perceived behavioural control.
- **Proposition 3 (Visibility and accountability).** The attitude–behaviour gap narrows when sustainability actions are publicly observable (e.g., guest-facing service) and reinforced through rapid feedback (customer reactions, operational checks), creating reinforcing loops among K, A, and P.
- **Proposition 4 (Expert modelling).** Industry demonstration accelerates KAP coupling by providing credible norms and tacit procedural know-how, enabling faster internalisation and routinisation of sustainability behaviours.

These propositions are presented as theoretically informed inferences from an exploratory design and should be tested using comparative and/or longitudinal studies.

5.1.2 Practical and pedagogical implications

Consistent with Propositions 1–3, sustainability learning is most effective when SDG goals are translated into behavioural anchors enacted under visible standards and rapid feedback. Instructional design should therefore map SDG 12 (Responsible Consumption and Production) onto role-specific procedures, such as whole-ingredient utilisation, energy-efficient cooking, food-waste upcycling, traceable/local sourcing, and guest-facing green communication, and integrate these into weekly modules and rotational roles so that teaching, learning, and assessment remain aligned [16], [17].

Industry co-teaching is most effective when delivered as demonstration → guided rehearsal → real-time feedback → refinement, shifting learners from general awareness to reliable behavioural enactment and supporting self-efficacy (Sun et al., 2025). Weekly reflective journals submitted via a digital platform can support metacognition and portfolio development when prompts require students to document actions taken, outcomes observed, and corrective adjustments [4].

Beyond outcome testing, programmes should collect behavioural and process evidence (e.g. instructor observations notes, operational artefacts, peer and customer feedback, and capstone evaluation comments) [4], [35]. When coded against SDG-aligned performance anchors, these

materials provide corroborating behavioural indicators that strengthen confidence in observed pre–post changes [16].

At the programme level, aligning course objectives with core-competency rubrics supports quality assurance and coherent progression [36]. Vertical integration, linking the restaurant laboratory learning with upstream courses (e.g., sourcing, cost control) and downstream courses (e.g., service management, marketing), supports a literacy → skills → behaviour pipeline [28]. Implementation fidelity can be strengthened through protected venue/time blocks, stable supply-chain partnerships, and periodic external review. Finally, micro-credentials/badges, competitive incentives, and public recognition can enhance motivation and programme visibility, while open access to anonymised course templates and validated measurement instruments supports replication and inter-institutional benchmarking [28], [37].

5.1.3 Transferability and scalability in resource-constrained contexts

Although the intervention was implemented in a high-fidelity restaurant laboratory with a small cohort (N=19), its core contribution is the instructional logic rather than the facilities alone. To clarify transferability, we distinguish between essential and adaptable components.

1. Essential Components (The Core Framework): the key mechanism is mapping specific SDGs indicators to professional tasks (e.g., SDG 12.3 to 'trimming waste measurement'). This scaffolding can be implemented without a full restaurant laboratory through classroom simulations, basic cooking labs, menu-planning modules, or campus food audits [38]. The KAP structure is also adaptable as a diagnostic tool and evaluation logic for sustainability literacy.
2. Adaptable Components (Delivery Modes):
   - Industry Co-teaching: If elite chefs are not feasible, programme can use asynchronous video demonstrations, guest lectures, or partnerships with local producers [23].
   - Facilities: The "restaurant laboratory" can be scaled to pop-up events, cafeteria audits or timed service simulations [27].
   - Class Size: For larger cohorts, intensive instructor supervision can be substituted with peer-assessment rubrics and digital portfolio tracking to maintain individual accountability [4].

Importantly, Propositions 1 and 3 imply that practice gains are strongest under authentic accountability and rapid feedback. In lower-fidelity settings, knowledge and attitudes may still improve, but practice gains may be smaller unless programmes recreate visibility and feedback (e.g., public showcases, audited waste metrics, structured peer evaluation). Overall, effectiveness depends less on elite resources per se than on preserving three mechanism carriers: (i) routinized behavioural anchors, (ii) rapid feedback, and (iii) social accountability/visibility.

5.2 Limitations and Directions for Future Research

This study employed a single-group pretest–posttest design. The absence of a control group and the small sample size (N = 19) constrain causal inference, as threats such as maturation or history cannot be ruled out [34]. Related threats, including testing effects from repeated measurement and reactivity/Hawthorne effects, may also have influenced outcomes in this highly monitored learning context. Instructor expectancy and intensive coaching may also have contributed to observed gains,

given the high-involvement instructional format. Accordingly, findings are interpreted as feasibility and directional change rather than definitive causal effects.

To strengthen interpretive confidence, we triangulated self-reported KAP gains with multi-source process evidence, including expert observations, student artifacts, operational records, and customer feedback, to assess convergence with enacted practices [4], [35]. Future research should improve external validity by incorporating comparative cohorts (e.g., waitlist or alternative-treatment groups) and sampling across multiple institutions, including resource-constrained settings [1].

Regarding measurement, the Practice (P) dimension still relied partly on self-report and instructor-graded rubrics. Although behavioural evidence was coded and mapped to validated indicators [16], we did not employ high-precision operational technologies (e.g., smart waste bins) to generate granular weight-based metrics [32], and only a subset of qualitative excerpts was double-coded; therefore, IRR coefficients were not computed. Future studies should employ multiple trained coders to establish IRR [35] and triangulate survey data with objective operational indicators (e.g., energy and water intensity, food-waste weight, proportion of traceable sourcing) and direct observation of customer-facing sustainability interactions.

To test mechanisms, future studies could employ mediation models (K→A→P and alternative pathways) and moderator analyses to examine boundary conditions (e.g., intensity of co-teaching, strength of feedback/accountability, local community engagement, peer norms) [6], [37]. Longitudinal follow-ups (e.g., during internships and part-time employment) are also needed to assess durability and generalisation of behavioural change [6], [38] [39]. Finally, cost–benefit analyses covering personnel time, venue utilisation, and material consumption would facilitate the development of scalable models and unit-cost projections [14], [30]. These economic evaluations are critical for informing institutional decisions about wider adoption and for sustaining long-term curricular innovation in sustainability education.

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Conflicts of Interest

The authors confirm that there are no conflicts of interest.

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