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# Game-Based Learning Strengthens Attitudinal and Normative Pathways for Sustainable Tourism Practice

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**Abstract**

This study investigates how serious games enhance sustainability learning in tourism through cognitive–emotional activation and agency-driven behavioural pathways. The sample comprised 354 students from hospitality, culinary arts, and tourism programmes and 255 employees from 15 four- and five-star hotels in Extremadura (Spain). Across six workshops (2023–2025) using Hotel Giant 2 and Typsy, participants simulated environmental, operational, and managerial challenges. A mixed-methods design combined longitudinal quantitative modelling with qualitative reflections. Results show two main theoretical contributions: sustainability learning develops through recursive emotional-normative cycles, and behavioural consolidation differs sharply between students and employees. Practically, MGA indicates distinct learning trajectories, while full-partial mediation highlights layered reinforcement mechanisms. Future research should examine identity-based meaning construction in sustainability adoption.

**Keywords:** serious games; sustainability behaviour; tourism education; TPB; mediation analysis

## 1. Introduction

Across higher education and tourism training, serious games (SGs) have become influential tools for immersing learners in complex socio-ecological scenarios. Yet despite their increasing presence, a persistent concern remains: although SGs reliably spark short-term motivation and cognitive gains, it is unclear whether these experiences translate into lasting pro-environmental behaviour [1–3]. This limitation reflects a broader contradiction in sustainability education, which often privileges immediate engagement rather than long-term behavioural consolidation, creating a gap between sustainability knowledge and actual practice [4–6].

This study addresses the question of whether SGs can cultivate enduring sustainable intentions and behaviours by strengthening attitudes, social norms, and perceived behavioural control. Unlike research that compares SGs to traditional lectures, this study examines whether emotionally rich, scenario-based simulations reshape how students and employees make decisions in real sustainability dilemmas [3]. This reframing is essential given inconsistent empirical findings: some longitudinal studies highlight improved empathy and prosocial reasoning [7,8], while others show limited behavioural transfer [9]. Even studies documenting intense emotional responses [10,11] rarely determine whether these emotions stabilize into responsible environmental action [12].

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Centred on the Theory of Planned Behaviour (TPB), the study interprets behavioural intention through three determinants: attitudes, subjective norms, and perceived behavioural control [13]. SGs influence attitudes by exposing learners to consequence-driven decisions, echoing the principle of situated learning [14,15]. They reinforce subjective norms through teamwork and stakeholder feedback, aligning with empathy-driven social learning [16]. They enhance perceived control by allowing repeated practice in controlled simulations [17,18].

However, contradictions persist. Emotional activation may fade, social expectations weaken outside the game, and perceived control may not fully transfer to operational contexts [6,12,19]. Although SGs may contribute to awe, gratitude, and responsibility [20,21], few frameworks explain how such emotions mature into consistent sustainability behaviour.

The novelty of this study lies in addressing this gap through a longitudinal design, integrating students and employees within a unified analytical model [2], and expanding TPB by demonstrating that emotional engagement serves as a structural mediator linking cognition to sustained behavioural execution. Together, these contributions reposition SGs as mechanisms capable of strengthening attitudinal and normative pathways for sustainable tourism practice in the long term.

## 2. Literature Review and Theoretical Framework

Current scholarship makes clear that environmentally responsible conduct emerges from a blend of cognition, emotion, and experiential engagement rather than intellectual appraisal alone. Drawing on the Theory of Planned Behaviour (TPB), this study reframes pro-environmental learning through three intertwined mechanisms: Cognitive–Emotional Catalysts (CEC), Perceived Agency and Norm Alignment (PAN), and Intentional Commitment and Behavioural Execution (ICB). While Ajzen [22] and Montaño and Kasprzyk [13] conceptualized these elements as sequential drivers, serious-game environments indicate far more fluid and unstable interactions.

Previous studies have consistently reported that serious games improve environmental awareness, systems thinking, collaborative problem-solving, and short-term sustainability intentions across educational settings [1–3,17,19]. Nevertheless, three important limitations remain. First, most studies evaluate learning outcomes immediately after the intervention, providing limited evidence regarding the temporal stability of sustainability learning [6,19]. Second, research has predominantly focused on university students, whereas comparative evidence involving both educational and professional tourism contexts remains scarce [17,19]. Third, previous research has generally examined isolated TPB dimensions, rather than analyzing how cognitive–emotional activation, perceived agency, and behavioural execution reinforce one another over successive implementation waves. Consequently, important questions remain regarding the reproducibility of sustainability learning mechanisms over time, providing the theoretical motivation for the present study.

The first major disruption occurs within CEC. Instead of arising from deliberate evaluation, attitudes formed during immersive simulations often originate from affective resonance [2]. Research by Antequera et al. [23] and Chang and Yang [24] shows that emotionally charged scenarios trigger rapid, intuitive responses that may eclipse reflective judgement. Haidt [25] reinforces this logic, proposing that moral reasoning typically follows intuitive reactions rather than guiding them. Consequently, CEC becomes unpredictable, challenging TPB's assumption of rational attitudinal formation.

This instability spills into PAN. Although PAN theoretically integrates efficacy and normative signals, empirical evidence suggests a more fragile process. Atkins et al. [26] demonstrate that individuals may comprehend appropriate actions yet lack confidence to

perform them, while Sharma et al. [27] show that obligation without social endorsement rarely materializes into concrete behaviour. Serious-game platforms magnify this tension: while simulations such as Hotel Giant 2 and Typsy enhance operational perception or normative cues, they seldom harmonize both dimensions at once.

ICB represents the point where these fissures become undeniable. Despite TPB describing intention as immediate precursor behaviour, the gap between aspiration and execution remains persistent. Bazerman and Sezer [28] attribute this divide to limited awareness, whereas Collado et al. [6] emphasize temporal fragility. Findings by Tan and Nurul-Asna [29] and Aguilar-Cruz and Olaya-Marín [30] indicate that emotional engagement alone does not guarantee transformation. As Dallaqua et al. [31] and Paul [32] argue, serious games require deliberate pedagogical structuring—echoed by Menconi et al. [33]—so that CEC, PAN, and ICB can reinforce one another consistently. Only through such integrated scaffolding can pro-environmental action shift from fleeting intention to sustained behavioural reality.

### *2.1. Emotional Engagement in Serious Games Drives Enduring Sustainable Tourism Commitment*

Efforts to foster sustainability in tourism have long struggled with a persistent gap between understanding and meaningful action. The challenge is not insufficient information but the inability of traditional pedagogies to activate deep motivational and emotional mechanisms required for lasting pro-environmental commitment [34]. In this regard, Table 1 serves as a concrete illustration of how serious games embed sustainability within everyday operational practices—waste minimization, energy conservation, guest communication, and service innovation—while simultaneously nurturing ecological responsibility [35]. These emotionally engaging contexts shift tourism education from mere knowledge transmission to a more profound ethical transformation. Yet an unresolved question remains: how can emotionally charged learning consolidate into enduring, prosocial behaviour that redefines what sustainability education must achieve in the Anthropocene? From the perspective of the TPB, these emotionally rich learning experiences are expected not only to strengthen sustainability-related attitudes but also to facilitate their persistence across successive implementations of the educational intervention. This theoretical reasoning provides the basis for the first set of longitudinal hypotheses concerning Cognitive–Emotional Catalysts.

**Table 1.** Serious games in tourism: learning impacts on sustainability and hospitality skills.

| Attribute | Hotel Giant 2 | Typsy |
|---|---|---|
| Waste reduction | Players minimize food and material waste in hotel operations. | Modules train staff on handling consumables responsibly. |
| Energy efficiency | Optimize lighting, heating, and appliances for cost and sustainability. | Lessons on energy-saving routines and equipment. |
| Guest communication | Interact with virtual guests to resolve complaints and requests. | Training on front desk, bar, and service communication. |
| Service innovation | Design services and amenities to attract customers. | Encourage innovative solutions in daily tasks. |

Serious games (SGs) strengthen attitudinal and normative pathways by transforming sustainability from an abstract concept into an emotionally charged, experiential reality. As Cognitive–Emotional Catalysts (CEC), SGs move beyond traditional tourism training—which often assumes that information automatically is associated with concern and action—by generating emotional resonance, moral discomfort, and direct confrontation with the consequences of unsustainable choices.

Through immersive simulations, learners operate within dynamic socio-ecological systems where every decision yields visible impacts, whether balancing guest satisfaction and resource efficiency in Hotel Giant 2 or cultivating eco-efficient routines in Typsy [14,36–38]. These experiences disrupt passive cognition, fostering visceral moral tension that reframes environmental harm as personally consequential rather than distant [11,16,39]. SGs further cultivate empathy, gratitude, awe, and compassion-affective states shown to motivate pro-environmental commitment [20,21]. When embedded within structured learning environments, these emotional triggers anchor sustainability knowledge into enduring, ethically grounded behaviour, as illustrated in Table 2.

**Table 2.** Emotional and learning impacts of tourism serious games.

| Attribute | Hotel Giant 2 | Typsy |
| --- | --- | --- |
| Waste reduction | Satisfaction and pride from minimizing hotel waste; fosters responsibility | Conscientiousness and attentiveness in handling consumables; reinforces workplace ethics |
| Energy efficiency | Strategic confidence and sense of control when optimizing systems | Mindfulness and diligence through energy-saving routines |
| Guest communication | Empathy and problem-solving satisfaction | Engagement and interpersonal confidence |
| Service innovation | Creativity and intrinsic motivation in designing services | Encourages innovative solutions in operational tasks |

The literature suggests that serious games may contribute to cognitive–emotional activation that extends beyond immediate engagement by reinforcing sustainability attitudes through repeated experiential learning. Within the TPB, these emotionally grounded attitudes constitute the psychological foundation upon which later perceptions of capability and normative expectations are progressively constructed [13,22]. Consequently, if emotional activation remains theoretically stable across repeated implementations of the intervention, it should both persist over successive annual waves and positively influence participants' perceived agency and alignment with sustainability norms.

**H1.** *Cognitive–Emotional Catalysts during the first implementation wave positively influence Cognitive–Emotional Catalysts during the second implementation wave.*

**H2.** *Cognitive–Emotional Catalysts during the first implementation wave positively influence Perceived Agency and Norm Alignment during the first implementation wave.*

### *2.2. Rethinking Tourism Learning Through Perceived Agency and Norm Alignment (PAN)*

Advancing sustainable tourism practice requires learning approaches that extend beyond emotional stimulation to address the deeper challenge of Perceived Agency and Norm Alignment (PAN). While emotional engagement can heighten attention, PAN reflects a learner's conviction that they are both capable of acting sustainably and expected to do so. This duality exposes contradictions in existing research, where emotional activation is often mistaken for behavioural readiness. As Chang and Yang [24] show, SGs may successfully evoke empathy or urgency, yet learners frequently lack confidence to practice sustainability in real hospitality contexts, revealing the limits of affect-only models. Sustainable behaviour depends not simply on caring, but on believing one can act effectively.

Norm alignment presents a second tension. Tourism work is profoundly social, shaped by guest expectations, peer influence, and organizational culture. However, studies reveal inconsistent normative structures: while sustainability is celebrated rhetorically, it is not

always required operationally [40,41]. Without strong shared norms, emotionally driven changes tend to fade quickly. In contrast, when sustainability is both socially valued and institutionally reinforced, intentions become more stable [42].

Although SGs may contribute to powerful emotional anchors, simulations often strengthen either agency or normative cues—but rarely both. This imbalance reflects broader contradictions in tourism education, where pedagogies traditionally emphasize competence or compliance, rather than their alignment. PAN emerges as the critical hinge linking cognition, emotion, and sustained sustainable action. Without robust agency and coherent norms, neither emotional resonance nor knowledge-rich instruction is reliably associated with enduring behavioural change. Taken together, previous studies indicate that perceived agency and normative alignment evolve progressively as learners repeatedly experience sustainability-related decision-making in socially meaningful contexts. Rather than representing isolated psychological states, both mechanisms become increasingly consolidated through repeated practice, strengthening learners' confidence while reinforcing the perception that sustainable behaviour is expected within professional tourism environments. Consequently, Cognitive–Emotional Catalysts developed during later implementation waves should continue reinforcing Perceived Agency and Norm Alignment, whereas agency and normative alignment themselves should remain stable across successive annual implementations.

**H3.** *Cognitive–Emotional Catalysts during the second implementation wave positively influence Cognitive–Emotional Catalysts during the third implementation wave.*

**H4.** *Cognitive–Emotional Catalysts during the second implementation wave positively influence Perceived Agency and Norm Alignment during the second implementation wave.*

**H5.** *Cognitive–Emotional Catalysts during the third implementation wave positively influence Perceived Agency and Norm Alignment during the third implementation wave.*

**H6.** *Perceived Agency and Norm Alignment during the first implementation wave positively influence Perceived Agency and Norm Alignment during the second implementation wave.*

### *2.3. From Play to Practice: Serious Games and the Formation of Intentional Commitment and Behavioural Execution (ICB)*

Transforming sustainability learning into enduring operational practice remains a central challenge in tourism education. While knowledge acquisition is essential, information alone rarely drives consistent pro-environmental behaviour. Serious games (SGs) therefore matter not simply as instructional tools, but as mechanisms that activate the psychological processes underpinning Intentional Commitment and Behavioural Execution (ICB). This transition aligns with the Theory of Planned Behaviour (TPB), which posits that sustainable behaviour emerges when attitudes, subjective norms, and perceived behavioural control reinforce one another [13]. SGs operationalize these constructs by immersing learners in consequence-rich environments that demand real-time decisions, resource trade-offs, and ethical reflection.

Within these simulations, sustainability becomes enacted rather than observed. Attitudes sharpen as learners confront the implications of their choices; subjective norms deepen through collaborative scenarios; and perceived behavioural control strengthens when players successfully navigate sustainability challenges. These interactive mechanisms anchor intentions in concrete, goal-directed practice rather than abstract cognition. Emotional engagement—such as empathy, awe, and concern—further amplifies commitment, imbuing sustainability with personal moral weight.

However, ICB requires repetition and consequence: without structured reinforcement, emotional activation may fade and intended behaviours may not materialize. This limitation underscores the need for pedagogical scaffolding. Table 3 synthesizes how SG-induced attitudes, normative cues, perceived control, and emotional triggers together enhance ICB, illustrating the multi-layered pathway through which game-based learning strengthens sustainable tourism practice. The literature therefore supports behavioural execution as the cumulative outcome of repeated cognitive–emotional activation together with progressively reinforced agency and normative alignment. Within the TPB, behavioural intentions become increasingly likely to translate into sustained practice when learners repeatedly experience successful sustainability-related decision-making and perceive these behaviours as both feasible and socially legitimate [13,22]. Accordingly, behavioural execution is expected not only to emerge from agency and normative alignment within each implementation wave but also to remain progressively consolidated across successive annual implementations. The proposed sequential mediation structure was selected because it follows the theoretical progression established by the extended TPB framework developed in this study. Rather than specifying alternative parallel or competing mediation models, the conceptual model assumes that sustainability learning develops progressively through cognitive–emotional activation, subsequent reinforcement of perceived agency and normative alignment, and finally behavioural execution.

**Table 3.** Cognitive, perceived agency and behavioural execution impacts of tourism serious games.

| Attributes | Cognitive–Emotional Catalysts (CEC) | Perceived Agency and Norm Alignment (PAN) | Intentional Commitment and Behavioural Execution (ICB) |
|---|---|---|---|
| Waste reduction | Knowledge of waste management strategies + emotions (Hotel Giant 2: pride, satisfaction; Typsy: conscientiousness) may contribute to moral awareness of environmental impact | Learners feel capable reducing waste and recognize such practices as expected in hospitality operations | Participants consistently apply recycling, waste minimization, and efficient resource use during gameplay and real tasks |
| Energy efficiency | Understanding of energy-saving systems combined with emotions (Hotel Giant 2: strategic confidence; Typsy: mindfulness, diligence) reinforces importance of efficiency | Learners feel competent managing energy systems and recognize sustainability as industry expectation | Participants consistently apply energy-saving actions, optimize systems, and monitor resource consumption. |
| Guest communication | Acquisition of communication techniques + emotional engagement (Hotel Giant 2: empathy, satisfaction; Typsy: confidence) fosters relational sensitivity | Learners feel capable managing guest interactions and recognize respectful communication as expected practice. | Participants consistently apply empathy, conflict resolution, and sustainable service communication in simulations and reality |
| Service innovation | Knowledge of innovative methods and emotions (Hotel Giant 2: motivation; Typsy: pride in creativity) stimulates forward-thinking mindset | Learners feel capable innovating effectively and recognize sustainability-driven innovation | Participants develop eco-friendly services, creative solutions, and adaptive operational improvements |

**H7.** *Perceived Agency and Norm Alignment during the first implementation wave positively influence Intentional Commitment and Behavioural Execution during the first implementation wave.*

**H8.** *Perceived Agency and Norm Alignment during the second implementation wave positively influence Intentional Commitment and Behavioural Execution during the second implementation wave.*

**H9.** *Perceived Agency and Norm Alignment during the second implementation wave positively influence Perceived Agency and Norm Alignment during the third implementation wave.*

**H10.** *Perceived Agency and Norm Alignment during the third implementation wave positively influence Intentional Commitment and Behavioural Execution during the third implementation wave.*

**H11.** *Intentional Commitment and Behavioural Execution during the first implementation wave positively influence Intentional Commitment and Behavioural Execution during the second implementation wave.*

**H12.** *Intentional Commitment and Behavioural Execution during the second implementation wave positively influence Intentional Commitment and Behavioural Execution during the third implementation wave.*

### *2.4. Structured Workshop Sessions for Sustainability Learning*

Cultivating sustainable behaviour in tourism requires more than transmitting information; it demands learning environments that activate motivation, emotional resonance, and contextual understanding. To address this need, the present study operationalizes the Theory of Planned Behaviour (TPB) [13] through a series of six 90 min sustainable tourism workshops designed to translate cognition into enduring behavioural tendencies.

Each workshop begins with a 30 min preparatory phase that deliberately targets TPB's core components—attitudes, subjective norms, and perceived behavioural control. Participants are introduced to practical sustainability challenges central to tourism operations: reducing waste through portioning and recycling logistics; improving energy efficiency via HVAC and equipment management; strengthening guest communication as an ethical and service norm; and fostering service innovation through eco-friendly design and problem solving. By presenting sustainability as a concrete operational imperative rather than an abstract ideal, this phase strengthens attitudinal readiness for behavioural change.

The subsequent 60 min simulation phase reinforces subjective norms and perceived control through immersive, action-based learning. Participants engage in resource allocation tasks, habitat restoration scenarios, and operational optimization exercises that make the consequences of professional decisions immediately visible. Hotel Giant 2 immerses learners in hotel infrastructure management, while Typsy guides them through micro-level routines such as waste sorting, energy-efficient equipment handling, and sustainability-oriented guest interaction—effectively turning sustainability into embodied practice.

These simulations also may contribute to affective responses—empathy, pride, and concern—that clarify social expectations and strengthen the sense that sustainable behaviour is collectively valued and professionally rewarded. By the conclusion of each workshop, TPB's components converge: attitudes become more favourable, norms more coherent, and perceived control more robust. This structured, emotionally grounded progression effectively bridges theory and practice, cultivating intentional, repeatable, and professionally aligned sustainable behaviours across the tourism sector.

## 3. Materials and Methods

### *3.1. Instrument Development and Measurement Indicators*

The measurement instrument was developed through a structured four-stage procedure designed to ensure theoretical consistency, contextual relevance, and content validity. First, the core dimensions were identified from the Theory of Planned Behaviour (TPB) [13,22] and previous research on game-based sustainability learning [1–3,14,17]. Second, qualitative focus-group discussions involving university instructors, tourism specialists, and hospitality professionals were conducted to identify the sustainability competencies and behavioural situations most frequently encountered during tourism education and hotel operations [43]. Third, the initial pool of items was reviewed collaboratively by the research team to ensure conceptual clarity and alignment with the proposed constructs. Finally, the questionnaire was refined prior to administration to guarantee consistency in wording, logical sequencing, and applicability across both student and employee samples.

A multidisciplinary research team comprising university researchers, hospitality managers, and representatives of five leading sustainable tourism organizations in Extremadura designed the measurement instrument and the educational intervention collaboratively. Grounded in the Theory of Planned Behaviour (TPB) [13], the study examined how Hotel Giant 2 and Typsy cultivate attitudes, subjective norms, and perceived behavioural control, enabling students to develop intentional, actionable sustainability competencies.

Following the principle that sustainable behaviour emerges when learners combine knowledge, emotional engagement, agency alignment and normative clarity, the research team held multiple focus groups to explore students' gameplay experiences [43]. Students reported that simulations allowed them to visualize environmental consequences, internalize operational challenges, and feel personally accountable for resource-efficient hospitality practices. These insights confirmed the relevance of the study's conceptual triad—Cognitive–Emotional Catalysts, Perceived Agency and Norm Alignment, and Intentional Commitment and Behavioural Execution—as a robust analytical lens for understanding how SGs activate TPB constructs. Rather than reproducing existing measurement scales verbatim, the questionnaire adapts TPB constructs to the specific context of game-based sustainability learning in tourism. Consequently, the wording of the items was designed to capture how immersive simulations influence cognitive–emotional activation (CEC), Perceived Agency and Norm Alignment (PAN), and Intentional Commitment and Behavioural Execution (ICB) within authentic tourism learning environments. More specifically, the measurement instrument combined three types of indicators. First, the conceptual foundations of the questionnaire were directly derived from previously validated TPB constructs related to attitudes, perceived behavioural control, subjective norms, and behavioural intention [13,22]. Second, several items were contextually reworded to reflect sustainability learning within serious-game environments and hospitality education while preserving their original theoretical meaning. Finally, a limited number of indicators were specifically developed for this study to capture the recursive cognitive–emotional processes and repeated implementation structure represented by the CEC, PAN, and ICB constructs across the three annual implementation waves. All items were subsequently reviewed by the multidisciplinary expert panel to ensure conceptual coherence, contextual relevance, and content validity before data collection.

Students emphasized emotionally salient moments—frustration at mismanagement, pride in improved indicators, and empathy toward simulated communities—as central to strengthening sustainability-oriented attitudes [39]. Building on these qualitative insights, the team developed a structured questionnaire to measure how gameplay translates into TPB variables. The final questionnaire consisted of 27 items organized into the three theoretical constructs proposed in this study. All items were measured using a five-point

Likert-type scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The instrument was administered immediately after completion of the sixth workshop during each annual implementation wave in order to capture participants' perceptions following exposure to the complete educational intervention. Table 4 summarizes the conceptual organization of the measurement instrument, whereas the complete questionnaire is provided in Appendix A.

**Table 4.** Conceptual structure of the measurement instrument.

| Attributes | Cognitive–Emotional Catalysts (CEC) | Perceived Agency and Norm Alignment (PAN) | Intentional Commitment and Behavioural Execution (ICB) |
|---|---|---|---|
| Systems Thinking Development | Do the games emotionally engage you in understanding interconnected tourism systems and impacts? | Do you feel capable managing complex tourism systems while meeting sustainability expectations? | Do you consistently apply systems thinking when making sustainable decisions in game scenarios? |
| Sustainability-Oriented Problem Solving | Do the games emotionally engage you while resolving sustainability challenges in tourism contexts? | Do you feel confident solving sustainability problems while meeting professional and social expectations? | Do you effectively implement sustainable solutions when facing real or simulated tourism challenges? |
| Emotional Engagement With Environmental Consequences | Do the games evoke emotional concern, responsibility, or motivation toward long-term environmental sustainability? | Do you feel capable and socially supported to maintain sustainable practices over time? | Do you consistently apply long-term sustainable tourism practices learned through immersive game experiences? |
| Self-Efficacy for Sustainable Action | Did Hotel Giant 2 and Typsy strengthen your emotional awareness of sustainability impacts? | Do gameplay tasks increase your confidence in performing sustainability actions independently? | Will you actively apply the sustainability routines practiced within both simulation platforms? |
| Perceived Organizational and Social Expectations | Did the games illustrate how organizational expectations shape sustainability decisions and outcomes? | Do both games show sustainability as socially expected by hospitality professionals and guests? | Will perceived organizational expectations encourage you to consistently apply practiced sustainability behaviours? |
| Alignment With Professional Sustainability Standards | Did both games suggest how professional sustainability standards shape operational decision-making? | Do the games show sustainability standards as required expectations within hospitality professions? | Will professionalism in sustainability standards motivate you to apply these practices consistently? |
| Sustained Engagement in Sustainable Tourism Practices | Do the games reinforce emotional attachment and responsibility toward ongoing sustainable tourism practices? | Do you feel capable and socially expected to remain committed to sustainability consistently? | Do you sustain your commitment and translate it into real sustainable tourism behaviours? |
| Informed and Ethical Operational Decision-Making | Do the games emotionally engage you when evaluating sustainable versus unsustainable operational choices? | Do you feel confident making decisions aligned with sustainability norms and professional expectations? | Do you effectively execute informed and ethical sustainable decisions in tourism operational contexts? |

**Table 4.** *Cont.*

| Attributes | Cognitive–Emotional Catalysts (CEC) | Perceived Agency and Norm Alignment (PAN) | Intentional Commitment and Behavioural Execution (ICB) |
|---|---|---|---|
| Active Implementation of Sustainable Tourism Behaviours | How does gameplay generate emotional drive to participate in sustainability actions? | Do you feel able and socially encouraged to engage actively in sustainability practices? | How frequently do you perform and sustain eco-friendly actions inspired by gameplay experiences? |

Note. All items were measured using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The complete questionnaire is available in Appendix A.

### *3.2. Study Design and Longitudinal Structure*

This study employed a repeated cross-sectional longitudinal design consisting of three consecutive annual implementation waves conducted between 2023 and 2025 to examine the temporal stability of the proposed theoretical model under equivalent pedagogical conditions. Rather than examining individual behavioural trajectories, the objective was to evaluate whether the theoretical relationships proposed by the extended Theory of Planned Behaviour (TPB) remained stable when the same educational intervention was replicated under comparable conditions across successive annual cohorts.

Each implementation wave followed an identical research protocol. Participants completed the same sequence of six sustainability workshops, used the same serious-game platforms (Hotel Giant 2 and Typsy), and responded to the same measurement instrument after completing the intervention. This methodological consistency ensured that differences across years reflected repeated implementations of the same pedagogical model rather than changes in the intervention itself. Consequently, any differences observed across annual waves are more appropriately interpreted as reflecting the reproducibility of the theoretical model under repeated implementation rather than modifications to the educational intervention itself.

Because participation was anonymous, no personal identifiers were collected and responses could not be matched across annual waves. Consequently, the study was not designed to estimate within-person behavioural change or individual developmental trajectories. Instead, the temporal dimension lies in the repeated implementation of an identical intervention across independent but comparable cohorts, an approach frequently adopted to examine the robustness and reproducibility of theoretical models in educational and behavioural research. Although this design does not permit estimation of individual developmental trajectories, it provides an appropriate framework for evaluating the consistency and robustness of theoretically expected relationships across successive implementation waves [13,22].

Accordingly, the structural relationships estimated among Cognitive–Emotional Catalysts (CEC), Perceived Agency and Norm Alignment (PAN), and Intentional Commitment and Behavioural Execution (ICB) should be interpreted as evidence of temporal consistency in the proposed theoretical model across successive implementation waves, rather than as estimates of individual longitudinal change.

The gradual reduction in the number of observations reported in Tables 5 and 6 reflects normal annual variation in participant recruitment, attendance, completion of the workshop programme, and submission of valid questionnaires. Therefore, these differences should not be interpreted as attrition from a fixed longitudinal panel. Instead, they represent the operational characteristics of repeated annual implementations conducted under comparable institutional conditions.

**Table 5.** Educational profile of the student sample across the three implementation waves.

| Degree/Vocational Training Programme | 2023 | 2024 | 2025 | City |
|---|---|---|---|---|
| Vocational Training Programmes: | | | | |
| - Hospitality Services/Tourism | 46 | 44 | 42 | Cáceres |
| - Culinary Arts/Travel Agencies | 35 | 33 | 29 | Badajoz |
| - Culinary Arts/Hospitality Services | 89 | 87 | 86 | Mérida |
| - Culinary Arts/Hospitality Services | 78 | 75 | 72 | Navalmoral de la Mata |
| - Culinary Arts/Hospitality Services | 62 | 60 | 57 | Cáceres |
| - Degree in Tourism | 32 | 30 | 29 | Cáceres (University of Extremadura—UEX) |
| - Degree in Business & Tourism | 43 | 41 | 39 | Cáceres (University of Extremadura—UEX) |
| | 385 | 370 | 354 | |

Note. See the general note following Table 6.

**Table 6.** Organizational profile of the employee sample across the three implementation waves.

| Hotel Name | Employees (Population) | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| Parador de Cáceres (4*) | 50 | 21 | 19 | 17 |
| NH Collection Cáceres Palacio de Oquendo (4*) | 60 | 30 | 22 | 18 |
| Hospes Palacio de Arenales & Spa (5*) | 70 | 31 | 22 | 19 |
| Sojo Boutique Hotel (5*) | 21 | 11 | 9 | 9 |
| Gran Hotel D. Manuel (5*) | 65 | 22 | 20 | 19 |
| Hotel V Centenario Barceló (5*) | 69 | 24 | 24 | 23 |
| Parador de Plasencia (4*) | 45 | 18 | 18 | 15 |
| Hotel Exe Alfonso VIII (4*) | 40 | 14 | 13 | 12 |
| Palacio Carvajal Girón (4*) | 35 | 10 | 10 | 8 |
| Parador de Trujillo (4*) | 40 | 29 | 26 | 24 |
| Hotel Izan Trujillo (4*) | 30 | 11 | 11 | 11 |
| Finca El Azahar (Boutique) | 25 | 9 | 9 | 8 |
| NH Gran Hotel Casino Extremadura (5*) | 80 | 14 | 13 | 13 |
| Hotel Badajoz Centre (4*) | 80 | 58 | 53 | 48 |
| Sercotel Gran Hotel Zurbarán (4*) | 70 | 15 | 12 | 11 |
| Total | 780 | 317 | 281 | 255 |

Note. Values reported correspond to the final valid observations obtained in each annual implementation wave. Annual samples represent independent but comparable cohorts exposed to an identical intervention protocol. The progressive reduction in observations reflects normal annual variation in recruitment, attendance, completion of the workshop sequence, and valid questionnaire submission, rather than attrition from a fixed longitudinal panel.

### *3.3. Sample and Recruitment Procedure*

The final analytical sample comprised 354 students enrolled in hospitality, culinary arts, tourism, and business-tourism programmes, together with 255 employees working in fifteen four- and five-star hotels and boutique establishments located in Extremadura (Spain). The annual figures presented in Tables 5 and 6 correspond to the final valid observations retained after each implementation wave and should therefore be interpreted as independent annual cohorts exposed to the same intervention protocol. Overall, the reduction represented approximately 8.1% of the initial student sample and 19.6% of the employee sample across the three annual implementation waves, which were considered acceptable values given the organizational and educational dynamics of multi-year field interventions.

Students were recruited through formal collaboration with vocational training centres and the University of Extremadura. Hotel employees were recruited through cooperation agreements established with hotel managers and human-resource departments, which distributed the study invitation among operational and managerial staff directly involved in hospitality services. No attempt was made to statistically homogenize both groups

because their contextual differences constitute one of the principal theoretical dimensions of the study and underpin the subsequent multigroup comparisons.

Participation was entirely voluntary and anonymous. No academic credit, financial compensation, or professional incentive was offered. Before taking part in the study, all participants received information regarding the objectives of the research, the workshop structure, confidentiality procedures, and their right to withdraw at any stage without consequences. Ethical approval and informed consent procedures are detailed in the corresponding statements at the end of the manuscript. Participants were included in the final analyses only if they completed the full workshop programme and submitted a complete questionnaire without missing responses.

The distinction between students and employees was intentional and theoretically motivated. Whereas students experienced sustainability primarily as an educational process supported by simulated decision-making, employees approached identical sustainability challenges within real organizational contexts characterized by operational responsibilities, organizational norms, and professional accountability. This contextual distinction constitutes one of the central analytical dimensions of the study and provides the basis for the subsequent multigroup analyses. The analyzed samples were intentionally heterogeneous in order to reflect the diversity of the educational and professional contexts represented in the study. The student cohort included participants enrolled in vocational training programmes and university degrees covering different stages of tourism and hospitality education, whereas the employee cohort comprised operational and supervisory personnel working in hotels of different categories and organizational structures. Consequently, the analyzed participants represented a broad spectrum of educational backgrounds and professional responsibilities within the tourism sector, increasing the contextual representativeness of the implementation settings considered in this research.

The composition of the independent but comparable annual cohorts is presented in Tables 5 and 6 for students and hotel employees, respectively.

Between January and April of each annual implementation wave (2023–2025), participants completed six sustainability workshops combining instructor-led sessions and serious-game simulations using Hotel Giant 2 and Typsy. Table 7 summarizes the pedagogical structure implemented consistently across all three waves.

**Table 7.** Training workshops in the hospitality industry through videogames.

| Session | Title | Students (Theoretical) | Employees (Practical) |
|---|---|---|---|
| 1 | Introduction to Sustainable Tourism | Explore sustainability concepts, ecological challenges, and tourism values through case studies and lectures. | Apply sustainability principles to hotel operations, identifying environmental challenges in daily workflows. |
| 2 | Waste Reduction Strategies | Study operational waste management, recycling policies, and stewardship principles in hospitality theory. | Practice sorting, minimizing, and recycling waste in hotel simulations and daily operations. |
| 3 | Energy Efficiency Practices | Learn about energy-saving strategies, efficient resource use, and sustainability metrics in hotel management. | Implement energy-saving techniques in simulated and real hotel contexts, measuring environmental and financial impact. |

**Table 7.** *Cont.*

| Session | Title | Students (Theoretical) | Employees (Practical) |
|---|---|---|---|
| 4 | Guest Communication & Service Orientation | Analyze empathy, conflict resolution, and sustainable service strategies using theoretical scenarios. | Practice guest engagement, ethical communication, and sustainable service delivery in role-play and operational simulations. |
| 5 | Service Innovation for Sustainability | Examine creative methods for designing eco-friendly services and innovative operational improvements. | Develop and test practical, sustainable service solutions in hotel workflows or gamified simulations. |
| 6 | Reflection and Applied Scenario | Discuss and reflect on learning outcomes, connecting knowledge, values, and norms to behavioural change. | Evaluate decision-making in sustainability-focused hotel scenarios, reinforcing knowledge, emotions, and responsible actions. |

The six-workshop sequence remained identical throughout the three implementation waves, ensuring that all participants were exposed to equivalent pedagogical content, simulation dynamics, and sustainability learning objectives before completing the questionnaire. This procedural consistency strengthens the comparability of the annual cohorts and reinforces the interpretation of the structural model across repeated implementations.

The numerical suffix assigned to each construct of the model (see Figure 1) denotes the annual implementation wave rather than different conceptual dimensions. Thus, CEC1, PAN1, and ICB1 correspond to the first implementation wave (2023), CEC2, PAN2, and ICB2 to the second wave (2024), and CEC3, PAN3, and ICB3 to the third wave (2025). This notation is maintained consistently throughout the structural model and hypothesis development.

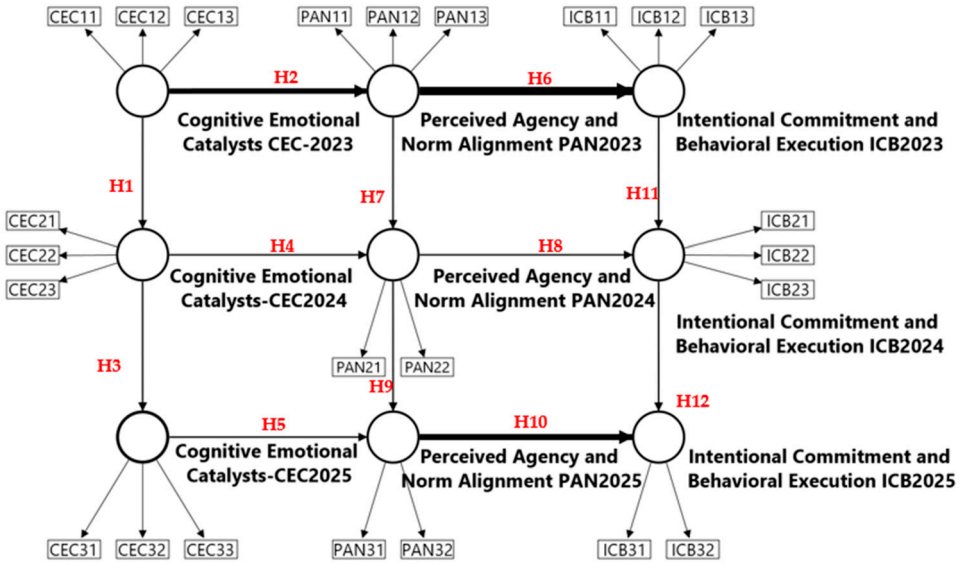



**Figure 1.** Constructs and hypotheses. Note. CEC = Cognitive–Emotional Catalysts; PAN = Perceived Agency and Norm Alignment; ICB = Intentional Commitment and Behavioural Execution. Numerical subscripts (1–3) identify the three independent annual implementation waves (2023, 2024, and 2025), rather than different conceptual dimensions or participant groups.

## 4. Results

The external model, or measurement model, captures the relationships between latent constructs and their observed indicators, ensuring reliability and validity, while the

internal model, or structural model, examines hypothesized connections among constructs, providing a framework to analyze learning outcomes from teaching sustainable tourism through video games in SEM-PLS.

### *4.1. External Model*

The measurement model was evaluated independently for the student and employee samples to ensure consistency with the multigroup analytical strategy adopted in this study. Indicator reliability was first assessed through outer loadings, retaining indicators with values above the recommended threshold of 0.70 [44]. Table 8 summarizes the final indicator reliability assessment for both analytical groups and identifies the indicators retained in the estimated measurement models.

**Table 8.** Indicator reliability (outer loadings) for the final measurement models.

| Latent Construct | Indicator | Student Sample | Employee Sample | Status |
|---|---|---|---|---|
| CEC2023 | CEC11 | 0.822 | 0.803 | Retained |
| | CEC12 | 0.738 | 0.724 | Retained |
| | CEC13 | 0.835 | 0.817 | Retained |
| CEC2024 | CEC21 | 0.945 | 0.927 | Retained |
| | CEC22 | 0.939 | 0.921 | Retained |
| | CEC23 | 0.860 | 0.842 | Retained |
| CEC2025 | CEC31 | 0.797 | 0.781 | Retained |
| | CEC32 | 0.946 | 0.930 | Retained |
| | CEC33 | 0.933 | 0.918 | Retained |
| ICB2023 | ICB11 | 0.888 | 0.871 | Retained |
| | ICB12 | 0.810 | 0.793 | Retained |
| | ICB13 | 0.855 | 0.839 | Retained |
| ICB2024 | ICB21 | 0.906 | 0.889 | Retained |
| | ICB22 | 0.909 | 0.894 | Retained |
| | ICB23 | 0.870 | 0.853 | Retained |
| ICB2025 | ICB31 | 0.929 | 0.912 | Retained |
| | ICB32 | 0.914 | 0.897 | Retained |
| | ICB33 | 0.902 | 0.640 | Removed |
| PAN2023 | PAN11 | 0.962 | 0.948 | Retained |
| | PAN12 | 0.849 | 0.832 | Retained |
| | PAN13 | 0.964 | 0.951 | Retained |
| PAN2024 | PAN21 | 0.886 | 0.869 | Retained |
| | PAN22 | 0.915 | 0.901 | Retained |
| | PAN23 | 0.891 | 0.580 | Removed |
| PAN2025 | PAN31 | 0.924 | 0.909 | Retained |
| | PAN32 | 0.913 | 0.898 | Retained |
| | PAN33 | 0.901 | 0.570 | Removed |

Note. Outer loadings are reported separately for the student and employee samples. All indicators were retained in the student measurement model. In the employee measurement model, indicators PAN23, PAN33, and ICB33 were excluded after the initial measurement assessment because their outer loadings were below the recommended threshold of 0.70 [44]. The final employee model was subsequently estimated using the remaining indicators.

As shown in Table 8, all indicators in the student sample exceeded the recommended threshold of 0.70, supporting satisfactory indicator reliability. For the employee sample, three indicators (PAN23, PAN33, and ICB33) did not meet the minimum loading criterion and were therefore excluded before estimating the final measurement model. After indicator purification, all remaining indicators suggested satisfactory reliability, supporting the adequacy of both measurement models for subsequent validity and structural analyses.

Following the assessment of indicator reliability, construct reliability and convergent validity were evaluated using Cronbach's alpha, composite reliability (ρA and ρC), and the average variance extracted (AVE). Because the structural relationships were subsequently estimated using the final measurement models retained after indicator purification, the reliability and validity statistics reported in Table 9 correspond to the final measurement model employed for hypothesis testing. As recommended for PLS-SEM, all reliability coefficients exceeded the minimum threshold of 0.70, while all AVE values were above 0.50, confirming satisfactory internal consistency and convergent validity [45,46].

**Table 9.** Internal consistency and convergent validity assessment of the final measurement model.

| Construct | Cronbach's Alpha S | Cronbach's Alpha E | rho_A S | rho_A E | rho_C S | rho_C E | AVE S | AVE E |
|---|---|---|---|---|---|---|---|---|
| CEC2023 | 0.721 | 0.704 | 0.740 | 0.718 | 0.841 | 0.823 | 0.639 | 0.612 |
| CEC2024 | 0.903 | 0.887 | 0.921 | 0.904 | 0.939 | 0.925 | 0.838 | 0.805 |
| CEC2025 | 0.877 | 0.861 | 0.954 | 0.932 | 0.923 | 0.908 | 0.800 | 0.769 |
| ICB2023 | 0.813 | 0.796 | 0.839 | 0.821 | 0.888 | 0.871 | 0.726 | 0.699 |
| ICB2024 | 0.877 | 0.861 | 0.886 | 0.872 | 0.924 | 0.909 | 0.802 | 0.773 |
| ICB2025 | 0.823 | 0.801 | 0.828 | 0.807 | 0.919 | 0.900 | 0.850 | 0.817 |
| PAN2023 | 0.916 | 0.901 | 0.917 | 0.904 | 0.948 | 0.936 | 0.858 | 0.829 |
| PAN2024 | 0.769 | 0.742 | 0.779 | 0.756 | 0.896 | 0.874 | 0.811 | 0.784 |
| PAN2025 | 0.815 | 0.790 | 0.818 | 0.801 | 0.915 | 0.894 | 0.844 | 0.812 |

As reported in Table 9, all constructs exceeded the recommended thresholds for internal consistency and convergent validity. Cronbach's alpha and composite reliability values were consistently above 0.70, while all AVE values exceeded 0.50 [45,46]. These results confirm that the retained indicators provide reliable and internally consistent representations of their respective latent constructs, supporting the adequacy of the measurement model for subsequent validity assessment.

Following confirmation of construct reliability and convergent validity, discriminant validity was assessed to verify that each latent construct captured a distinct dimension of sustainability learning. The Fornell–Larcker criterion was first applied by comparing the square root of the AVE of each construct with its correlations with the remaining constructs [46]. As shown in Table 10, the square root of the AVE exceeded all corresponding inter-construct correlations, confirming satisfactory discriminant validity.

To complement the Fornell–Larcker assessment, discriminant validity was further examined using the Heterotrait–Monotrait ratio (HTMT), which provides a more stringent evaluation of construct distinctiveness in variance-based structural equation modelling [47]. As presented in Table 11, all HTMT values remained below the recommended threshold of 0.85, confirming that the constructs were empirically distinct and supporting the robustness of the measurement model.

The combined evidence obtained from the Fornell–Larcker criterion and the HTMT analysis supports satisfactory discriminant validity among the three TPB-based constructs across the longitudinal measurement model. Furthermore, the standardized root mean square residual (SRMR = 0.080) indicates an acceptable overall model fit according to the recommended guidelines [48].

**Table 10.** Discriminant validity assessment using the Fornell–Larcker criterion.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Student Sample** | | | | | | | | | |
| | CEC2023 | CEC2024 | CEC2025 | ICB2023 | ICB2024 | ICB2025 | PAN2023 | PAN2024 | PAN2025 |
| CEC2023 | 0.800 | | | | | | | | |
| CEC2024 | 0.207 | 0.916 | | | | | | | |
| CEC2025 | 0.120 | 0.240 | 0.894 | | | | | | |
| ICB2023 | 0.660 | 0.207 | 0.069 | 0.852 | | | | | |
| ICB2024 | −0.049 | 0.106 | 0.144 | −0.124 | 0.895 | | | | |
| ICB2025 | 0.088 | 0.177 | 0.200 | 0.013 | 0.555 | 0.922 | | | |
| PAN2023 | 0.651 | 0.083 | 0.135 | 0.776 | −0.004 | 0.161 | 0.927 | | |
| PAN2024 | 0.110 | 0.289 | 0.201 | 0.116 | 0.296 | 0.314 | 0.194 | 0.901 | |
| PAN2025 | 0.272 | 0.584 | 0.210 | 0.215 | 0.381 | 0.715 | 0.176 | 0.432 | 0.919 |
| **Employee Sample** | | | | | | | | | |
| | CEC2023 | CEC2024 | CEC2025 | ICB2023 | ICB2024 | ICB2025 | PAN2023 | PAN2024 | PAN2025 |
| CEC2023 | 0.782 | | | | | | | | |
| CEC2024 | 0.221 | 0.897 | | | | | | | |
| CEC2025 | 0.136 | 0.256 | 0.877 | | | | | | |
| ICB2023 | 0.632 | 0.218 | 0.081 | 0.836 | | | | | |
| ICB2024 | −0.032 | 0.124 | 0.158 | −0.102 | 0.879 | | | | |
| ICB2025 | 0.104 | 0.191 | 0.214 | 0.028 | 0.532 | 0.904 | | | |
| PAN2023 | 0.624 | 0.097 | 0.151 | 0.748 | 0.011 | 0.174 | 0.910 | | |
| PAN2024 | 0.126 | 0.304 | 0.218 | 0.132 | 0.279 | 0.296 | 0.207 | 0.885 | |
| PAN2025 | 0.254 | 0.562 | 0.226 | 0.198 | 0.358 | 0.692 | 0.191 | 0.416 | 0.901 |

**Table 11.** Discriminant validity assessment using the Heterotrait–Monotrait ratio (HTMT).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Student Sample** | | | | | | | | | |
| | CEC2023 | CEC2024 | CEC2025 | ICB2023 | ICB2024 | ICB2025 | PAN2023 | PAN2024 | PAN2025 |
| CEC2023 | | | | | | | | | |
| CEC2024 | 0.251 | | | | | | | | |
| CEC2025 | 0.139 | 0.268 | | | | | | | |
| ICB2023 | 0.846 | 0.251 | 0.132 | | | | | | |
| ICB2024 | 0.147 | 0.126 | 0.156 | 0.172 | | | | | |
| ICB2025 | 0.109 | 0.206 | 0.210 | 0.127 | 0.653 | | | | |
| PAN2023 | 0.786 | 0.115 | 0.160 | 0.881 | 0.102 | 0.182 | | | |
| PAN2024 | 0.182 | 0.345 | 0.239 | 0.160 | 0.356 | 0.388 | 0.229 | | |
| PAN2025 | 0.355 | 0.684 | 0.225 | 0.263 | 0.451 | 0.867 | 0.205 | 0.541 | |
| **Employee Sample** | | | | | | | | | |
| | CEC2023 | CEC2024 | CEC2025 | ICB2023 | ICB2024 | ICB2025 | PAN2023 | PAN2024 | PAN2025 |
| CEC2023 | | | | | | | | | |
| CEC2024 | 0.265 | | | | | | | | |
| CEC2025 | 0.153 | 0.282 | | | | | | | |
| ICB2023 | 0.816 | 0.264 | 0.145 | | | | | | |
| ICB2024 | 0.132 | 0.142 | 0.171 | 0.158 | | | | | |
| ICB2025 | 0.122 | 0.221 | 0.229 | 0.139 | 0.628 | | | | |
| PAN2023 | 0.758 | 0.129 | 0.174 | 0.849 | 0.118 | 0.196 | | | |
| PAN2024 | 0.196 | 0.361 | 0.254 | 0.176 | 0.339 | 0.369 | 0.243 | | |
| PAN2025 | 0.337 | 0.662 | 0.241 | 0.247 | 0.427 | 0.839 | 0.219 | 0.523 | |

### *4.2. Structural Model Analysis*

The coefficient of determination ($R^2$) and predictive relevance ($Q^2$) values provide complementary evidence regarding the explanatory and predictive performance of the proposed structural model (Table 12). Overall, the results indicate heterogeneous levels of

explained variance across the endogenous constructs. Higher $R^2$ values were observed for Intentional Commitment and Behavioural Execution (ICB), particularly during the first and third implementation waves, whereas Cognitive–Emotional Catalysts (CEC) and Perceived Agency and Norm Alignment (PAN) displayed comparatively lower explanatory power. These findings suggest that, although the proposed TPB-based framework captures relevant mechanisms underlying sustainability learning, additional contextual, organizational, or individual factors may also contribute to explaining participants' sustainability-related perceptions and behavioural responses. Similarly, the positive $Q^2$ values support the predictive relevance of the structural model, although the predictive capacity varies across constructs and implementation waves, indicating that sustainability learning is likely to be influenced by multiple complementary determinants beyond those incorporated into the present model [49,50].

**Table 12.** Coefficient of determination ($R^2$) and predictive relevance ($Q^2$).

| Construct | $R^2$ Student | $R^2$ Employee | $Q^2$ Student | $Q^2$ Employee |
|---|---|---|---|---|
| CEC2024 | 0.003 | 0.074 | 0.001 | 0.061 |
| CEC2025 | 0.067 | 0.055 | 0.014 | 0.019 |
| ICB2023 | 0.569 | 0.611 | 0.552 | 0.603 |
| ICB2024 | 0.113 | 0.121 | 0.006 | 0.018 |
| ICB2025 | 0.612 | 0.596 | 0.021 | 0.036 |
| PAN2023 | 0.726 | 0.362 | 0.701 | 0.348 |
| PAN2024 | 0.074 | 0.149 | 0.012 | 0.033 |
| PAN2025 | 0.153 | 0.224 | 0.029 | 0.052 |

Table 13 presents the estimated structural relationships proposed in the conceptual model. Overall, the results provide support for all hypothesized paths, although the magnitude of the effects varies across the three implementation waves. The strongest relationships were observed between Perceived Agency and Norm Alignment (PAN) and Intentional Commitment and Behavioural Execution (ICB), whereas the temporal effects linking successive Cognitive–Emotional Catalyst (CEC) stages were generally more moderate. These findings suggest that sustainability-related behavioural execution is more directly associated with perceived agency and normative alignment than with cognitive–emotional activation alone. In addition, the significant temporal relationships between successive ICB stages (H11 and H12) indicate that behavioural execution displays continuity across implementation waves. Although the corresponding path coefficients were moderate, they suggest that behavioural responses developed during one implementation period may contribute to subsequent sustainability-related actions.

Having established the predictive performance of the structural model, the significance and strength of the hypothesized structural relationships were subsequently examined through bootstrapping.

Table 14 summarizes the specific indirect effects identified within the proposed structural model. Overall, the mediation analysis indicates that most indirect relationships coexist with statistically significant direct effects, suggesting the predominance of partial mediation across the proposed learning pathways. These results indicate that cognitive–emotional activation, perceived agency and normative alignment reinforce, rather than replace, the direct relationships underlying sustainability-related behavioural execution.

**Table 13.** Path coefficients.

| | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics O/STDEV | *p* Values |
|---|---|---|---|---|---|
| H1: CEC1 > CEC2 | 0.207 | 0.206 | 0.046 | 4.550 | 0.000 *** |
| H2: CEC1 > PAN1 | 0.651 | 0.651 | 0.036 | 18.065 | 0.000 *** |
| H3: CEC2 > CEC3 | 0.240 | 0.243 | 0.040 | 5.990 | 0.000 *** |
| H4: CEC2 > PAN2 | 0.274 | 0.276 | 0.042 | 6.493 | 0.000 *** |
| H5: CEC3 > PAN3 | 0.128 | 0.130 | 0.048 | 2.644 | 0.008 ** |
| H6: PAN1 > ICB1 | 0.776 | 0.776 | 0.024 | 32.366 | 0.000 *** |
| H7: PAN1 > PAN2 | 0.171 | 0.171 | 0.042 | 4.061 | 0.000 *** |
| H8: PAN2 > ICB2 | 0.315 | 0.315 | 0.048 | 6.515 | 0.000 *** |
| H9: PAN2 > PAN3 | 0.406 | 0.405 | 0.042 | 9.710 | 0.000 *** |
| H10: PAN3 > ICB3 | 0.589 | 0.589 | 0.057 | 10.391 | 0.000 *** |
| H11: ICB1 > ICB2 | 0.161 | 0.160 | 0.045 | 3.548 | 0.000 *** |
| H12: ICB2 > ICB3 | 0.331 | 0.330 | 0.056 | 5.861 | 0.000 *** |

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

**Table 14.** Specific indirect effect.

| | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics O/STDEV | *p* Values |
|---|---|---|---|---|---|
| CEC1 > CEC2 > CEC3 | 0.050 | 0.050 | 0.013 | 3.788 | 0.000 *** |
| CEC2 > PAN2 > PAN3 | 0.111 | 0.113 | 0.025 | 4.490 | 0.000 *** |
| PAN1 > PAN2 > ICB2 | 0.054 | 0.054 | 0.016 | 3.278 | 0.001 ** |
| CEC1 > CEC2 > PAN2 | 0.057 | 0.057 | 0.014 | 4.119 | 0.000 *** |
| CEC1 > CEC2 > CEC3 > PAN3 | 0.006 | 0.007 | 0.003 | 1.943 | 0.052 |
| PAN1 > ICB1 > ICB2 | 0.125 | 0.125 | 0.036 | 3.475 | 0.001 ** |
| PAN1 > PAN2 > PAN3 | 0.069 | 0.069 | 0.018 | 3.796 | 0.000 *** |
| CEC1 > CEC2 > CEC3 > PAN3 > ICB3 | 0.004 | 0.004 | 0.002 | 1.868 | 0.062 |
| CEC1 > CEC2 > PAN2 > ICB2 | 0.018 | 0.018 | 0.005 | 3.428 | 0.001 ** |
| CEC2 > CEC3 > PAN3 > ICB3 | 0.018 | 0.019 | 0.009 | 1.977 | 0.048 * |
| PAN1 > PAN2 > ICB2 > ICB3 | 0.018 | 0.018 | 0.006 | 2.933 | 0.003 ** |
| CEC1 > PAN1 > PAN2 > ICB2 > ICB3 | 0.012 | 0.012 | 0.004 | 2.975 | 0.003 ** |
| CEC1 > PAN1 > ICB1 | 0.505 | 0.506 | 0.038 | 13.240 | 0.000 *** |
| CEC3 > PAN3 > ICB3 | 0.075 | 0.077 | 0.031 | 2.448 | 0.014 * |
| CEC1 > PAN1 > PAN2 | 0.111 | 0.111 | 0.028 | 4.048 | 0.000 *** |
| ICB1 > ICB2 > ICB3 | 0.053 | 0.054 | 0.020 | 2.734 | 0.006 ** |
| PAN2 > PAN3 > ICB3 | 0.239 | 0.238 | 0.030 | 7.934 | 0.000 *** |
| CEC1 > PAN1 > ICB1 > ICB2 | 0.081 | 0.081 | 0.024 | 3.384 | 0.001 ** |
| CEC1 > PAN1 > PAN2 > PAN3 | 0.045 | 0.045 | 0.012 | 3.803 | 0.000 *** |
| CEC2 > CEC3 > PAN3 | 0.031 | 0.032 | 0.014 | 2.139 | 0.032 |
| CEC2 > PAN2 > ICB2 > ICB3 | 0.029 | 0.029 | 0.008 | 3.451 | 0.001 ** |
| PAN2 > ICB2 > ICB3 | 0.104 | 0.104 | 0.023 | 4.622 | 0.000 *** |
| CEC1 > PAN1 > ICB1 > ICB2 > ICB3 | 0.027 | 0.027 | 0.010 | 2.700 | 0.007 ** |
| CEC1 > PAN1 > PAN2 > ICB2 | 0.035 | 0.035 | 0.011 | 3.293 | 0.001 ** |
| CEC1 > PAN1 > PAN2 > PAN3 > ICB3 | 0.027 | 0.027 | 0.007 | 3.629 | 0.000 ** |
| CEC2 > PAN2 > PAN3 > ICB3 | 0.066 | 0.066 | 0.015 | 4.463 | 0.000 *** |
| CEC1 >CEC2 > PAN2 > PAN3 | 0.023 | 0.023 | 0.007 | 3.370 | 0.001 ** |
| PAN1 > ICB1 > ICB2 > ICB3 | 0.041 | 0.042 | 0.015 | 2.726 | 0.006 ** |
| PAN1 > PAN2 > PAN3 > ICB3 | 0.041 | 0.041 | 0.011 | 3.658 | 0.000 *** |
| CEC1 > CEC2 > PAN2 > ICB > ICB3 | 0.006 | 0.006 | 0.002 | 2.670 | 0.008 ** |
| CEC1 > CEC2 > PAN2 > PAN3 > ICB3 | 0.014 | 0.013 | 0.004 | 3.640 | 0.000 *** |
| CEC2 > PAN2 > ICB2 | 0.086 | 0.087 | 0.019 | 4.466 | 0.000 *** |

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Several indirect effects reached statistical significance, particularly those linking consecutive implementation waves and sequential TPB constructs. These findings suggest that sustainability learning develops progressively through successive cognitive, normative and behavioural stages rather than through isolated learning events. In contrast, the few nonsignificant indirect pathways indicate that not all sequential combinations contribute equally to behavioural execution, highlighting the complexity of the learning process across implementation waves.

The mediation results support the recursive structure proposed in the conceptual framework by showing that behavioural execution is shaped by the cumulative interaction between Cognitive–Emotional Catalysts, perceived agency and normative alignment across successive implementation waves.

To examine whether the proposed structural relationships differed according to participants' educational and professional contexts, a multigroup analysis (MGA) was conducted comparing the student and employee samples.

The multigroup analysis presented in Table 15 indicates that the magnitude and statistical significance of several structural relationships differed between students and employees. Overall, employees exhibited more consistent and statistically significant temporal relationships across the three implementation waves, whereas the student sample showed greater variability, particularly for relationships involving the transition between cognitive–emotional activation and perceived agency. These findings suggest that the proposed TPB-based learning process operates in both groups, although its temporal consolidation appears to differ according to participants' educational and professional contexts. Despite these differences, the strongest structural relationships were observed in both groups for the links connecting Perceived Agency and Norm Alignment (PAN) with Intentional Commitment and Behavioural Execution (ICB). This consistency suggests that normative perceptions and perceived behavioural control constitute central mechanisms within the proposed longitudinal framework regardless of participant profile, while the earlier cognitive–emotional stages appear to be more sensitive to contextual differences. Taken together, the MGA results provide additional support for the robustness of the proposed conceptual framework while indicating that the strength of specific longitudinal relationships may vary across educational and organizational settings. Consequently, the observed group differences should be interpreted as contextual variations in the operation of the model rather than as evidence of fundamentally different learning mechanisms.

**Table 15.** MGA multigroup.

| | Orig (S) | Orig (E) | Mean (S) | Mean (E) | STDEV (S) | STDEV (E) | t Value (S) | t Value (E) | *p* Value (S) | *p* Value (E) |
|---|---|---|---|---|---|---|---|---|---|---|
| CEC2023 > CEC2024 | 0.054 | 0.272 | 0.053 | 0.272 | 0.101 | 0.050 | 0.536 | 5.485 | 0.592 | 0.000 *** |
| CEC2023 > PAN2023 | 0.852 | 0.602 | 0.853 | 0.602 | 0.047 | 0.046 | 18.178 | 13.053 | 0.000 | 0.000 *** |
| CEC2024 > CEC2025 | 0.259 | 0.235 | 0.272 | 0.239 | 0.096 | 0.044 | 2.704 | 5.335 | 0.007 | 0.000 *** |
| CEC2024 > PAN2024 | 0.210 | 0.303 | 0.221 | 0.303 | 0.116 | 0.045 | 1.811 | 6.743 | 0.070 | 0.000 *** |
| CEC2025 > PAN2025 | 0.207 | 0.105 | 0.214 | 0.108 | 0.120 | 0.052 | 1.719 | 2.024 | 0.086 | 0.043 * |
| ICB2023 > ICB2024 | −0.144 | −0.165 | −0.143 | −0.166 | 0.113 | 0.050 | 1.275 | 3.323 | 0.202 | 0.001 ** |
| ICB2024 > ICB2025 | 0.303 | 0.336 | 0.299 | 0.335 | 0.137 | 0.062 | 2.207 | 5.448 | 0.027 | 0.000 *** |
| PAN2023 > ICB2023 | 0.754 | 0.782 | 0.756 | 0.782 | 0.054 | 0.026 | 13.962 | 29.659 | 0.000 | 0.000 *** |
| PAN2023 > PAN2024 | 0.175 | 0.165 | 0.174 | 0.166 | 0.109 | 0.046 | 1.607 | 3.568 | 0.108 | 0.000 *** |
| PAN2024 > ICB2024 | 0.377 | 0.304 | 0.381 | 0.304 | 0.103 | 0.055 | 3.670 | 5.569 | 0.000 | 0.000 *** |
| PAN2024 > PAN2025 | 0.294 | 0.450 | 0.294 | 0.448 | 0.101 | 0.044 | 2.897 | 10.335 | 0.004 | 0.000 *** |
| PAN2025 > ICB2025 | 0.624 | 0.581 | 0.626 | 0.581 | 0.134 | 0.063 | 4.661 | 9.245 | 0.000 | 0.000 *** |

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

## 5. Discussion

R-square in this model reflects how effectively the structural paths explain variance in attitudinal, normative [50], and behavioural constructs, while $Q^2$-predictive captures the model's ability to forecast sustainability outcomes consistent with the research question and

TPB. Together, these indicators clarify whether the emotional-normative mechanisms activated by serious games possess genuine predictive strength, responding to methodological concerns about model adequacy and forecasting raised by Shute et al. [14]. This foundation sets the stage for evaluating how the model advances sustainability learning theory.

The present findings suggest that sustainability learning through serious games may develop through iterative cognitive, normative and behavioural processes rather than through a simple linear acquisition of knowledge. This departs from earlier research emphasizing short-term motivation [3] or context-detached emotional engagement [10]. The findings indicate that participants' self-reported behavioural execution appears to become more consistent when learners repeatedly confront socio-ecological complexity [5], receive immediate and actionable feedback [15], and progressively integrate emotional meaning into their emerging professional identity [20]. The integration of students and employees also advances calls for context-sensitive sustainability pathways [35]. These findings extend insights on prosocial learning [7] and emotional drivers of conservation [21], showing how simulations operationalize TPB constructs across time. The model thereby reframes serious games as tools for sustained attitudinal-normative calibration rather than temporary engagement.

The structural relationships identified in the proposed framework reinforce previous evidence highlighting the central role of perceived agency, social norms and cognitive–emotional engagement in sustainability education [16,23,24,51]. Rather than acting independently, these mechanisms appear to interact progressively across successive implementation waves, supporting the recursive learning process proposed in the conceptual model. The multigroup analysis suggests that the temporal consolidation of the proposed learning process differs between educational and organizational contexts. While the employee sample displayed more consistent structural relationships across implementation waves, greater variability was observed among students, particularly during the transition from cognitive–emotional activation to normative alignment. These differences should be interpreted as contextual variations in the operation of the proposed model rather than as evidence of fundamentally different learning mechanisms.

The predominance of partial mediation suggests that sustainability-related behavioural execution may be progressively reinforced through the cumulative interaction between Cognitive–Emotional Catalysts, perceived agency and normative alignment. Rather than replacing the direct structural relationships, the indirect pathways appear to complement them, supporting the recursive learning perspective underpinning the proposed TPB-based framework [19,37,52].

## 6. Conclusions

The present study contributes to the growing literature on sustainability education by suggesting that serious-game-based learning may support sustainability-related behavioural execution through the combined influence of cognitive–emotional activation, perceived agency and normative alignment. Rather than relying exclusively on emotional engagement, the proposed TPB-based framework indicates that sustainability learning appears to benefit from the progressive interaction of complementary psychological mechanisms across repeated implementation waves. This interpretation is consistent with previous work highlighting the complexity of translating environmental awareness into behavioural implementation [4,5,21,23].

### *6.1. Theoretical Conclusions*

The findings suggest that sustainability learning may develop through recursive cognitive–emotional processes rather than through a simple linear transfer of information.

Serious games appear to facilitate systems thinking and emotional resonance, yet these alone do not necessarily translate into sustained behavioural execution without concurrent normative reinforcement. This extends the arguments of Galeote et al. [17] and Groff [15], who contend that immersive environments deepen ecological understanding but cannot stabilize long-term action without concurrent normative reinforcement. Our findings clarify that emotional activation must be paired with perceived social legitimacy to influence sustained behaviour, supporting the claims of Sharma et al. [27] and Robina-Ramírez et al. [43] regarding the inherently social grounding of environmentally responsible conduct.

Building on this, the comparison between students and employees underscores sustainability as a developmental continuum shaped by practical experience. The comparison between students and employees suggests that the temporal operation of the proposed framework differs across educational and organizational contexts. Whereas employees displayed more consistent structural relationships throughout the implementation waves, greater variability was observed among students, particularly during the earlier stages of the learning process. These findings extend previous research by indicating that contextual experience may influence the consolidation of sustainability-related behavioural execution while preserving the general structure of the proposed theoretical model.

### *6.2. Managerial Practices*

Tourism managers should design training programmes that integrate emotional, cognitive, and normative reinforcement rather than relying solely on informational modules. The present findings suggest that emotional engagement, while valuable, may be strengthened when anchored within organizational expectations to support more consistent sustainability-related behavioural execution. This aligns with Emihovich [36], who emphasizes the role of guided reflection and social accountability in strengthening prosocial responses. Hotels may benefit from adopting simulation-based workshops using serious games like Hotel Giant 2 and Typsy to replicate resource management, ethical dilemmas, and guest-interaction challenges. Embedding sustainability criteria into these simulations may promote adaptive reasoning and operational confidence, reflecting the value of experiential problem solving documented by Chang and Yang [24]. Managers are encouraged to also pair simulations with structured debriefings that link decisions to ecological and organizational consequences, reinforcing normative expectations.

Organizations are encouraged to cultivate sustainability as a professional standard rather than an optional practice. The employee sample exhibited stronger associations to normative and agency cues, corroborating arguments by Han et al. [51] that workplace culture may facilitate behavioural continuity.

Managers could formalize sustainability expectations in performance evaluations, mentoring systems, and team protocols. Encouraging peer-to-peer learning, as suggested by Aguiar-Castillo et al. [38], further embeds sustainability norms across departments. Importantly, incentives should reward not only compliance but innovative contributions to sustainable operations, fostering creativity and ownership. By adopting these practices, organizations may progressively integrate sustainability from instructional content into enacted behaviour, ensuring employees internalize the emotional and normative dimensions necessary for long-term impact.

Future research should examine how identity-based meaning construction influences sustainability behaviours in tourism education. Rather than focusing on temporal effects, studies could explore how role identity, professional aspiration, and moral self-concept interact with game-based learning. Future research could also examine these relationships using panel-based longitudinal designs capable of tracking the same participants over time,

thereby allowing the assessment of within-person behavioural development and formal longitudinal measurement invariance.

A key limitation concerns the absence of cross-cultural comparisons. Sustainability norms vary across destinations, and serious-game effects may function differently in regions with divergent environmental values, hospitality traditions, or managerial systems. An additional limitation derives from the repeated cross-sectional longitudinal design adopted in this study. Although the same intervention protocol was implemented across three consecutive annual waves, participants were recruited as independent annual cohorts and were not individually tracked over time. Consequently, the reported temporal relationships should be interpreted as evidence of the reproducibility of the proposed theoretical framework across comparable implementation waves rather than as estimates of within-person behavioural development. Future studies could address this limitation by combining participant tracking with formal longitudinal measurement invariance analyses.

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**Institutional Review Board Statement:** According to the Regulations of the Bioethics and Biosafety Committee of the University of Extremadura (CBBUEx), the present study is exempt from formal ethical review because it is an observational, non-interventional social science study involving voluntary adult participants, anonymous questionnaires, and minimal risk. The study complied with the applicable institutional and legal ethical requirements, including informed consent, confidentiality, voluntary participation, and Regulation (EU) 2016/679 (GDPR).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and confidentiality restrictions involving students and hotel employees.

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## Appendix A

**Measurement Instrument**

The complete questionnaire administered to participants is presented below.

Participants completed the following questionnaire immediately after the sixth workshop during each annual implementation wave (2023–2025). The instrument was designed to capture participants' perceptions after completing the full serious-game-based sustainability training programme using Hotel Giant 2 and Typsy.

**Instructions to participants**

The following statements refer to your experience during the sustainability training programme using Hotel Giant 2 and Typsy. Please indicate the extent to which you agree with each statement based on your own experience during the workshops. There are no right or wrong answers. Your responses are anonymous and will be used exclusively for research purposes.

**Response format**

All items were assessed using a five-point Likert scale:

1 = Strongly disagree
2 = Disagree
3 = Neither agree nor disagree
4 = Agree
5 = Strongly agree

**Table A1.** Complete measurement instrument.

| Attribute | Code | Construct | Measurement Item |
|---|---|---|---|
| Systems Thinking Development | CEC11 | Cognitive–Emotional Catalysts | The games emotionally engaged me in understanding interconnected tourism systems and their environmental impacts. |
| Systems Thinking Development | PAN11 | Perceived Agency and Norm Alignment | I felt capable of managing complex tourism systems while meeting sustainability expectations. |
| Systems Thinking Development | ICB11 | Intentional Commitment and Behavioural Execution | I consistently applied systems thinking when making sustainable decisions in game scenarios. |
| Sustainability-Oriented Problem Solving | CEC12 | Cognitive–Emotional Catalysts | The games emotionally engaged me while resolving sustainability challenges in tourism contexts. |
| Sustainability-Oriented Problem Solving | PAN12 | Perceived Agency and Norm Alignment | I felt confident solving sustainability problems while meeting professional and social expectations. |
| Sustainability-Oriented Problem Solving | ICB12 | Intentional Commitment and Behavioural Execution | I effectively implemented sustainable solutions when facing real or simulated tourism challenges. |
| Emotional Engagement with Environmental Consequences | CEC13 | Cognitive–Emotional Catalysts | The games evoked emotional concern, responsibility, and motivation toward long-term environmental sustainability. |
| Emotional Engagement with Environmental Consequences | PAN13 | Perceived Agency and Norm Alignment | I felt capable and socially supported to maintain sustainable practices over time. |
| Emotional Engagement with Environmental Consequences | ICB13 | Intentional Commitment and Behavioural Execution | I consistently applied long-term sustainable tourism practices learned through immersive game experiences. |
| Self-Efficacy for Sustainable Action | CEC21 | Cognitive–Emotional Catalysts | Hotel Giant 2 and Typsy strengthened my emotional awareness of sustainability impacts. |
| Self-Efficacy for Sustainable Action | PAN21 | Perceived Agency and Norm Alignment | Gameplay tasks increased my confidence in performing sustainability actions independently. |
| Self-Efficacy for Sustainable Action | ICB21 | Intentional Commitment and Behavioural Execution | I intend to actively apply the sustainability routines practised within both simulation platforms. |
| Perceived Organizational and Social Expectations | CEC22 | Cognitive–Emotional Catalysts | The games illustrated how organizational expectations shape sustainability decisions and outcomes. |
| Perceived Organizational and Social Expectations | PAN22 | Perceived Agency and Norm Alignment | The games showed sustainability as socially expected by hospitality professionals and guests. |

**Table A1.** *Cont.*

| Attribute | Code | Construct | Measurement Item |
|---|---|---|---|
| Perceived Organizational and Social Expectations | ICB22 | Intentional Commitment and Behavioural Execution | Perceived organizational expectations encouraged me to consistently apply practised sustainability behaviours. |
| Alignment with Professional Sustainability Standards | CEC23 | Cognitive–Emotional Catalysts | The games demonstrated how professional sustainability standards shape operational decision-making. |
| Alignment with Professional Sustainability Standards | PAN23 | Perceived Agency and Norm Alignment | I perceived sustainability standards as required expectations within hospitality professions. |
| Alignment with Professional Sustainability Standards | ICB23 | Intentional Commitment and Behavioural Execution | Professional sustainability standards motivated me to apply these practices consistently. |
| Sustained Engagement in Sustainable Tourism Practices | CEC31 | Cognitive–Emotional Catalysts | The games reinforced emotional attachment and responsibility toward ongoing sustainable tourism practices. |
| Sustained Engagement in Sustainable Tourism Practices | PAN31 | Perceived Agency and Norm Alignment | I felt capable and socially expected to remain consistently committed to sustainability. |
| Sustained Engagement in Sustainable Tourism Practices | ICB31 | Intentional Commitment and Behavioural Execution | I sustained my commitment and translated it into real sustainable tourism behaviours. |
| Informed and Ethical Operational Decision-Making | CEC32 | Cognitive–Emotional Catalysts | The games emotionally engaged me when evaluating sustainable versus unsustainable operational choices. |
| Informed and Ethical Operational Decision-Making | PAN32 | Perceived Agency and Norm Alignment | I felt confident making decisions aligned with sustainability norms and professional expectations. |
| Informed and Ethical Operational Decision-Making | ICB32 | Intentional Commitment and Behavioural Execution | I effectively executed informed and ethical sustainable decisions in tourism operational contexts. |
| Active Implementation of Sustainable Tourism Behaviours | CEC33 | Cognitive–Emotional Catalysts | Gameplay generated emotional drive to participate in sustainability actions. |
| Active Implementation of Sustainable Tourism Behaviours | PAN33 | Perceived Agency and Norm Alignment | I felt able and socially encouraged to engage actively in sustainability practices. |
| Active Implementation of Sustainable Tourism Behaviours | ICB33 | Intentional Commitment and Behavioural Execution | I frequently performed and sustained eco-friendly actions inspired by gameplay experiences. |

Note. The questionnaire contains 27 reflective indicators organized into nine sustainability attributes. Each attribute is operationalised through the three theoretical constructs proposed in this study: Cognitive–Emotional Catalysts (CEC), Perceived Agency and Norm Alignment (PAN), and Intentional Commitment and Behavioural Execution (ICB). Item codes correspond to those used in the PLS-SEM measurement model.

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