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RESEARCH ARTICLE

REVISED Operationalizing the European sustainability competence framework: Development and validation of learning outcomes for GreenComp

[version 3; peer review: 4 approved]

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Abstract

Background

The European sustainability competence framework (GreenComp) lacks clearly defined learning outcomes, hindering its effective implementation and assessment. This paper addresses this critical gap by developing measurable learning outcomes within the OpenPass4Climate project.

Methods

A structured approach involving co-design workshops with 48 stakeholders across four countries, expert validation by a 12-member

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panel using a modified Delphi method, and comprehensive coverage analysis was employed. This iterative process led to the development of 40 learning outcomes aligned with GreenComp's four competence areas. These outcomes were formulated to be observable, measurable, and assessable.

Results

The process successfully yielded 40 learning outcomes, providing concrete, actionable targets that operationalize GreenComp's theoretical framework into practical educational tools. This developed framework facilitates the recognition of sustainability competencies through Open Badges and supports the integration of sustainability education across formal, non-formal, and informal learning contexts.

Conclusions

This work contributes to advancing Education for Sustainable Development. However, challenges persist in ensuring universal applicability, balancing standardization with contextual adaptation, and maintaining the holistic nature of sustainability within micro-credentialing systems.

Hintergrund

Dem europäischen Nachhaltigkeitskompetenz-Rahmen (GreenComp) fehlen klar definierte Lernergebnisse, was seine effektive Umsetzung und Bewertung behindert. Dieser Artikel behandelt diese kritische Lücke durch die Entwicklung messbarer Lernergebnisse innerhalb des OpenPass4Climate-Projekts.

Methoden

Ein strukturierter Ansatz mit Co-Design-Workshops mit 48 Akteuren aus vier Ländern, Expertenvalidierung durch ein 12-köpfiges Panel mittels einer modifizierten Delphi-Methode und umfassender Abdeckungsanalyse wurde angewandt. Dieser iterative Prozess führte zur Entwicklung von 40 Lernergebnissen, die mit den vier Kompetenzbereichen von GreenComp übereinstimmen. Diese Ergebnisse wurden formuliert, um beobachtbar, messbar und bewertbar zu sein.

Ergebnisse

Der Prozess erbrachte erfolgreich 40 Lernergebnisse und lieferte konkrete, umsetzbare Ziele, die GreenComps theoretischen Rahmen in praktische Bildungsinstrumente operationalisieren. Dieser

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entwickelte Rahmen erleichtert die Anerkennung von Nachhaltigkeitskompetenzen durch Open Badges und unterstützt die Integration von Nachhaltigkeitsbildung in formale, non-formale und informelle Lernkontexte.

Schlussfolgerungen

Diese Arbeit trägt zur Weiterentwicklung der Bildung für nachhaltige Entwicklung bei. Dennoch bestehen Herausforderungen bei der Gewährleistung universeller Anwendbarkeit, der Ausbalancierung von Standardisierung mit kontextueller Anpassung und der Beibehaltung der ganzheitlichen Natur der Nachhaltigkeit innerhalb von Mikro-Zertifizierungssystemen.

Contexte

Le cadre européen de compétences en matière de durabilité (GreenComp) manque de résultats d'apprentissage clairement définis, ce qui entrave sa mise en œuvre et son évaluation efficaces. Cet article comble cette lacune critique en développant des résultats d'apprentissage mesurables dans le cadre du projet OpenPass4Climate.

Méthodes

Une approche structurée impliquant des ateliers de co-conception avec 48 parties prenantes de quatre pays, la validation par un panel de 12 experts utilisant une méthode Delphi modifiée, et une analyse de couverture complète a été employée. Ce processus itératif a conduit au développement de 40 résultats d'apprentissage alignés sur les quatre domaines de compétences de GreenComp. Ces résultats ont été formulés pour être observables, mesurables et évaluables.

Résultats

Le processus a permis de produire avec succès 40 résultats d'apprentissage, fournissant des objectifs concrets et réalisables qui opérationnalisent le cadre théorique de GreenComp en outils éducatifs pratiques. Ce cadre développé facilite la reconnaissance des compétences en durabilité grâce aux Open Badges et soutient l'intégration de l'éducation à la durabilité dans les contextes d'apprentissage formel, non formel et informel.

Conclusions

Ce travail contribue à faire progresser l'Éducation au Développement Durable. Cependant, des défis persistent pour assurer l'applicabilité

universelle, équilibrer la standardisation avec l'adaptation contextuelle, et maintenir la nature holistique de la durabilité au sein des systèmes de micro-certification.

Contesto

Il quadro europeo delle competenze sulla sostenibilità (GreenComp) manca di risultati di apprendimento chiaramente definiti, ostacolando la sua implementazione e valutazione efficaci. Questo articolo affronta questa lacuna critica sviluppando risultati di apprendimento misurabili all'interno del progetto OpenPass4Climate.

Metodi

È stato impiegato un approccio strutturato che coinvolge workshop di co-progettazione con 48 parti interessate di quattro paesi, la validazione da parte di un panel di 12 esperti utilizzando un metodo Delphi modificato e un'analisi di copertura completa. Questo processo iterativo ha portato allo sviluppo di 40 risultati di apprendimento allineati con le quattro aree di competenza di GreenComp. Questi risultati sono stati formulati per essere osservabili, misurabili e valutabili.

Risultati

Il processo ha prodotto con successo 40 risultati di apprendimento, fornendo obiettivi concreti e attuabili che operazionalizzano il quadro teorico di GreenComp in strumenti educativi pratici. Questo quadro sviluppato facilita il riconoscimento delle competenze sulla sostenibilità attraverso gli Open Badges e supporta l'integrazione dell'educazione alla sostenibilità nei contesti di apprendimento formale, non formale e informale.

Conclusioni

Questo lavoro contribuisce al progresso dell'Educazione allo Sviluppo Sostenibile. Tuttavia, persistono sfide nel garantire l'applicabilità universale, bilanciare la standardizzazione con l'adattamento contestuale e mantenere la natura olistica della sostenibilità all'interno dei sistemi di micro-certificazione.

Antecedentes

El marco europeo de competencias en sostenibilidad (GreenComp) carece de resultados de aprendizaje claramente definidos, lo que dificulta su implementación y evaluación efectivas. Este artículo aborda esta brecha crítica mediante el desarrollo de resultados de

aprendizaje medibles dentro del proyecto OpenPass4Climate.

Métodos

Se empleó un enfoque estructurado que involucra talleres de co-diseño con 48 las partes interesadas por un panel de 12 cuatro países, validación de expertos utilizando un método Delphi modificado y un análisis integral de cobertura. Este proceso iterativo condujo al desarrollo de 40 resultados de aprendizaje alineados con las cuatro áreas de competencia de GreenComp. Estos resultados fueron formulados para ser observables, medibles y evaluables.

Resultados

El proceso produjo exitosamente 40 resultados de aprendizaje, proporcionando objetivos concretos y accionables que operacionalizan el marco teórico de GreenComp en herramientas educativas prácticas. Este marco desarrollado facilita el reconocimiento de competencias en sostenibilidad a través de Open Badges y apoya la integración de la educación en sostenibilidad en contextos de aprendizaje formal, no formal e informal.

Conclusiones

Este trabajo contribuye al avance de la Educación para el Desarrollo Sostenible. Sin embargo, persisten desafíos para asegurar la aplicabilidad universal, equilibrar la estandarización con la adaptación contextual y mantener la naturaleza holística de la sostenibilidad dentro de los sistemas de micro-acreditación.

Plain Language summary

The European Union developed the European sustainability competence framework (GreenComp) to define the competencies citizens need to address environmental challenges and climate change. However, this framework remained abstract, lacking concrete specifications of what individuals should be able to demonstrate as evidence of these competencies.

This research addresses this gap by developing 40 specific, measurable learning outcomes that operationalize the GreenComp framework. The development process involved collaborative workshops with 48 stakeholders from four European countries, including educators from formal education settings, trainers from non-formal contexts, and learners across various educational levels from vocational training to doctoral studies.

The proposed learning outcomes were validated by a panel of 12 sustainability education experts through two iterative rounds. A systematic coverage analysis ensured that all knowledge, skill, and attitude elements specified in the original framework were addressed.

This analysis identified critical gaps in philosophical dimensions, economic transformation models, and resource conflict dynamics, leading to the creation of four additional learning outcomes.

The final set of 40 learning outcomes provides educational institutions, training organizations, and assessment bodies with concrete targets for curriculum development and competency evaluation. These outcomes enable the implementation of recognition systems, including digital badges and micro-credentials, that document specific sustainability competencies. This framework supports the integration of sustainability education across formal, non-formal, and informal learning contexts throughout Europe, contributing to the development of citizens capable of addressing complex socio-ecological challenges.

Keywords
Education for Sustainable Development, Open Badges, Assessment, Knowledge-Skills-Attitudes, Sustainability Competencies

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REVISED **Amendments from Version 2**

This revision responds to reviewer feedback by adding substantial methodological detail, practical implementation guidance, and critical perspectives that strengthen the manuscript's scientific rigor and stakeholder utility.

Methodological enhancements: The Methods section now includes objective eligibility criteria for the expert panel (≥5 years relevant practice and/or ≥5 peer-reviewed outputs), explicit geographical distribution across six European countries, and a detailed explanation of the co-design synthesis process, including concrete examples of outcome merging and the three internal ranking criteria used.

Practical implementation: A new "Implementation notes" subsection in Results provides two worked assessment examples: one demonstrating a complete assessment pathway for a single learning outcome, and another illustrating integrated assessment of multiple outcomes through a community sustainability project using constellation-based approaches.

Critical perspectives: The Discussion now includes a new subsection critically examining micro-credentialing risks, specifically addressing "badge inflation" and "checklist drift," alongside concrete governance safeguards to preserve the transformative, holistic aims of education for sustainable development.

Cultural adaptability: A new Discussion subsection outlines a four-step protocol for adapting learning outcomes to diverse cultural contexts, while the Limitations section explicitly acknowledges the Western/Southern European perspective and identifies embedded assumptions requiring attention in future validations.

Visual enhancement: Figure 1 has been added to illustrate the coverage analysis progression from gap identification to enhancement actions.

Practical roadmap: The Future directions section has been expanded with actionable guidance across five implementation domains: educator capacity building, curriculum integration, progression pathways, quality assurance, and institutional support.

Any further responses from the reviewers can be found at the end of the article

Introduction

The mounting evidence of climate change and environmental degradation has catalyzed a fundamental shift in how educational institutions conceptualize their role in preparing learners for an uncertain future (Nusche *et al.*, 2024). The European Union's response, embodied in the European sustainability competence framework (GreenComp) (Bianchi *et al.*, 2022), represents a significant policy intervention aimed at systematically developing citizens' capabilities to navigate and address complex socio-ecological challenges. However, the translation of this ambitious framework into concrete educational practice remains problematic, revealing a critical gap between policy aspiration and pedagogical implementation.

This research is guided by a central methodological challenge: How can the GreenComp framework be operationalized into a set of valid, assessable learning outcomes that are fit for purpose within a European-level recognition system?

EU competence frameworks for lifelong learning

The European Commission's Joint Research Centre has developed a family of reference frameworks (LifeComp, EntreComp, DigComp, and GreenComp) to establish a shared understanding of key competences for citizens across formal, non-formal, and informal learning contexts. These "competency models" serve to describe learning outcomes and thus provide frameworks for operationalizing educational goals (Klieme *et al.*, 2004). However, they vary significantly in their level of detail and implementation guidance.

LifeComp, the European framework for "personal, social and learning to learn" competences, consists of nine competencies organized in three areas (Personal, Social, Learning to Learn). It is explicitly conceptual and non-prescriptive, intended to inform curriculum and learning-activity design, but does not include a progression model or a formal catalogue of learning outcomes.

EntreComp, the Entrepreneurship Competence Framework, articulates 15 competences in three interrelated areas (Ideas & Opportunities, Resources, Into Action), mapped along an 8-level progression model, and provides a comprehensive list of 442 learning outcomes to guide curriculum design and assessment (Bacigalupo *et al.*, 2016).

DigComp, the Digital Competence Framework for Citizens, defines 21 digital competences across five areas, described at eight proficiency levels, and is being extended via the "DigComp: Learning outcomes" project to develop intended learning outcomes and supporting materials for diverse application contexts. The development of learning outcomes for DigComp may serve as the basis for the European Digital Skills Certificate (EDSC), conceptualized as a quality label for digital skills certification across Europe.

GreenComp, the European Sustainability Competence Framework, identifies 12 sustainability competences organized into four areas (Embodying Sustainability Values, Embracing Complexity, Envisioning Sustainable Futures, Acting for Sustainability), each described by a competency descriptor plus Knowledge–Skills–Attitudes (KSAs). While the framework's background document references "behavioral learning outcomes" (Scalabrino, 2022), and the main framework document acknowledges the need to incorporate learning outcomes into sustainability pedagogies (Bianchi *et al.*, 2022), neither establishes formal, assessable learning outcomes nor a progression model, resulting in an "implementation vacuum".

The GreenComp framework – Focus of this study

EntreComp and DigComp already define or are in the process of defining detailed learning outcomes, and LifeComp remains at a conceptual level without specific outcome descriptors. In this study, the authors propose a set of measurable learning outcomes for GreenComp. In doing so, it aims to fill the current gap in operationalizing the sustainability competences of GreenComp, transforming its descriptive KSAs into assessable statements that educators and trainers can use to guide curriculum development, implementation, and evaluation.

Current state of GreenComp assessment

The landscape of GreenComp assessment initiatives reveals a complex tapestry of approaches (Javorka *et al.*, 2024), each grappling with the fundamental challenge of operationalizing sustainability competencies into measurable outcomes. These diverse efforts, while demonstrating considerable innovation and commitment, collectively illuminate both the possibilities and persistent limitations in translating the framework's ambitious vision into practical assessment tools.

Traditional knowledge-focused assessment approaches dominate the current landscape, exemplified by TASK™ by Sulitest, which achieves comprehensive coverage of knowledge elements (100% alignment) while demonstrating more limited capacity in assessing skills (70% alignment) and attitudes (30% alignment) (Sulitest, 2023). This imbalance, far from being merely technical, reflects deeper epistemological assumptions about what constitutes legitimate and measurable learning in sustainability education. CertiSkill™ similarly privileges cognitive dimensions through its certification exam based on 30 multiple-choice questions aligned with UNI/Pdr 109.2:2021 standards, while the Engineers4Europe project's Green Skills micro-credential, despite its innovative platform delivery and broad disciplinary appeal, ultimately relies on three knowledge-based quizzes to assess competencies in corporate sustainability and ESG.

Attempts to address the skills dimension of GreenComp have produced varied approaches with differing levels of rigor. The My Personality Skills® framework by Fundacja represents a private sector initiative offering the MY PS GreenComp Certificate, with examinations spanning all four GreenComp areas. However, the proprietary nature of this assessment raises questions about transparency and alignment with the open, collaborative spirit of the European competence frameworks. More innovative approaches emerge in the self-assessment domain, where BCN+B's Be Ready For Now employs a 48-question reflective instrument examining sustainability habits and knowledge, though its self-reporting methodology limits its utility for formal competence recognition.

The assessment of attitudes and values, arguably the most transformative dimension of sustainability education, remains particularly underdeveloped. The Advancing Sustainability Education's Sustainability Competence Mindset Map (SCMM) represents one of the few initiatives explicitly capturing attitudinal dimensions of sustainability competence capacity building. The SCMM is a formative self-reflective assessment based on the key sustainability competence frameworks (Brundiers *et al.*, 2021; Redman & Weik, 2021) and has been validated across disciplines in higher education (Annelin & Boström, 2023; Annelin & Boström, 2024a). It is a facilitating tool that supports teacher course planning and curriculum design, where teachers follow the progression of the affective intrapersonal attitudes of students over different periods of time (a course, a semester, a year, a program). Teachers can communicate the learning experience with the students by using visual aids, reflective work, and complementary assessment techniques. The outcome of the SCMM assessment is automated via online tools integrated with data software to produce visual and comparable diagrams of the class progression. The tool is applied in the understanding that sustainability competence capacity building is a nonlinear, life-long learning process. This nonlinear relation is captured in the visual diagrams presented. The SCMM is used to complement the integration of knowledge and skills assessment necessary for a traditional holistic competence assessment.

Educational technology has offered novel pathways for engagement, though not necessarily for rigorous assessment. The GameComp–Green Edugames Erasmus+ project exemplifies this trend through its gamified approach, featuring 36 self-reflective questions that award badges and points, creating motivational affordances while formal competence certification calls for established validity and reliability standards.

Providing a more methodologically robust but more narrowly focused example, the EduCITY project uses mobile augmented reality games (MARGs) to assess sustainability competencies within smart learning city environments. This research-driven initiative demonstrates how a deep and specific assessment can be operationalized, but it also highlights the challenge of comprehensive coverage. Its assessment model, as presented, explicitly targets only one of the four GreenComp competence areas: 'Embodying Sustainability Values'. Within this specific area, the project employs a rigorous mixed-methods approach, triangulating data from a validated GreenComp-based questionnaire with automated gameplay performance logs. While its scope is partial, the EduCITY model provides a structured and evidence-based method for evaluating competencies fostered through experiential, technology-enhanced learning, a level of detail not present in initiatives that claim broader coverage based on self-reflection or participation alone (Marques *et al.*, 2025).

The ASSESS project developed a more pedagogically sophisticated approach, creating rubrics for Green Competencies assessment across multiple levels (primary, secondary, higher education, and business contexts) with an accompanying mobile application. Their framework emphasizes dialogic assessment through co-creation of rubrics between teachers and students, peer and self-assessment capabilities, and collaborative discussion of evaluation criteria (Sousa *et al.*, 2024). While this dialogic approach is powerful for fostering student agency and formative development, its reliance on context-specific, co-created criteria stands in direct tension with the goals of a standardized recognition framework. The method's pedagogical strength in the classroom, therefore, presents a significant challenge for issuing portable credentials, whose currency depends on a high degree of comparability and inter-institutional trust.

The emergence of Open Badge initiatives represents a particularly promising yet problematic development in GreenComp operationalization. The GoGreen - Youth Navigator project's Green Badges system, hosted on the Cities of Learning platform and announced for pilot testing in January 2025, allows activity organizers to tag skills and competencies while enabling participants to earn badges and share learning experiences. However, the absence of defined learning outcomes or

systematic assessment criteria reduces these badges to participation certificates rather than competence credentials. The same platform hosts the Climate for All project's "Climate for All Facilitator Training", where a 5-hour course includes a GreenComp Reflection badge recognizing "experiential understanding" gained through game-based learning, a formulation that sidesteps the challenge of defining what such understanding entails or how it might be evidenced beyond self-report.

More substantial efforts at badge-based recognition emerge in formal educational contexts. The University of Florence's "Education Towards Sustainable Futures" badge, launched in June 2023 as part of The European University for Well-Being [EUniWell] Erasmus+ project, recognizes completion of a hybrid course for future teachers comprising five days of training, self-learning activities, and evaluation. While this initiative demonstrates closer alignment with formal educational quality assurance through its explicit connection to the GreenComp methodological framework, it remains fundamentally a credential of participation rather than assessed competence.

This proliferation of initiatives collectively reveals both the widespread recognition of GreenComp's importance and the persistent conceptual and methodological challenges in its implementation. Each project's idiosyncratic interpretation of what constitutes evidence of sustainability competencies has created a fragmented landscape where innovation flourishes but coherence and comparability remain elusive. The absence of shared assessment criteria, quality assurance mechanisms, or interoperability frameworks means that a learner's sustainability competencies may be recognized entirely differently, or not at all, across institutional and national boundaries. This patchwork approach, while reflecting healthy experimentation, ultimately undermines GreenComp's vision of providing a common European framework for sustainability competencies, highlighting the urgent need for more systematic approaches to learning outcome definition and assessment methodology.

The need for learning outcomes in GreenComp

Learning outcomes are essential for operationalizing competence frameworks, as they translate competencies into concrete, observable, and assessable statements of what learners should know and be able to do. The development of clear learning outcomes for GreenComp provides concrete targets for curriculum design and assessment in formal education, while guiding the development of non-formal learning experiences and workplace training. They enable the validation and recognition of informal learning through frameworks like Open Badges and support the evaluation of educational interventions for sustainability competence development.

Yet the challenge of developing learning outcomes for GreenComp extends beyond these technical considerations of measurement and validation. Sustainability competencies embody what Wals (2015) terms "gestalt competencies", i.e., holistic capabilities that emerge from the integration of knowledge, values, and action in ways that resist decomposition into discrete elements. This conceptualization reveals a fundamental paradox at the heart of our endeavor: educational systems require specificity for assessment and credentialing, while sustainability challenges demand integrated, systemic responses that transcend disciplinary and methodological boundaries.

The "wicked" nature of sustainability problems compounds this challenge. Characterized by complexity, uncertainty, value conflicts, and systemic interdependencies, these problems resist reduction to discrete, measurable outcomes. UNESCO's framework for Education for Sustainable Development (UNESCO, 2019) emphasizes the need to develop three interconnected dimensions: cognitive (knowledge and understanding) (Spaccatini *et al.*, 2023), socio-emotional (values and attitudes) (Lozano *et al.*, 2022), and behavioral dimension (often referred to as conative, encompassing goal-directed actions and capabilities) (Presseau *et al.*, 2019). This tripartite model suggests that traditional approaches to learning outcome development, which typically privilege cognitive dimensions as more readily assessable, may be fundamentally insufficient for capturing the transformative potential of sustainability education.

Furthermore, sustainability education carries an explicitly normative dimension that distinguishes it from other competence frameworks in the European portfolio. While DigComp can maintain relative neutrality regarding digital tool use, treating technology as a means rather than an end, and EntreComp can embrace diverse entrepreneurial values within a broadly capitalist framework, GreenComp necessarily embeds particular values about human-nature relationships, intergenerational justice, and systemic transformation. This normative dimension creates profound tensions when developing learning outcomes that must be both prescriptive enough to guide learning and open enough to accommodate diverse cultural and ideological contexts.

The gestalt nature of sustainability competencies thus presents a double bind: decompose them too much and they lose their transformative essence, becoming mere technical skills divorced from the values and systemic thinking that give them meaning; leave them too holistic and they become impossible to assess, reducing credentials to vague attestations of exposure rather than evidence of capability. This tension between the holistic nature of sustainability competencies and the analytical requirements of educational systems represents not merely a technical challenge to be solved, but a fundamental feature of sustainability education that must be navigated thoughtfully.

Our approach to developing learning outcomes for GreenComp must therefore acknowledge and work within these tensions rather than attempting to resolve them prematurely. The outcomes must be specific enough to guide educational practice and enable recognition, while remaining open enough to accommodate the emergent, contextual, and transformative nature of sustainability learning. They must honor the gestalt quality of sustainability competencies while providing sufficient structure for implementation across diverse educational contexts. Most critically, they must maintain the normative vision of sustainability transformation while respecting cultural diversity and local knowledge systems.

The OpenPass4Climate context

The OpenPass4Climate project (2022-1-FR01-KA220-HED-000089354) provides the institutional context for this learning outcome development, with its focus on creating an open recognition alliance system for sustainability competencies. The project aims to tackle climate change by implementing innovative teaching and learning methods, with one of its key objectives being the development of Open Badges for recognition of non-formal and informal learning related to sustainability competencies, ultimately leading to certification of competencies through Europass. This technological and institutional infrastructure shapes the requirements for learning outcomes, which must be granular enough for badge-based recognition while comprehensive enough to represent meaningful competency development. This presents a central methodological challenge: leveraging the accessibility of micro-credentials without succumbing to the very reductionism that a holistic framework like GreenComp seeks to avoid. The methodology described below was designed explicitly to navigate this tension.

Methodology

The development of learning outcomes for GreenComp required a methodological approach that could navigate multiple tensions: between theoretical comprehensiveness and practical applicability, between standardization and contextual flexibility, and between expert knowledge and stakeholder accessibility. A systematic, iterative approach was chosen, comprising four interconnected phases: initial co-design, first expert validation, coverage analysis, and second expert validation. This multi-phase approach allowed for progressive refinement while maintaining alignment with both the GreenComp framework and CEDEFOP guidelines for learning outcome development.

Phase 1: Initial co-design process

The co-design phase represented a deliberate departure from expert-driven approaches to learning outcome development. Rather than beginning with technical specifications derived from learning theory, we initiated a collaborative process across the four OpenPass4Climate consortium institutions. Each institution assembled carefully balanced stakeholder groups: (1) at least three educators from formal education (university faculty at UniLaSalle, NOVA, and University of Valladolid; vocational trainers at CSCI Novara); (2) at least three practitioners from non-formal settings, recruited from corporate sustainability professionals engaged in the project's 'Work Package 5 - Impact evaluation, enlargement & policy recommendations'); and (3) at least five learners representing different educational levels, such as vocational and A-level students (CSCI Novara), Bachelor's and Master's students (UniLaSalle, NOVA), and doctoral candidates (University of Valladolid). Learner participants were volunteers selected via a convenience sampling approach from those involved in the prior surveys and focus groups of the project's 'Work Package 3 - Nature & assessment of engagement' (Martín-Ramos *et al.*, 2025). By bringing together these diverse perspectives (spanning educational levels, professional contexts, and implementation settings), we ensured the resulting learning outcomes would be meaningful across the full spectrum of contexts where GreenComp might be applied.

The co-design process unfolded through a series of structured workshops conducted over three months. Each institution hosted four workshops (one per GreenComp competence area) online via Microsoft Teams and Miro collaborative platform, conducted in local languages without time constraints to facilitate nuanced discussion. Participants worked in interdisciplinary groups to translate abstract KSA statements into concrete learning outcomes.

To structure the KSA translation process, we employed Bloom's revised taxonomy (Anderson & Krathwohl, 2001) as a heuristic device rather than a rigid framework. Participants were encouraged to consider how each competence might manifest at different cognitive levels, from basic comprehension to creative synthesis. However, we found that many sustainability competencies resisted easy categorization within Bloom's framework, particularly those involving affective dimensions or systems thinking. This led to iterative refinement of outcomes that attempted to capture the holistic nature of competencies while maintaining sufficient specificity for assessment purposes.

The learning outcomes were formulated according to the Centre Européen pour le Développement de la Formation Professionnelle (CEDEFOP) guidelines for defining, writing and applying learning outcomes (CEDEFOP, 2022), ensuring they were observable (describing a behavior or product that can be observed), measurable (assessable using specific criteria), and student-centered (focusing on what the learner will be able to do). Each outcome was designed to integrate relevant knowledge, skills, and attitudes from the GreenComp framework, translating the abstract KSAs into concrete statements of what learners should demonstrate.

Following the institutional workshops, a cross-consortium synthesis process was undertaken by project staff (without participation from learners or non-formal trainers) to consolidate the proposals. Translation of outputs from the local languages into English was validated by bilingual consortium members to preserve conceptual accuracy. Similar outcomes were merged, and internal Delphi surveys were used to rank and select the top three learning outcomes for each of the 12 competencies. The initial co-design phase produced 36 learning outcomes, three for each of the 12 GreenComp competencies.

To ensure transparency in consolidation, outcomes were merged when they addressed the same specific KSA set and proposed overlapping observable behaviors and measurable criteria; for instance, two drafts that both targeted 1.2-S3 and 1.2-S4 with similar 'stakeholder mapping and inclusive facilitation' evidence were merged into one outcome with clarified scope and verbs. Internal Delphi ranking (two rounds, staff-only) prioritized: (i) precise alignment to the KSA granularity, (ii) clarity of measurability/observability in the 'Observable'

and 'Measurable' components, and (iii) non-duplication across outcomes within each competence area. Ties were resolved by selecting the version with the stronger evidence pathway and more transferable evaluation methods to avoid context-specific formulations. The final three outcomes per competence thus represent the highest-ranked, non-overlapping formulations ready for validation.

Phase 2: First expert validation round

The expert validation phase employed a modified Delphi approach designed to balance quality assurance with practical constraints, such as the project timeline and expert availability. Our expert panel comprised 12 specialists (8 women, 4 men) selected based on objective thresholds of expertise—(i) ≥5 years of relevant work in sustainability education/assessment and/or (ii) ≥5 relevant peer-reviewed or equivalent outputs—together with familiarity with European competence frameworks; selection criteria included authorship of GreenComp-related publications or reports, active engagement in the GreenComp Community, and participation in EU sustainability education projects such as TWIN-IN, ASSESS, EduC3, GrowLearnOut, GreenScent, GreenAtYou, and Entrepreneurship4All. The resulting panel represented diverse institutional contexts: five from higher education institutions, five from NGOs focused on sustainability education, one independent researcher, and the GreenComp Community manager, with current working countries including Sweden, Greece, Portugal, Spain, Italy, and North Macedonia. While this ensured strong topic coverage, it skewed toward Southern/Western Europe, a limitation addressed in the Discussion. This institutional diversity proved crucial during the validation process, as experts brought culturally and contextually specific insights that challenged the universalist assumptions embedded in our initial formulations.

The validation was conducted asynchronously using anonymous Microsoft Forms following an initial briefing via Teams. One form was created per competence area, with experts evaluating each learning outcome through a binary choice: 'valid as is' or 'not valid/requires improvement'. Selection of the latter option triggered a text field for detailed feedback and improvement suggestions. Forms remained open for four weeks to allow sufficient time for thoughtful evaluation.

Each learning outcome was assessed against four criteria

- Alignment: Clear relationship to the target GreenComp competence
- Measurability: Use of clear, assessable verbs and specific performance indicators
- Student-centricity: Focus on learner capabilities rather than teaching activities
- Observability: Potential for demonstration through observable behaviors or products

Analysis followed a conservative protocol: any learning outcome marked as 'not valid/requires improvement' by at least one expert was flagged for revision, regardless of overall approval rates. This approach ensured that all expert concerns were addressed. Qualitative feedback was analyzed thematically to identify recurring concerns and suggestions for improvement, with particular attention to cases where experts disagreed on validity judgments

Phase 3: Coverage analysis

Following the first validation round, we conducted a systematic coverage analysis to assess how comprehensively the learning outcomes addressed all aspects of the GreenComp framework. The primary goal was to verify that our 36 proposed learning outcomes collectively operationalized every individual KSA statement in the official GreenComp publication, ensuring no competence element remained unaddressed

The coverage analysis methodology involved three steps:

- Step 1: Matrix development. We created a comprehensive matrix mapping each validated learning outcome to specific knowledge, skill, and attitude statements within the GreenComp framework. Each cell in the matrix indicated whether a particular KSA element was addressed by one or more learning outcomes.
- Step 2: Gap identification. Through systematic analysis of the mapping matrix, we identified KSA elements that were either not addressed or insufficiently represented in the current outcome set. This analysis examined both horizontal coverage (across all competencies) and vertical coverage (across knowledge, skills, and attitudes within each competence).
- Step 3: Pattern analysis. We analyzed the patterns of gaps to understand whether they reflected systematic biases or specific challenges in operationalizing certain aspects of sustainability competencies. This involved examining whether gaps clustered around particular types of content (e.g., philosophical dimensions, cultural aspects, systemic perspectives).

The coverage analysis was conducted independently by three researchers, with discrepancies resolved through discussion and reference to the original GreenComp documentation. This triangulation approach enhanced the reliability of gap identification.

Phase 4: Second expert validation round

Based on the experts' first validation round feedback, revisions were made to the learning outcomes to improve their clarity, specificity, and evaluability. Concerning the coverage analysis findings, we developed strategies to address identified gaps through two approaches: (1) modification of existing learning outcomes to incorporate additional KSA elements, and (2) creation of new learning outcomes targeting unaddressed areas. All proposed changes were subjected to a second round of expert validation.

The second validation round followed a more focused protocol. Unlike the anonymous first round, experts

received personalized documentation packages via email containing:

- Detailed rationales for each proposed modification or addition
- Explicit mapping of how changes addressed prior comments or coverage gaps
- Comparison between the original and revised formulations

Experts provided direct, non-anonymous feedback within two weeks, enabling iterative clarification where needed. This approach facilitated deeper engagement with contentious additions, particularly learning outcomes challenging anthropocentric perspectives or addressing resource conflict dynamics. Experts were asked to evaluate not only the technical quality of these outcomes but also their appropriateness within the GreenComp framework and potential implementation challenges.

Results

The iterative development process produced a comprehensive set of 40 learning outcomes that operationalize the GreenComp framework while addressing critical gaps identified through systematic analysis. These results reflect the integration of stakeholder co-design, expert validation, and coverage enhancement across two major iterations.

First iteration outcomes

The initial co-design phase successfully generated 36 learning outcomes, three for each of the 12 GreenComp competencies. The first expert validation round revealed strong overall alignment with the framework, with 21 outcomes (58.3%) approved without modifications and 15 outcomes (41.7%) requiring revisions.

The outcomes receiving unanimous or near-unanimous approval clustered in areas where GreenComp provides clear, concrete guidance. These included:

- Area I (Embodying Sustainability Values): 3 outcomes addressing critique of sustainability arguments, inclusive solution construction, and nature preservation advocacy.
- Area II (Embracing Complexity): 8 outcomes focusing on systems analysis, interaction mapping, critical evaluation, and problem differentiation.
- Area III (Envisioning Sustainable Futures): 2 outcomes addressing decision-making with tradeoffs and interdisciplinary synthesis.
- Area IV (Acting for Sustainability): 8 outcomes covering political analysis, advocacy, coalition building, and initiative evaluation.

Concerning the remaining 15 learning outcomes, revisions included changes only to components for 4 learning outcomes (11.1%) and changes to both the main statement and other components for 11 learning outcomes (30.6%). Looking at component changes, observable components were revised in 14 learning outcomes (93.3% of changed learning outcomes), measurable components in 10 learning outcomes (66.7%), and evaluation methods in 12 learning outcomes (80.0%).

The revisions centered around several key themes:

- Improved action verbs: Many learning outcomes were revised to use more precise action verbs that clearly signal the level of learning expected. For example, “integrate” was changed to “connect,” “demonstrate” was changed to “adapt,” and “develop” was changed to “formulate”.
- Learner-centered approach: Observable components were revised to focus explicitly on what the learner can do rather than abstract qualities or outputs. For example, “Integration observable through synthesis of individual contributions” was changed to “The learner can map their personal sustainability actions to specific elements of shared sustainability frameworks, identify roles within collective initiatives, develop action plans...”
- Increased specificity and context: Learning outcomes were revised to provide clearer contexts and specify the scope of application. For example, “Implement principles of resource efficiency, reuse, and sharing” was changed to “Apply resource efficiency, reuse, and sharing principles in personal and group contexts.”
- Enhanced measurability: Vague measurable components were replaced with more concrete, assessable criteria. For example, “Scoring coherence and collective impact of coordinated actions” was changed to “Rubrics can assess the coherence between individual and collective actions, clarity of role definition, evidence of adaptation to collective contexts, and tangible contributions to shared sustainability goals.”
- Accessibility for non-specialists: Learning outcomes that required specialist knowledge were revised to be more accessible. For example, evaluation methods like “Environmental impact assessment projects” were changed to “Guided environmental impact assessment projects” to make them more accessible to non-specialists.
- Balancing individual and collaborative elements: Many learning outcomes were revised to balance individual action with collaborative and social dimensions. For example, “Initiate precautionary actions” was changed to “Apply the precautionary principle through targeted actions”, focusing on application rather than leadership/initiation, which might be intimidating for some learners.
- Clarity in complex concepts: Ambiguous or complex concepts were clarified. For example, “Develop strategies to manage transitions from environmental changes” was changed to “Formulate adaptive strategies to manage socio-ecological transitions necessitated

by environmental and societal changes," providing clearer parameters for what constitutes a transition.

Coverage analysis findings

The systematic coverage analysis revealed significant patterns in how the initial 36 learning outcomes addressed the GreenComp framework:

Well-covered areas included knowledge elements (87% of GreenComp knowledge statements were addressed), systems thinking aspects (with a comprehensive coverage across all three competence areas), and action-oriented skills (with a strong representation in Area IV, Acting for Sustainability).

With regard to the identified gaps, the analysis revealed systematic underrepresentation in four critical areas:

- Philosophical and ethical dimensions, with limited coverage of the intrinsic value of nature, ecocentric perspectives, and environmental ethics foundations.
- Cultural diversity in sustainability, with insufficient attention to diverse cultural conceptualizations of human-nature relationships.
- Economic transformation, with the absence of learning outcomes addressing alternative economic models and decoupling strategies.
- Conflict and resource dynamics, with no outcomes explicitly connecting resource depletion to social conflicts and environmental disasters.

Concerning coverage imbalances, attitudes were less comprehensively addressed compared to knowledge and skills; Area I (Embodying Sustainability Values) showed the most significant gaps, particularly in competence 1.3 (Promoting Nature); and systemic and structural dimensions were underrepresented relative to individual behavioral changes. Figure 1 visualizes these coverage patterns (Panel A) and maps how identified gaps systematically informed enhancement strategies (Panel B), demonstrating the evidence-based progression from gap identification to targeted learning outcome modifications and additions.

Enhancement strategies

To address identified gaps while maintaining a manageable number of learning outcomes, we employed two strategies (Figure 1B).

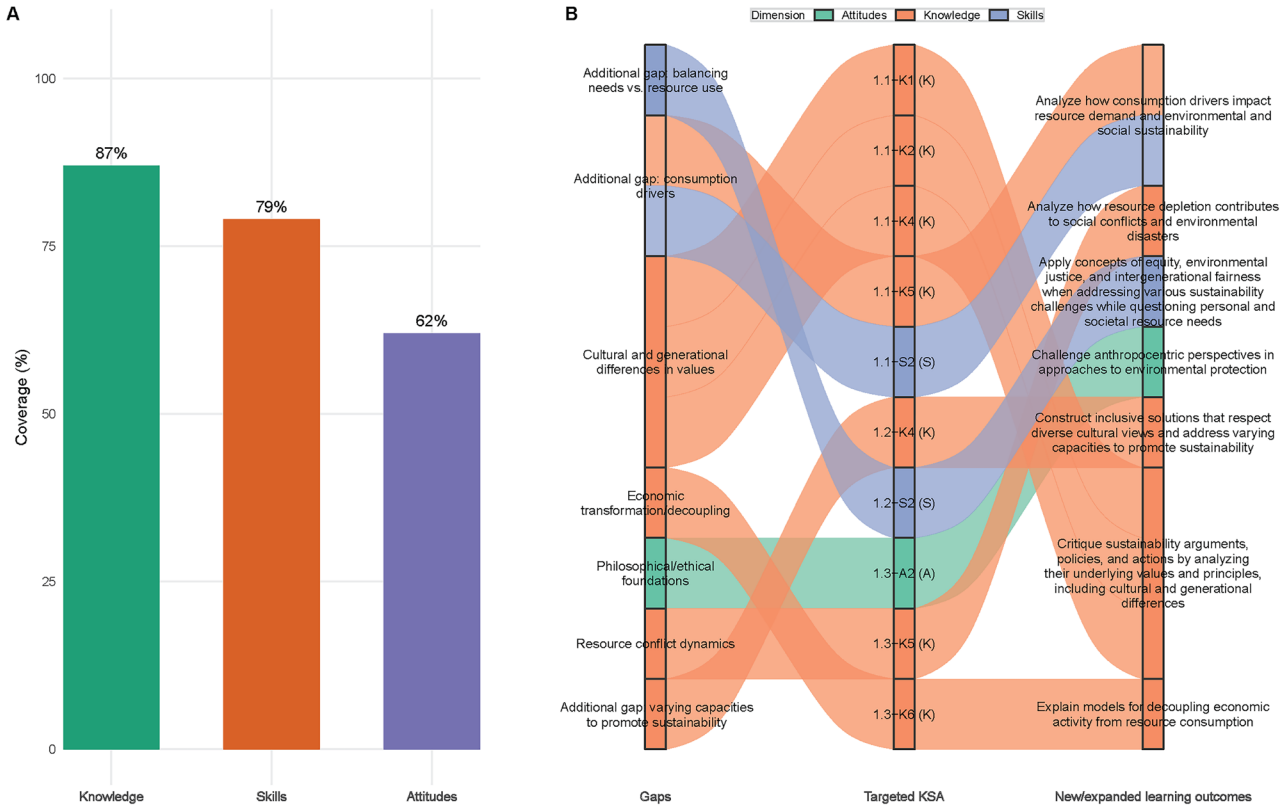

Figure 1. Coverage analysis: from gaps to actions. Panel A shows the proportion of GreenComp knowledge, skills, and attitudes addressed by the 36 initial learning outcomes in the coverage analysis. Panel B summarizes the four principal gap clusters (philosophical/ethical foundations; cultural and generational differences in values; economic transformation/decoupling; resource conflict dynamics) and indicates the targeted KSA elements and the specific new or expanded learning outcomes introduced in the second iteration to close those gaps; additional gaps addressed include consumption drivers, balancing personal/societal needs versus resource use, and varying capacities to promote sustainability.

The first strategy entailed the modification of existing learning outcomes. Three existing learning outcomes were expanded to incorporate additional KSA elements:

- Valuing sustainability learning outcome 1: Added cultural and generational dimensions to address the gap in coverage of 1.1-K4.
- Supporting fairness learning outcome 1: Integrated personal needs assessment with resource minimization to address the gap in coverage of 1.2-S2.
- Supporting fairness learning outcome 2: Included varying capacities for sustainability promotion to address the gap in coverage of 1.2-K4.

The second strategy involved the creation of new learning outcomes. Four new learning outcomes were developed to address critical gaps in the KSAs of the associated GreenComp competencies:

- Analyzing consumption drivers and their environmental and social impacts (1.1-K5).
- Explaining models for decoupling economic activity from resource consumption (1.3-K6).
- Analyzing how resource depletion contributes to social conflicts and environmental disasters (1.3-K5).
- Challenging anthropocentric perspectives in environmental protection approaches (1.3-A2).

Second iteration results

The second expert validation round focused on the eight modified or new learning outcomes. Three learning outcomes required further refinement based on expert feedback:

- Valuing Sustainability learning outcome 4 was enhanced to explicitly include social alongside environmental sustainability dimensions, with corresponding adjustments to measurable criteria and evaluation methods.
- Promoting Nature learning outcome 5 was expanded to balance coverage between social conflicts and environmental disasters, addressing expert concerns about incomplete scope. Measurable criteria were changed to explicitly include "connections between resource depletion and environmental disasters" and "feedback loops between resource scarcity and environmental degradation."
- Promoting Nature learning outcome 6: The suggestion to include "attributing equal importance to human and non-human beings" was carefully considered but ultimately refined to emphasize that approaches should consider multiple species' interests "as morally significant in their own right," maintaining philosophical accuracy while avoiding absolute equality claims that might not align with established ecocentric positions.

Final learning outcome distribution

The development process resulted in 40 learning outcomes (Table 1, Annex I in the Extended Data) distributed across the four GreenComp competence areas with a strategic emphasis on foundational values. Area I: Sustainability Values contains 13 learning outcomes, reflecting its foundational importance for sustainability competence development as the ethical grounding that informs all other aspects. The remaining three areas (Area II: Embracing Complexity, Area III: Envisioning Sustainable Futures, and Area IV: Acting for Sustainability) each contain 9 learning outcomes, providing balanced coverage of the analytical, future-oriented, and action-focused dimensions of sustainability competence.

For each outcome, Annex I provides detailed specifications of observable behaviors, measurable criteria, and evaluation methods that can be assembled into mixed-method assessment packages (analytic rubrics, portfolios, peer/self-review). To illustrate practical implementation, the following Implementation notes section presents two worked examples: one demonstrating a complete assessment pathway for a single outcome, and another showing how multiple outcomes can be assessed holistically within an integrated project.

Implementation notes

To support practical application of these learning outcomes, we provide two worked examples demonstrating assessment approaches that maintain rigor while honoring the holistic nature of sustainability competencies. The first example illustrates a detailed assessment pathway for a single learning outcome, while the second demonstrates how multiple outcomes can be assessed through an integrated project that preserves their gestalt quality.

Worked example (single outcome): LO 2.2.1 Evaluate the reliability of sustainability information sources and claims

Learning context: University-level sustainability course or adult education workshop on environmental literacy (adaptable across levels by adjusting source complexity and scaffolding).

Evidence requirements: Learners submit three annotated source evaluations covering different source types (e.g., peer-reviewed journal article, policy document or technical report, popular media article) plus a reflective memo (approximately 500 words) explaining their evaluation reasoning and identifying challenges encountered.

Assessment instrument: Four-criterion analytic rubric, each criterion scored on 4 levels (Developing / Adequate / Proficient / Exemplary):

- Credibility checks (KSA 2.2-K1, 2.2-S3): Does the learner systematically evaluate author credentials, publication venue reputation, peer review status, and institutional affiliations? Exemplary level: Consistently identifies multiple credibility indicators and explains their significance for source reliability.

Table 1. Complete set of forty GreenComp learning outcomes.

Competence area	Competence	Learning outcome	KSA coverage
I. Sustainability values	*1.1 Valuing sustainability*	1. Critique sustainability arguments, policies, and actions by analyzing their underlying values and principles, including cultural and generational differences	1.1-K1, 1.1-K2, 1.1-K4, 1.1-S1, 1.1-S2, 1.1-A3, 1.1-A4
		2. Negotiate solutions that reach a consensus aligned with specific sustainability principles while respecting diverse stakeholder perspectives	1.1-S4, 1.1-S5, 1.1-A2
		3. Design and implement a personal action plan applying concrete sustainability principles to daily choices	1.1-K3, 1.1-K6, 1.1-S3, 1.1-A1
		4. Analyze how consumption drivers impact resource demand and environmental and social sustainability	1.1-K5, 1.1-S2
	1.2 Supporting fairness	1. Apply concepts of equity, environmental justice, and intergenerational fairness when addressing various sustainability challenges while questioning personal and societal resource needs	1.2-K1, 1.2-K2, 1.2-S1, 1.2-S2, 1.2-A1
		2. Construct inclusive solutions that respect diverse cultural views and address varying capacities to promote sustainability	1.2-K4, 1.2-S3, 1.2-S4
		3. Advocate for the preservation of nature for current and future generations	1.2-K3, 1.2-A2, 1.2-A3
	1.3 Promoting nature	1. Explain the interconnectedness between human well-being and ecosystem health, including analyzing personal impacts on natural systems	1.3-K1, 1.3-K2, 1.3-K3, 1.3-S1, 1.3-S5, 1.3-A4
		2. Participate actively in specific practices that restore, regenerate, and promote harmonious coexistence with nature	1.3-S4, 1.3-A1, 1.3-S3, 1.3-A5
		3. Value the rights and roles of other life forms in maintaining ecological balance	1.3-K4, 1.3-S2, 1.3-A3
		4. Explain models for decoupling economic activity from resource consumption	1.3-K6
		5. Analyze how resource depletion contributes to social conflicts and environmental disasters	1.3-K5
		6. Challenge anthropocentric perspectives in approaches to environmental protection	1.3-A2
II. Embracing complexity	*2.1 Systems thinking*	1. Analyze how human activities across domains impact environmental and societal systems	2.1-K1, 2.1-K2, 2.1-S1, 2.1-S2, 2.1-A1, 2.1-A3
		2. Map the interactions, feedback, and cascading effects within complex sustainability issues	2.1-K4, 2.1-K5, 2.1-S3, 2.1-S5, 2.1-A2, 2.1-A4, 2.1-A5
		3. Apply systems modeling, life cycle assessment techniques, and resource minimization methods to sustainability challenges	2.1-K3, 2.1-S4
	2.2 Critical thinking	1. Evaluate the reliability of sustainability information sources and claims	2.2-K1, 2.2-K4, 2.2-S3, 2.2-S5, 2.2-A5
		2. Deconstruct arguments to identify underlying assumptions, biases, and contexts	2.2-K2, 2.2-K3, 2.2-K5, 2.2-S2, 2.2-A2
		3. Formulate evidence-based perspectives on sustainability issues that integrate diverse human and non-human considerations	2.2-K1, 2.2-S1, 2.2-S4, 2.2-A1, 2.2-A3, 2.2-A4
	2.3 Problem framing	1. Differentiate between simple, complicated, and complex sustainability problems	2.3-K1, 2.3-K2, 2.3-K4, 2.3-A2
		2. Transform sustainability problem definitions by systematically integrating diverse stakeholder viewpoints and systems-level considerations	2.3-K3, 2.3-S1, 2.3-S2, 2.3-A4
		3. Select appropriate strategies to mitigate, adapt, and solve sustainability challenges	2.3-K5, 2.3-S3, 2.3-S4, 2.3-S5

Competence area	Competence	Learning outcome	KSA coverage
III. Envisioning sustainable futures	*3.1 Futures literacy*	1. Create alternative scenario models that question current paradigms and envision transformative sustainable futures	3.1-K1, 3.1-K5, 3.1-S1, 3.1-A4
		2. Assess opportunities, risks, and implications of different future scenarios	3.1-K4, 3.1-S2, 3.1-A3
		3. Design a pathway with interventions toward a preferred sustainable future	3.1-K2, 3.1-K3, 3.1-S3, 3.1-S4, 3.1-A1, 3.1-A2
	3.2 Adaptability	1. Adapt personal practices in response to changing sustainability contexts, constraints, and new information	3.2-K4, 3.2-S1, 3.2-S2, 3.2-A2, 3.2-A4
		2. Make decisions by evaluating sustainability tradeoffs across domains and scales	3.2-K5, 3.2-S3, 3.2-A5
		3. Formulate adaptive strategies to manage socio-ecological transitions necessitated by environmental and societal changes	3.2-K1, 3.2-K2, 3.2-K3, 3.2-S3, 3.2-S4, 3.2-A1, 3.2-A3
	3.3 Exploratory thinking	1. Synthesize knowledge from various disciplines to approach sustainability issues	3.3-K1, 3.3-K4, 3.3-S1, 3.3-S2, 3.3-S3
		2. Experiment with innovative problem-solving methods, such as systems thinking, to address sustainability challenges	3.3-K2, 3.3-K3, 3.3-A1, 3.3-A4
		3. Accommodate diverse perspectives when exploring sustainable solutions	3.3-S5, 3.3-A2, 3.3-A3
IV. Acting for sustainability	*4.1 Political agency*	1. Analyze how political systems, policies, and power impact sustainability	4.1-K1, 4.1-S1, 4.1-A4
		2. Apply knowledge and skills for effective participation in democratic processes to advance sustainability policies	4.1-K3, 4.1-S2, 4.1-S4, 4.1-A1
		3. Advocate for political responsibility and sustainability accountability	4.1-K2, 4.1-K4, 4.1-S3, 4.1-A2, 4.1-A3
	4.2 Individual initiative	1. Evaluate one's potential to drive positive environmental changes	4.2-K1, 4.2-K3, 4.2-K4, 4.2-K5, 4.2-S4, 4.2-S6, 4.2-A2, 4.2-A3, 4.2-A4,
		2. Apply resource efficiency, reuse, and sharing principles in personal and group contexts	4.2-S1, 4.2-S5, 4.2-A5
		3. Apply the precautionary principle through targeted actions that help prevent ecological and human harm	4.2-K2, 4.2-S2, 4.2-S3, 4.2-A1
	4.3 Collective action	1. Build diverse coalitions by identifying stakeholder strengths and roles	4.3-K1, 4.3-S1, 4.3-S5
		2. Facilitate, initiate, or actively participate in inclusive community processes for coordinated sustainability action	4.3-K2, 4.3-K3, 4.3-K4, 4.3-S2, 4.3-S3, 4.3-S4, 4.3-A2, 4.3-A5
		3. Connect personal sustainability actions to the collective implementation of explicitly defined sustainability visions	4.3-S6, 4.3-A1, 4.3-A3, 4.3-A4

– Bias identification (KSA 2.2-K4, 2.2-S5): Does the learner recognize funding sources, rhetorical framing, omissions, and potential conflicts of interest? Exemplary level: Identifies subtle biases including omissions and framing effects, not just explicit conflicts of interest.

– Triangulation (KSA 2.2-S3, 2.2-S5): Does the learner cross-reference claims across multiple independent sources and seek primary evidence? Exemplary level: Systematically verifies claims through multiple independent sources and distinguishes primary from secondary evidence.

– Reflective justification (KSA 2.2-K1, 2.2-A5): Does the learner clearly explain evaluation reasoning, acknowledge uncertainty, and identify own potential biases?

Exemplary level: Provides sophisticated justification, acknowledges knowledge limitations and uncertainty, reflects on own biases that might influence evaluation.

Instructional sequence:

- Mini-lesson (1 hour): Introduce source evaluation principles with sustainability-specific examples (e.g., industry-funded studies, advocacy group reports)
- Guided practice (30 min): Collaborative evaluation of sample sources with instructor facilitation
- Independent analysis (2–3 hours, out of class): Learners complete three source evaluations
- Peer review (30 min): Partners exchange annotations and provide structured feedback
- Rubric scoring (instructor): Apply analytic rubric to annotated sources and reflective memo
- Feedback and reflection (20 min): Learners review scored rubrics and write brief reflection
- Optional revision: Learners may revise one source evaluation based on feedback to demonstrate learning progression

Explicit KSA coverage: This outcome directly addresses 2.2-K1 (understanding that sustainability knowledge evolves and claims require verification), 2.2-K4 (recognizing potential for misleading information), 2.2-S3 (evaluating information sources), 2.2-S5 (approaching sustainability claims skeptically), and 2.2-A5 (maintaining healthy skepticism while remaining open to evidence).

Integrated assessment example (preserving gestalt): Community sustainability intervention

Task: Co-design and implement a small-scale intervention with a community partner, including systems analysis, stakeholder engagement, and a reflective rationale.

Aligned outcomes: 2.1 'Map interactions/feedbacks' (Area II), 3.1 'Design a pathway toward a preferred future' (Area III), 4.3 'Facilitate/participate in inclusive community processes' (Area IV) with explicit KSA tags drawn from Annex I.

Evidence: Portfolio with (a) systems map and leverage points, (b) stakeholder engagement log and artifacts, (c) intervention plan and implementation notes, (d) reflective memo linking ethics and tradeoffs, all aligned to Annex I observables.

Judging approach: One 4-criterion analytic rubric (systems insight; inclusive process; pathway coherence/feasibility; reflective ethics), brief scorer calibration on two exemplars, and a peer-review checkpoint to surface bias and triangulate judgments, minimizing fragmentation across outcomes.

Discussion

Situating our contribution within the GreenComp assessment landscape

The proliferation of assessment initiatives targeting GreenComp competencies reveals both the recognized importance of sustainability education and the persistent challenges in its operationalization. Our review of existing approaches reveals a fragmented landscape characterized by partial coverage, methodological limitations, and implicit assumptions about the nature of sustainability competencies.

The dominant pattern across existing initiatives is the privileging of cognitive dimensions over affective and behavioral ones. TASK™ by Sulitest, despite its comprehensive alignment with GreenComp's knowledge elements (100% coverage), achieves only 70% coverage of skills and 30% of attitudes. This imbalance reflects not merely technical limitations but deeper assumptions about what constitutes legitimate educational assessment. The measurability of factual knowledge through traditional testing formats creates path dependencies that marginalize the transformative dimensions of sustainability education.

This limitation is critical because, as Mezirow (1981) argues, a core aim of education for sustainability must be to transform learners' perspectives, helping them reconsider and change problematic frames of reference while reshaping fundamental attitudes. Our contribution responds directly to this transformative imperative. Unlike initiatives that primarily focus on knowledge assessment, the developed learning outcomes address all three dimensions of learning (cognitive, social-emotional, and behavioral) across all 12 GreenComp competencies. In contrast to self-assessment tools, the learning outcomes are designed to be observable through specific behaviors or products and measurable using defined criteria. Rather than treating knowledge, skills, and attitudes as separate elements, the learning outcomes integrate these components into holistic statements of what learners should be able to demonstrate.

The philosophical grounding of our approach also distinguishes it from technocratic assessment initiatives. By explicitly incorporating learning outcomes that challenge anthropocentric worldviews and require engagement with environmental ethics, we acknowledge that sustainability education cannot be value-neutral. This normative dimension, while complicating assessment, is essential for the transformative potential of sustainability education.

Challenges and limitations

The development of learning outcomes for GreenComp revealed several persistent challenges that reflect deeper tensions in sustainability education. The most fundamental challenge concerns the tension between the holistic, transformative nature of sustainability competencies and the analytical requirements of learning outcome specifications. The learning outcomes are presented as discrete units, but sustainability competencies, with

their emphasis on systems thinking, value transformation, and collective action, resist decomposition into discrete, observable behaviors.

Cultural and contextual variability presents another significant challenge. While our expert panel represented diverse European contexts, the learning outcomes inevitably embed certain cultural assumptions about sustainability, education, and assessment. What constitutes "supporting fairness" or "promoting nature" varies significantly across cultural contexts, and our formulations, despite attempts at inclusivity, reflect predominantly Western European perspectives. Future research should therefore focus on validating and adapting these learning outcomes in non-European contexts, engaging with diverse cultural knowledge systems to enrich and decolonize the framework.

The cultural and geographical scope of our development process represents a significant limitation. Co-design workshops occurred exclusively in Western and Southern European institutions (France, Portugal, Spain, Italy), and the expert panel, while including diverse institutional types, concentrated geographically in Southern and Western Europe (detailed in Methods). This concentration means the learning outcomes inevitably reflect educational traditions, policy contexts, and sustainability priorities predominant in these regions, potentially embedding assumptions that require adaptation for other contexts.

Specific culturally embedded elements include: emphases on individual agency and democratic participation (particularly in Area IV: Acting for Sustainability) that may require reframing for contexts with different political systems or more collectivist cultural orientations; anthropocentrism-critique (LO 1.3.6) framed through Western environmental ethics that could benefit from incorporation of Indigenous or non-Western cosmologies of human-nature relationships; and assessment approaches (in Annex I) that privilege written individual work, potentially disadvantaging contexts with different literacy traditions or more oral/collective educational cultures. Additionally, the balance across learning outcomes—with substantial emphasis on individual responsibility alongside systemic change—may reflect Western European sustainability discourse that could differ from priorities in other regions facing different sustainability challenges or policy landscapes.

The cultural adaptation protocol below provides concrete guidance for contextualization, but we emphasize that adaptation cannot be performed by the original developers alone—it requires engagement with educators, learners, and knowledge holders from diverse contexts. Future research should include comparative implementation studies in Eastern and Northern European contexts, as well as beyond Europe where GreenComp frameworks are increasingly referenced, to identify culturally specific elements, test adaptation strategies, and potentially develop complementary outcomes addressing underrepresented perspectives. Only through such inclusive, iterative development can sustainability competence frameworks authentically support diverse pathways toward global sustainability goals while respecting cultural diversity and local knowledge systems.

The assessment challenge remains particularly acute. While we have specified observable and measurable dimensions for each learning outcome, the actual assessment of complex competencies like "challenging anthropocentric perspectives" requires sophisticated approaches that go beyond traditional testing. Portfolio assessment, peer evaluation, and community-based projects offer possibilities, but these require resources and expertise that may not be available in all educational contexts.

Cultural adaptability and contextualization

The learning outcomes were developed through a participatory process centered in Western and Southern European institutions, necessarily reflecting the educational traditions, policy contexts, and sustainability priorities of these regions. Responsible implementation across diverse European and global contexts requires systematic cultural adaptation rather than direct transfer.

We propose a four-stage adaptation protocol for educators and institutions implementing these outcomes in contexts beyond Western/Southern Europe:

Stage 1—Local stakeholder engagement: Before implementing outcomes, convene diverse local stakeholders (educators from the target educational sector, learners representing the intended population, community sustainability practitioners, and where relevant, Indigenous or cultural knowledge holders) to: (a) identify which outcomes align well with local sustainability priorities and educational approaches without modification, (b) flag outcomes requiring adjustment in language, emphasis, or examples to reflect local cultural values and educational philosophies, and (c) identify critical local sustainability issues underrepresented in the current outcome set that may warrant additional locally developed outcomes.

Stage 2—Linguistic and conceptual localization: Translate not merely language but underlying concepts and framings. For example, outcomes emphasizing "political agency" and "democratic processes" (e.g., LO 4.1.2) may require reframing for contexts with different governance structures, shifting emphasis toward appropriate forms of civic engagement available in the specific political system. Outcomes addressing "nature preservation" (e.g., LO 1.2.3) may benefit from expansion to explicitly incorporate Indigenous cosmologies or non-Western philosophical traditions of human-nature relationships where these are culturally central. Outcomes challenging "anthropocentric perspectives" (LO 1.3.6) may need adjustment to align with diverse cultural traditions regarding human-nature relationships.

Stage 3—Contextual examples and evidence adaptation: The Observable, Measurable, and Evaluation methods components detailed in Annex I provide starting points but require

contextualization. Adapt these to: (a) reference locally relevant sustainability issues and familiar examples, (b) employ assessment approaches aligned with local educational traditions (e.g., supplementing individual portfolio assessment with collective or oral assessment methods where culturally appropriate), (c) ensure evaluation methods are feasible given local resource constraints and institutional capacities, and (d) maintain cultural sensitivity in topics that may be politically sensitive or culturally contested in specific contexts.

Stage 4—Pilot testing with iterative refinement: Implement adapted outcomes initially on a small scale (e.g., single course, small cohort, one institution), systematically gather feedback from both educators and learners regarding cultural appropriateness, practical feasibility, and perceived relevance, document needed refinements, and revise based on evidence before broader implementation. This iterative approach allows for ongoing learning and adjustment rather than assuming universal applicability.

This adaptation protocol acknowledges that sustainability competencies manifest and develop differently across cultural contexts, and that educational quality requires respect for local knowledge systems and educational traditions rather than uncritical transfer of Western European frameworks.

Implications for practice

The implementation of these learning outcomes in educational practice requires consideration of context, resources, and pedagogical approaches. Educators implementing these outcomes should view them not as rigid prescriptions but as flexible frameworks that can be adapted to local contexts while maintaining alignment with GreenComp's core intentions.

Digital badge systems offer several affordances for competency recognition. Badges provide granular documentation of specific competencies achieved (Hickey & Willis, 2017). They can increase learner motivation through visible progress markers and social recognition (Abramovich *et al.*, 2013). However, implementation approaches vary significantly in their effectiveness. Some badge systems risk fragmenting holistic competencies into disconnected micro-credentials, potentially undermining the integrated nature of sustainability education (Lockley *et al.*, 2016). This fragmentation echoes a broader challenge in sustainability education: the tendency toward isolated learning experiences that fail to connect across disciplines, contexts, and real-world applications (Christie *et al.*, 2013; Sipos *et al.*, 2008). Students consistently report frustration with compartmentalized sustainability courses that don't translate into integrated understanding or action (Hopkinson & James, 2010). More effective badge implementations recognize 'constellations' of learning outcomes, requiring learners to demonstrate competence across cognitive, behavioral, and affective domains. For instance, a badge might require combining a systems analysis with a collective action initiative before a credential is awarded. This approach better honors the holistic 'gestalt' nature of sustainability competence. However, the labor market reception of such credentials remains mixed, with some employers valuing the specific competency documentation while others remain unfamiliar with badge-based credentials (Carey & Stefaniak, 2018; Raish & Rimland, 2016).

Professional development for educators represents perhaps the most critical factor for the successful implementation of these learning outcomes. The competencies assume educators who can facilitate complex learning processes, assess transformative capabilities, and navigate the inherently value-laden terrain of sustainability education (Annelin & Boström, 2024b). This extends far beyond technical training in assessment methods. Educators require deep engagement with sustainability concepts, systems thinking pedagogies, and transformative learning approaches (Burns, 2015; Sterling, 2024). They need support in developing facilitation skills for managing potentially contentious discussions about values, justice, and systemic change. Furthermore, educators themselves must engage in the same transformative learning processes they seek to facilitate, examining their own assumptions about human-nature relationships and sustainability transitions (Moore, 2005). Without substantial investment in such comprehensive professional development, even the most carefully designed learning outcomes risk being implemented in ways that perpetuate transmissive rather than transformative education.

Critical perspective: Micro-credentialing risks and necessary safeguards

While digital badges offer affordances for recognizing diverse learning pathways, we must address the significant risk of trivialization—where profound sustainability competencies become reduced to checklists that credential compliance rather than transformation. This risk is not incidental but structural, reflecting a fundamental tension between micro-credentialing logic and ESD's transformative aims.

Micro-credentialing systems privilege granularity (discrete, independently assessable units), standardization (comparable criteria across contexts), and transferability (credentials readable across institutional boundaries). Sustainability competencies, conversely, are emergent (arising from integration of elements), contextual (manifesting differently across situations), and values-laden (requiring normative judgment). The gestalt quality of these competencies—their irreducibly holistic nature—resists decomposition into the atomized units that credentialing systems favor.

This structural tension creates specific vulnerabilities. Badge inflation occurs when issuers proliferate credentials without corresponding assessment rigor, devaluing badges as quality signals. Checklist drift occurs when evidence requirements weaken from authentic competence demonstration to mere participation markers, as the administrative burden of rigorous assessment pressures issuers toward simpler verification. Commodification reduces complex capabilities involving ethical reasoning, systems thinking, and collective action to tradeable tokens that may credential exposure rather than transformation.

These risks are neither hypothetical nor easily dismissed. Sustainability education's transformative potential—its capacity to foster critical consciousness and systemic change—can be undermined when badge pursuit replaces deeper educational engagement or when credentials signal compliance with existing paradigms rather than capability to challenge them.

Necessary safeguards to counter trivialization include:

- Evidence rigor: Outcome-level assessment criteria must specify authentic performance integrating knowledge, skills, and attitudes. As detailed in Annex I, each outcome includes explicit observable behaviors and measurable criteria that require genuine competence demonstration, not mere exposure.
- Constellation-based credentialing: Where feasible, badges should recognize integrated competence clusters assessed through complex tasks (as illustrated in the integrated assessment example) rather than atomized micro-skills assessed in isolation.
- Transparent issuer accountability: Badge metadata must specify assessment criteria, evidence requirements, evaluator qualifications, and issuer accreditation, enabling critical evaluation by learners, employers, and institutions.
- Systematic quality assurance: Issuers must implement moderation protocols including inter-rater reliability checks, calibration with exemplars, and periodic review of assessment standards.
- Progressive pathways with explicit levels: Badge systems should articulate staged competence development (e.g., foundational, intermediate, advanced) rather than flat landscapes where all credentials appear equivalent, supporting authentic growth rather than accumulation.
- Integration with transformative pedagogy: Badge pursuit must be embedded in educational experiences fostering critical consciousness, not positioned as replacements for deeper learning.

These safeguards mitigate but do not eliminate fundamental tensions between standardization and transformation. As implementation proceeds, ongoing critical vigilance is necessary to ensure that operationalization serves rather than undermines sustainability education's transformative aims. The learning outcomes we present provide necessary infrastructure for quality credentialing, but infrastructure alone cannot ensure educational integrity—that requires sustained commitment to rigorous assessment and critical pedagogy.

Future directions: implementation roadmap and research agenda

Effective implementation of these learning outcomes requires deliberate capacity building, resource allocation, and systematic quality assurance. We outline a practical roadmap for educators, institutions, and policymakers before discussing research priorities.

Educator capacity building: Professional development should provide: (a) short-format training modules (3-6 hours) covering GreenComp foundations, outcome selection and adaptation for specific contexts, assessment design aligned to outcomes, and interpretation of Annex I specifications; (b) practice-based workshops where educators design assessments for their own teaching contexts with peer review, not lecture-based transmission; (c) ongoing communities of practice for sharing adapted materials, troubleshooting challenges, and collaborative refinement. This approach builds practical capability rather than theoretical knowledge alone.

Curriculum integration strategies: Rather than wholesale redesign, educators should: (a) map existing course/program outcomes to GreenComp to identify current strengths and gaps; (b) strategically infuse sustainability outcomes into existing courses (e.g., adding LO 2.2.1 on source evaluation to research methods; incorporating LO 1.3.1 on ecosystem interdependence into life sciences), fostering transdisciplinary integration; (c) shift toward project-based and portfolio assessment generating evidence for multiple outcomes simultaneously (as illustrated in our integrated assessment example); (d) develop mechanisms to credential sustainability competencies from community engagement and activism, not just formal coursework.

Progression pathways across educational levels: Current outcomes target primarily upper secondary, vocational, and higher education. For primary and lower secondary education, outcomes require developmental adaptation with: (a) reduced abstraction and cognitive complexity, (b) more concrete, familiar contexts, (c) greater scaffolding and support, while maintaining alignment to underlying GreenComp competencies. Progressive complexity should be explicit—for example, systems thinking might progress from identifying direct cause-effect in familiar issues (primary), to mapping interactions in local challenges (secondary), to analyzing feedback loops and leverage points in complex systems (higher education). Making this progression visible to learners supports metacognitive awareness and motivation.

Quality assurance and moderation: Consistent, fair assessment requires: (a) development and sharing of annotated work exemplars at different competence levels for calibration; (b) periodic calibration sessions where educators collectively score sample work, discuss discrepancies, and align standards; (c) peer moderation systems where educators review samples of each other's assessment decisions; (d) where appropriate, learner involvement in rubric co-creation and self/peer assessment, fostering metacognition while providing additional evidence.

Policy and institutional support: Effective implementation requires: (a) dedicated resources (time, funding) for professional development, assessment redesign, quality assurance, and community partnerships; (b) recognition in faculty workload models that designing quality assessment for complex competencies exceeds traditional exam preparation time; (c) regional or national networks for sharing resources (tools, professional

development materials, exemplars), reducing duplication; (d) explicit mapping to national and European qualification frameworks (EQF) for credential portability; (e) employer and civil society engagement in dialogues about competence demonstration and credential value, ensuring credibility and relevance.

Research priorities: Beyond implementation support, several research directions warrant attention:

A primary step is to conduct extensive field testing in diverse educational settings. This is essential not only to validate the practical utility of the learning outcomes but also to inform the development of guidance for their contextual adaptation. To ensure the framework's long-term relevance as sustainability challenges evolve, it would be prudent to establish a review cycle to periodically reassess its effectiveness.

The development of robust assessment frameworks is another priority. This includes creating tools and rubrics that can capture the complexity of sustainability competencies while remaining practical for educators. Crucially, this work should include examples of low-resource assessment methods to ensure applicability across varied economic and institutional contexts.

To support educators, the creation of comprehensive implementation guides is vital. Such guides could be complemented by integrated learning modules that address multiple competencies simultaneously and supporting materials that address prerequisite knowledge requirements. Building on this, the creation of progression pathways showing how learners can develop competencies over time would address a significant gap and would help educators design coherent learning sequences. While the current framework avoids specifying rigid levels to maintain flexibility, future iterations could consider creating differentiated versions for different educational levels (e.g., primary, secondary, vocational, higher education) to enhance usability.

Finally, integration with existing curriculum frameworks and qualification systems presents both an opportunity and a challenge. The learning outcomes must be translated into language and structures that align with national and regional education systems while maintaining their transformative potential. This requires ongoing dialogue between European-level framework development and national implementation efforts.

Conclusions

This paper has presented the methodology and results of developing learning outcomes for the European sustainability competence framework (GreenComp) as part of the OpenPass4Climate project. The development process, involving co-design among educational stakeholders, validation by an international panel of experts, and comprehensive coverage analysis, has produced 40 learning outcomes that operationalize GreenComp's competencies while addressing critical gaps in the original framework.

The resulting learning outcomes represent more than technical specifications for assessment. They embody a vision of sustainability education that integrates cognitive understanding, emotional engagement, and behavioral transformation. By explicitly incorporating philosophical dimensions, challenging anthropocentric assumptions, and connecting individual and collective action, they point toward a more transformative approach to sustainability education than purely skills-based frameworks allow.

The tensions revealed in this process (between standardization and contextualization, between measurability and transformation, between individual and systemic change) are not merely technical challenges to be resolved but fundamental features of sustainability education. The learning outcomes we have developed attempt to hold these tensions productively rather than resolve them prematurely.

As the climate crisis accelerates and planetary boundaries strain, the urgency of sustainability education intensifies. Our learning outcomes provide infrastructure for this educational transformation, but infrastructure alone cannot create change. The transformation requires educators willing to challenge disciplinary boundaries, institutions ready to restructure assessment paradigms, and societies prepared to question fundamental values. The learning outcomes are tools for this work, but the work itself remains ahead.

The ultimate test of our framework will not be its technical elegance or theoretical sophistication but its capacity to catalyze meaningful change. Do learners who develop these competencies act differently in the world? Do educational programs using these outcomes produce graduates capable of systemic thinking and collective action? Does the framework contribute to the broader transformation toward sustainability? These questions cannot be answered through methodology but only through practice, experimentation, and ongoing reflection.

In offering these learning outcomes to the educational community, we invite not just implementation but co-evolution. The framework should grow, adapt, and transform through use. It should incorporate perspectives excluded from our initial process. It should respond to emerging sustainability challenges and educational innovations. Most fundamentally, it should serve not as an endpoint but as a catalyst for the ongoing work of creating educational systems adequate to our planetary moment.

Ethics and consent

Ethical approval and consent were not required.

Data availability statement

UVaDOC Documentary Repository of the University of Valladolid: Operationalizing the European sustainability competence framework: Development and validation of learning outcomes for GreenComp. https://uvadoc.uva.es/handle/10324/76293

This project contains the following extended data:

– Annex I: GreenComp learning outcomes.

All data are available under the terms of the Creative Commons Zero "No rights reserved" data waiver (CC0 Public domain dedication).

Acknowledgements

The authors thank Valeria Napoli (GreenComp Community), Nikola Neshkoski (EcoLogic), Vanni Resta (Uninettuno University), Chiara Scalabrino (TCO Development), María Vallejo-Salgado (B Lab Spain), and Sandra Troia (ALL DIGITAL AISBL) for their valuable contributions to the expert validation process.

References

Abramovich S, Schunn C, Higashi RM: **Are badges useful in education? It depends upon the type of badge and expertise of learner.** *Educ Technol Res Dev.* 2013; **61**(2): 217–232.
Publisher Full Text

Anderson LW, Krathwohl DR: **A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives: complete edition.** Addison Wesley Longman, 2001.
Reference Source

Annelin A, Boström GO: **An assessment of key sustainability competencies: a review of scales and propositions for validation.** *Int J Sustain High Educ.* 2023; **24**(9): 53–69.
Publisher Full Text

Annelin A, Boström GO: **Sustainability competence assessment validation.** In: T. Wall, L. Viera Trevisan, W. Leal Filho, & A. Shore (Eds.), *Sustainability in business education, research and practices.* Springer Nature Switzerland, 2024a; 209–226.
Publisher Full Text

Annelin A, Boström GO: **Interdisciplinary perspectives on sustainability in higher education: a sustainability competence support model.** *Front Sustain.* 2024b; **5**: 1416498.
Publisher Full Text

Bacigalupo M, Kampylis P, Punie Y, *et al.*: **EntreComp: the entrepreneurship competence framework.** Publication Office of the European Union, 2016.
Publisher Full Text

Bianchi G, Pisiotis U, Cabrera Giraldez M: **GreenComp - The European sustainability competence framework.** Publications Office of the European Union, 2022.
Publisher Full Text

Brundiers K, Barth M, Cebrián G, *et al.*: **Key competencies in sustainability in higher education—Toward an agreed-upon reference framework.** *Sustain Sci.* 2021; **16**(1): 13–29.
Publisher Full Text

Burns H: **Transformative sustainability pedagogy: learning from ecological systems and indigenous wisdom.** *J Transform Educ.* 2015; **13**(3): 259–276.
Publisher Full Text

Carey KL, Stefaniak JE: **An exploration of the utility of digital badging in higher education settings.** *Education Tech Research Dev.* 2018; **66**(5): 1211–1229.
Publisher Full Text

CEDEFOP: **Defining, writing and applying learning outcomes: a European handbook (2nd ed.).** Publications Office, 2022.
Publisher Full Text

Christie BA, Miller KK, Cooke R, *et al.*: **Environmental sustainability in higher education: how do academics teach?** *Environ Educ Res.* 2013; **19**(3): 385–414.
Publisher Full Text

Hickey DT, Willis JE: **Where open badges appear to work better: findings from the Design Principles Documentation Project.** Center for Research on Learning and Technology, Indiana University, 2017.
Reference Source

Hopkinson P, James P: **Practical pedagogy for embedding ESD in science, technology, engineering, and mathematics curricula.** *Int J Sustain High Educ.* 2010; **11**(4): 365–379.
Publisher Full Text

Javorka Z, Nieth L, Marinelli E, *et al.*: **GreenComp in practice: case studies on the use of the European competence framework—Analytical report.** Publications Office of the European Union, 2024.
Publisher Full Text

Klieme E, Avenarius H, Blum W, *et al.*: **The development of national educational standards: an expertise**. Bundesministerium für Bildung und Forschung, 2004.
Reference Source

Lockley J, Derryberry A, West D: **Drivers, affordances, and challenges of digital badges**. In: D. Ifenthaler, N. Bellin Mularski, & D. K. Mah (Eds.), *Foundation of digital badges and micro credentials*. Springer, 2016; 55–70.
Publisher Full Text

Lozano A, López R, Pereira FJ, *et al.*: **Impact of Cooperative Learning and Project-Based Learning through emotional intelligence: a comparison of methodologies for implementing SDGs.** *Int J Environ Res Public Health.* 2022; **19**(24): 16977.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Marques MM, Ferreira Santos J, Rodrigues R, *et al.*: **Mobile augmented reality games towards smart learning city environments: learning about sustainability.** *Computers.* 2025; **14**(7): 267.
Publisher Full Text

Martín-Ramos P, Correa-Guimaraes A, Fourati-Jamoussi F, *et al.*: **Understanding climate engagement and open recognition in European higher education: a mixed-methods study across four countries [version 2; peer review: 1 approved with reservations].** *Open Res Europe.* 2025; **5**: 121.
Publisher Full Text

Mezirow J: **A critical theory of adult learning and education.** *Adult Educ.* 1981; **32**(1): 3–24.
Publisher Full Text

Moore J: **Is higher education ready for transformative learning? A question explored in the study of sustainability.** *J Transform Educ.* 2005; **3**(1): 76–91.
Publisher Full Text

Nusche D, Fuster Rabella M, Lauterbach S: **Rethinking education in the context of climate change: leverage points for transformative change**. (OECD Education Working Papers No. 307). OECD Publishing, 2024.
Publisher Full Text

Presseau J, McCleary N, Lorencatto F, *et al.*: **Action, Actor, Context, Target, Time (AACTT): a framework for specifying behaviour.** *Implement Sci.* 2019; **14**(1): 102.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Raish V, Rimland E: **Employer perceptions of critical information literacy skills and digital badges.** *College & Research Libraries.* 2016; **77**(1): 87–113.
Publisher Full Text

Redman A, Wiek A: **Competencies for advancing transformations towards sustainability.** *Front Educ.* 2021; **6**: 785163.
Publisher Full Text

Scalabrino C: **European sustainability competence framework background document: literature review, analysis of frameworks and proposals.** Publications Office of the European Union, 2022.
Publisher Full Text

Sipos Y, Battisti B, Grimm K: **Achieving transformative sustainability learning: engaging head, hands, and heart.** *Int J Sustain High Educ.* 2008; **9**(1): 68–86.
Publisher Full Text

Sousa D, Menchaca I, Doran P, *et al.*: **Towards disruptive and dialogic assessment systems supported by technology**. In: J. A. C. Gonçalves, J. L. S. M. Lima, J. P. Coelho, F. J. García Peñalvo, & A. García Holgado (Eds.), *Proceedings of TEEM 2023. TEEM 2023. Lecture Notes in Educational Technology*. Springer, Singapore, 2024.
Publisher Full Text

Spaccatini F, Riva P, Richetin J, *et al.*: **From past to present (for a better future): the moderating role of cognitive mindset on spillover effects in environmental behaviors.** *Curr Psychol.* 2023; **42**(18): 15858–15873.
Publisher Full Text

Sterling S: **Transformative learning and sustainability: sketching the**

conceptual ground (2011). In: *Learning and Sustainability in Dangerous Times: The Stephen Sterling Reader*. Agenda Publishing, 2024; 149–162.
Publisher Full Text

Sulitest: **Sulitest TASK content alignment with the EU GreenComp framework**. 2023.
Reference Source

UNESCO: **Educational content up close: examining the learning dimensions of education for sustainable development and global citizenship education**. UNESCO, 2019.
Publisher Full Text

Wals AEJ: **Beyond unreasonable doubt: education and learning for socio-ecological sustainability in the Anthropocene**. Wageningen University, 2015.
Reference Source

Open Peer Review

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Version 3

Reviewer Report 08 November 2025

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✔ **Tom KUPPENS**
UHasselt – Hasselt University, Agoralaan, Belgium

The authors operationalised the European sustainability competence framework GreenComp into a validated set of observable, measurable and assessable learning outcomes. The article is one of the outcomes of the Erasmus funded OpenPass4Climate project. The authors adopted a four-phased approach, consisting of (1) a multistakeholder co-design process, (2) followed by a modified Delphi for expert validation, (3) analysis of the full coverage of the GreenComp framework, and (4) a final validation round with experts for the full set of adjusted learning outcomes. This approach resulted in a set of learning outcomes and corresponding assessment criteria that can mainly be used educational stakeholders in upper secondary, vocational and higher education in Western and Southern Europe. Moreover, the authors critically discuss the usability of the assessment tools and its potential risks within the context of open badge initiatives.
The article contains several strengths, including its roadmap to contextualise and develop the assessment tool even further, for instance, w.r.t. different educational cultures, education levels, disciplines or regional contexts. Moreover, the assessment tool goes beyond the tradition of evaluating the cognitive learning outcomes only, by also proposing attitudinal and behavioural learning outcomes and corresponding assessment criteria. Moreover, the authors address the very important tension between the granularity and holism of assessing sustainability competences. Another strength consists of the collaborative multistakeholder process which increases the potential uptake by and impact among educational practitioners.
I would like to suggest the following improvements:

- The authors use the concept of ‘education for sustainable development’ which is contested because of the negative connotations of the word ‘development’. Since their approach is student-centred, why not use the concept of ‘learning for sustainability’ proposed by the European Commission?
- The translation of the first sentence of the ‘Métodos’ section in Spanish does not fully correspond to the English version. The authors are recommended to check consistency of the translation.
- Some descriptions of author roles seem to be rather project roles (e.g. project admin) and hence seem to be of little relevance in the contributions section.

- The authors refer to several EU competence frameworks for lifelong learning. It might be inspirational to also mention the FinComp framework because of its progression model, which might reflect potential next steps for building on the authors' work on the GreenComp operationalisation.
- In the introduction, the authors mention that educational institutions fundamentally shifted the conceptualisation of their role, however, it is mainly experts and policy makers who advocate for this shift. The next step is for educational institutions to implement this, but this is far from reality yet. The authors might want to rephrase the first sentence of their introduction.
- When referring to Sulitest, it is unclear what the alignment percentages mean. The authors might want to elaborate on the meaning and determination of these percentages.
- Other projects that have been working on GreenComp assessment and roadmaps, include GreenScent and ECF4CLIM. Moreover, also the IMPACT project (impactforaction.eu) on impact assessment of the action competence for sustainability might be of interest here. The authors also refer to assessment scales such as SCMM, however, they do not refer to the sustainability consciousness questionnaire (SCQ) of Gericke et al. (2019) yet. I would also like to make the authors aware of developments in the assessment of transformative learning by referring to "A review of transformative learning assessment tools" published by Ngan Ha Nguyen, Thuy Nga Nguyen and Thi Thuy Tang in the Proceedings of the 4th Hanoi forum on pedagogical and educational sciences. It might be relevant to refer to these projects, scales and assessment instruments too in the section on "Current state of GreenComp assessment".
- The authors often refer to several tensions. One tension that has not been mentioned yet, is the tension between the normative character of sustainability education and the danger of a too instrumental approach towards sustainability education. It would be highly appreciated if the authors can reflect on how their assessment instrument address this tension as well.
- The authors use Bloom's taxonomy to operationalize the diverse KSAs of GreenComp. However, Bloom's taxonomy is mostly known for his taxonomy for cognitive learning activities. One advantage is that it probably helped to make the knowledge (K) descriptions more observable/measurable. Although this can be helpful for developing observable learning outcomes for the knowledge (K) and skills (S) of GreenComp, it might be more problematic for the attitudes (A). Can you clarify how a the use of Bloom's taxonomy might have influenced the learning outcomes? Could you recommend taxonomies that might be helpful for the more attitudinal dimensions of GreenComp?
- The authors adopted a modified Delphi approach. It is recommended to explain what the 'modified' dimension of the modified Delphi consisted of. How did information from the literature review or the introduction determine the questions asked in the Delphi rounds?
- For the readers and future users of your assessment tool, it would be helpful to add the matrix that maps each of the KSA statements with the final learning outcomes as supplementary material to the article.
- When the authors explain the revisions of the learning outcomes after the first validation round, they provide examples of improved action verbs. However, for some examples the 'improvement' is not really clear. For instance, the verb 'demonstrate' has been improved to 'adapt', whereas these two verbs actually have different meanings. Maybe it is better to provide less examples and provide just one example with its full learning objectives statement to make the improvement clearer.
- Although most learning outcomes in table 1 have a clear connection with sustainability, for

some this connection is still missing. Is it possible to reformulate the ones that lack the link to sustainability a little bit in that direction. See for instance the learning outcomes (LO) corresponding to competence 2.2 (LO2), 3.1 (LO2) and 4.3 (LO1). Moreover, it might be relevant to also include the social dimension of sustainability in LO1 of competence 4.2.

- In the discussion, the authors refer to Mezirow's publication from 1981 to argue that the core aim of EfS must be to transform learners' perspectives. However, to the best of my knowledge, Mezirow himself did not address sustainability education in that paper. The authors might want to reformulate that statement. It would also be of added value if the authors could more deeply argue why and how their learning outcome assessment tool enables to detect potential change of problematic frames of reference.
- The worked example for a single learning outcome is of high added value for a potential user. The worked example for the integrated assessment, however, lacks the same amount of detail. To make that worked example more useful for potential users, it is recommended to elaborate on the integrated example more deeply.
- When discussing the tensions in the first paragraph of the 'Challenges and limitations' section, I would be interested to also see some reflection on the room for open-endedness in transformative sustainability education and how this is reflected in the proposed assessment framework (see also my earlier recommendation to discuss the tension between the normative character of EfS and the risk of a too instrumentalistic approach).

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Learning for sustainability, teacher education

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 03 November 2025

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Ioan Prigoreanu
University of Life Sciences (IULS), Iaşi, Romania

The article is well structured, scientifically rigorous, fully documented, and meets the requirements of an international academic Indexed. It can be considered suitable for Indexed in its current form.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: management, audit, accounting, sustainability,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 28 October 2025

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Thais Dibbern
State University of Campinas, Campinas, Brazil

My assessment of the revised manuscript is complete. The authors have fully responded to my feedback, resulting in a more robust paper.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public policy, sustainability, higher education studies

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

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The manuscript presents a significant effort to operationalize the European sustainability competence framework (GreenComp) by developing 40 measurable learning outcomes. The authors build upon the OpenPass4Climate project, employing a four-phase methodology: co-design workshops with stakeholders, a first expert validation (modified Delphi method), systematic coverage analysis, and a second expert validation. The process involved stakeholders from formal and non-formal education, learners at multiple levels, and an international expert panel.

The outcomes were carefully aligned with GreenComp's four competence areas and the Knowledge–Skills–Attitudes (KSA) structure, and they were refined to ensure measurability, observability, and student-centered formulation. Importantly, the authors addressed previously identified gaps by adding outcomes on philosophical, ethical, and systemic dimensions, as well as on economic transformation and resource conflict dynamics.

The article contributes to Education for Sustainable Development (ESD) by moving GreenComp from an abstract policy tool toward practical implementation. The manuscript is well-written, methodologically transparent (particularly in version 2), and highly relevant to the European education and sustainability policy landscape.

Points for improvement (required for scientific soundness)

The manuscript presents learning outcomes that are measurable and observable, yet it does not provide sufficient detail on how they can be practically assessed. Without clear assessment tools, the applicability of the outcomes in real educational contexts remains limited.

Include at least one illustrative example of assessment methods (e.g., portfolio evaluation, project-based assessment, peer and self-assessment, or rubrics) linked to a specific learning outcome, to demonstrate feasibility in practice.

Although the authors acknowledge cultural constraints, the proposed outcomes are largely framed from a Western European perspective. Considering GreenComp's intended broad application across Europe and beyond, stronger attention to cultural adaptability is necessary. Explicitly highlight these limitations and propose strategies to adapt the outcomes to diverse cultural, educational, and socio-political contexts, including Eastern European and global perspectives.

The manuscript appropriately addresses the inherent tension between “gestalt competencies” and measurable outcomes. However, it does not sufficiently illustrate how holistic sustainability competencies can be preserved in assessment and credentialing systems. Provide concrete examples of integrated or constellation-based assessment approaches that could help avoid the fragmentation of competencies into disconnected elements.

The “Future Directions” section outlines useful research avenues but remains focused primarily on academic implications. To maximize practical relevance, a clearer roadmap for application in educational practice would be beneficial. Expand this section to include specific guidance for educators and policymakers, such as strategies for teacher training, curriculum integration, and progression pathways across different educational levels.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: management, audit, accounting, sustainability,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 15 Oct 2025

Pablo Martín-Ramos

R3-Q1 & Q2. Practical assessment detail and illustrative example
Q1: "*The manuscript presents learning outcomes that are measurable and observable, yet it does not provide sufficient detail on how they can be practically assessed. Without clear assessment tools, the applicability of the outcomes in real educational contexts remains limited.*"

Q2: *"Include at least one illustrative example of assessment methods (e.g., portfolio evaluation, project-based assessment, peer and self-assessment, or rubrics) linked to a specific learning outcome, to demonstrate feasibility in practice."*
Response: We appreciate this important observation. While Annex I provides detailed specifications for each learning outcome—including observable behaviors, measurable criteria, and suggested evaluation methods—we recognize that concrete worked examples significantly enhance practical applicability for educators. To address this concern, we have added a new "Implementation notes" subsection in the Results section that presents two complementary assessment examples: the first one provides a complete assessment pathway for a single learning outcome, while the second example demonstrates integrated assessment of multiple outcomes through a community sustainability intervention project, illustrating how educators can assess several learning outcomes holistically through a single complex task while maintaining the gestalt nature of sustainability competencies and avoiding fragmentation. Additionally, we have added signposting text in the Results section (before Table 1) that explicitly directs readers to these worked examples and to the comprehensive assessment specifications in Annex I, making the connection between the learning outcomes framework and practical implementation tools more transparent.
Changes made to manuscript: A paragraph has been added to the Results > Final learning outcome distribution, and two examples have been included in the new Results/Implementation notes subsection.

R3-Q3. Cultural adaptability and contextualization
"*Although the authors acknowledge cultural constraints, the proposed outcomes are largely framed from a Western European perspective. Considering GreenComp's intended broad application across Europe and beyond, stronger attention to cultural adaptability is necessary. Explicitly highlight these limitations and propose strategies to adapt the outcomes to diverse cultural, educational, and socio-political contexts, including Eastern European and global perspectives.*"
Response: This is a crucial point, and we agree that the framework's Western/Southern European origins must be explicitly acknowledged alongside a concrete strategy for cultural adaptation. We have made two significant additions to address this concern. First, we have added a new subsection to the Discussion, "Cultural adaptability and contextualization", which outlines a four-step protocol for adapting the learning outcomes to diverse contexts. This protocol involves (i) local co-design and stakeholder engagement, (ii) translation and localization of concepts (not just words), (iii) integration of locally salient issues and knowledge traditions, and (iv) equity-by-design checks. Second, we have substantially expanded the Discussion > Limitations section to explicitly state the current geographical scope, identify specific Western assumptions embedded in some outcomes (e.g., regarding political agency, democratic participation, human-nature relationships), and note the need for future comparative validations with partners in Eastern/Northern Europe and non-EU contexts.
Changes made to manuscript: (1) The Discussion > Limitations section has been expanded to elaborate on the cultural scope and outline next steps for validation. (2) A new subsection, "Cultural adaptability and contextualization", has been inserted in the Discussion section after "Challenges and limitations".

R3-Q4. Holistic competencies and constellation-based assessment

"*The manuscript appropriately addresses the inherent tension between 'gestalt competencies' and measurable outcomes. However, it does not sufficiently illustrate how holistic sustainability competencies can be preserved in assessment and credentialing systems. Provide concrete examples of integrated or constellation-based assessment approaches that could help avoid the fragmentation of competencies into disconnected elements.*"
Response: This concern is directly addressed through our response to Reviewer 2's Q3, where we provide a detailed worked example of constellation-based assessment demonstrating how multiple learning outcomes can be evaluated holistically through a single complex task using cross-cutting rubric criteria. Additionally, the critical analysis of micro-credentialing risks and safeguards (our response to R2-Q4) explicitly discusses constellation-based credentialing as a strategy to preserve gestalt competence while meeting recognition requirements. Together, these additions provide both concrete examples and conceptual frameworks for avoiding fragmentation.
Changes made to manuscript: (1) Integrated assessment example as detailed in response to R2-Q3; (2) critical micro-credentialing section as detailed in response to R2-Q4.

R3-Q5. Practical roadmap for educators and policymakers
"*The 'Future Directions' section outlines useful research avenues but remains focused primarily on academic implications. To maximize practical relevance, a clearer roadmap for application in educational practice would be beneficial. Expand this section to include specific guidance for educators and policymakers, such as strategies for teacher training, curriculum integration, and progression pathways across different educational levels.*"
Response: This is an excellent recommendation to enhance the practical relevance of our work. We have substantially revised and expanded the "Future Directions" section to provide concrete, actionable guidance across five key implementation domains: (1) educator capacity building through practice-based professional development; (2) curriculum integration strategies emphasizing transdisciplinary infusion; (3) staged progression pathways across educational levels; (4) quality assurance through calibration and moderation; and (5) institutional support requirements including resource allocation and policy alignment. This transforms the section from a primarily research-focused agenda into a practical implementation roadmap for practitioners and policymakers, while maintaining appropriate discussion of needed research.
Changes made to manuscript: The opening section of Discussion > Future Directions has been replaced with a comprehensive five-point practice roadmap.

Competing Interests: No competing interests were disclosed.

Reviewer Report 08 October 2025

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Thais Dibbern
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Dear Authors,
While the methodology is improved in Version 2, a few points could be sharper:

- **Expert Panel Selection:** The criteria are good, but stating the *number* of publications or years of experience would add objectivity. The gender balance (8 women, 4 men) is noted, but a brief mention of geographical distribution (beyond "diverse institutional contexts") would strengthen the claim of European representativeness.
- **Co-design Synthesis:** The process of merging "similar outcomes" and using "internal Delphi surveys" is described but could be more transparent. A brief example of what made outcomes "similar" and what criteria were used in the internal ranking would be useful.

About the discussions:

- The discussion could be strengthened by providing a concrete example of **how two or three different learning outcomes might be assessed together in a single, complex task** (e.g., a community project) to demonstrate how the "gestalt" can be preserved in practice.
- The section on digital badges is somewhat optimistic. It could more forcefully address the significant risk of **trivialization**—where profound competencies are reduced to a checklist for a badge. A deeper critique of the potential conflict between the micro-credentialing logic and the transformative, holistic aims of ESD would be valuable.

Furthermore, the abstract could be even more impactful by stating the *number* of experts (12) and stakeholders (48) involved, highlighting the scale of the validation process. Another recommendation is to **add a visual element** to the results, such as a chart summarizing the coverage analysis findings.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public policy, sustainability, higher education studies

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 15 Oct 2025

Pablo Martín-Ramos

R2-Q1. Expert panel selection: objectivity and geography
"*Expert Panel Selection: The criteria are good, but stating the number of publications or years of experience would add objectivity. The gender balance (8 women, 4 men) is noted, but a brief mention of geographical distribution (beyond 'diverse institutional contexts') would strengthen the claim of European representativeness*."
Response: We agree that providing objective thresholds and an explicit geographical distribution of the expert panel enhances the transparency and credibility of our validation process. The Methods section has been revised to include specific eligibility criteria for the experts (≥5 years of relevant practice and/or ≥5 relevant peer-reviewed outputs) and to list the countries where the experts are currently working (Sweden, Greece, Portugal, Spain, Italy, and North Macedonia). Furthermore, we have added a statement to the Discussion's Limitations section to explicitly acknowledge that this distribution skews toward Southern and Western Europe and have committed to broadening this representation in future validation cycles.
Changes made to manuscript: (1) The first paragraph of Methods > Phase 2: First expert validation round has been expanded to include the objective thresholds, gender balance, sectoral mix, and country distribution. (2) The Discussion > Limitations section has been updated to explicitly note the regional skew.

R2-Q2. Co-design synthesis: transparency
"*Co-design Synthesis: The process of merging 'similar outcomes' and using 'internal Delphi surveys' is described but could be more transparent. A brief example of what made outcomes 'similar' and what criteria were used in the internal ranking would be useful*."
Response: We agree that transparency is crucial for the methodological rigor of the consolidation phase. To clarify this process, we have amended the Methods section to include a concrete example of how two draft outcomes were merged because they targeted the same set of GreenComp Knowledge-Skills-Attitudes (KSAs) and had overlapping observable evidence. We have also explicitly stated the three criteria used for the internal ranking—(i) precise alignment to KSA granularity, (ii) clarity of measurability/observability, and (iii) non-duplication—and the tie-breaking protocol, making the synthesis logic both auditable and reproducible.
Changes made to manuscript: An example of the merging process and the explicit internal ranking criteria have been added to the end of the last paragraph of Methods > Phase 1: Initial co-design process.

R2-Q3. Preserving gestalt in integrated assessment
"*The discussion could be strengthened by providing a concrete example of how two or three different learning outcomes might be assessed together in a single, complex task (e.g., a*

community project) to demonstrate how the 'gestalt' can be preserved in practice."
Response: This is an excellent recommendation that addresses the central challenge of operationalizing competencies without losing their holistic nature. To demonstrate how the "gestalt" of sustainability competence can be preserved in practice, we have added an " Integrated assessment example" in the new Results/Implementation notes section. This example details how a single, complex task—a community sustainability intervention project—can be used to assess three distinct learning outcomes from different GreenComp areas (Systems Thinking, Futures Literacy, and Collective Action) simultaneously, using an integrated portfolio and a single analytic rubric with cross-cutting criteria rather than separate checklists.
Changes made to manuscript: A new example has been added to the Results/Implementation notes section, immediately after the 'Worked example (single outcome)', to illustrate an integrated, multi-outcome assessment task.

R2-Q4. Micro-credentials and the risk of trivialization
"*The section on digital badges is somewhat optimistic. It could more forcefully address the significant risk of trivialization—where profound competencies are reduced to a checklist for a badge. A deeper critique of the potential conflict between the micro-credentialing logic and the transformative, holistic aims of ESD would be valuable*."
Response: We fully agree with this critical observation and have revised the Discussion to move beyond an optimistic framing of digital badges. A new subsection has been added to critically examine the structural tensions between the logic of micro-credentialing and the transformative, holistic aims of ESD. This section explicitly addresses the risks of "badge inflation," where credentials are issued without rigor, and "checklist drift," where assessment degrades from authentic competence demonstration to mere participation. To counter this, we propose a series of concrete governance and quality assurance safeguards, including rigorous evidence standards tied to authentic performance, the use of constellation-based credentialing for integrated competencies, transparent issuer accountability through detailed metadata, systematic moderation and calibration protocols, and the embedding of badge acquisition within transformative pedagogical approaches rather than as a replacement for them.
Changes made to manuscript: A new subsection, "Critical perspective: Micro-credentialing risks and necessary safeguards", has been inserted in the Discussion section.

R2-Q5. Abstract enhancement with participant numbers
"*Furthermore, the abstract could be even more impactful by stating the number of experts (12) and stakeholders (48) involved, highlighting the scale of the validation process.*"
Response: We agree that including the specific number of participants in the abstract immediately conveys the scale of our validation work. The abstract has been revised to state that the process involved co-design workshops with 48 stakeholders and validation by a 12-member expert panel.
Changes made to manuscript: The second sentence of the Abstract has been revised to include the numbers of stakeholders and experts. Translations into French, German, Italian, and Spanish have been updated accordingly.

R2-Q6. Add a visual on coverage analysis
"*Another recommendation is to add a visual element to the results, such as a chart summarizing*

the coverage analysis findings."
Response: We agree that a visual element would enhance the accessibility and impact of the coverage analysis findings. In response to this suggestion, we have added a new figure (Figure 1) to the Results section. This figure shows the analytical progression from our coverage assessment to the concrete enhancement actions taken, providing readers with an at-a-glance understanding of the evidence-based process that strengthens the methodological rigor of our work.
Changes made to manuscript: "Figure 1. Coverage analysis: from gaps to actions" has been inserted in the Results section after the coverage analysis findings paragraph; the transition text in the "Enhancement strategies" subsection has been modified to explicitly reference the figure; streamlined redundant numerical details in the text to avoid duplication with the figure.

Competing Interests: No competing interests were disclosed.

Reviewer Report 15 September 2025

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Voicu-Dan Dragomir
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The authors have answered my recommendations regarding the methodological details necessary to bring credibility to the research.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Sustainability disclosure and environmental assessment.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 02 September 2025

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Voicu-Dan Dragomir
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[3] The Bucharest University of Economic Studies, Bucharest, Romania

The method for creating the competence framework is described, but there are a lot of details missing from this paper. For example, how were the workshops organized, who were the experts (as demographics) and how were they selected, how was the validation conducted etc. Also, the methods need to be explained as well: coverage analysis (for example), what did that entail? In the end, just the finished product is presented, but the method does not show the process in sufficient detail to make it credible or reproducible.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Sustainability disclosure and environmental assessment.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 02 Sep 2025
Pablo Martín-Ramos

We thank Dr. Dragomir for the careful review and constructive feedback. We acknowledge that greater methodological transparency is essential for credibility and reproducibility. We have substantially expanded the Methods section to provide comprehensive details on workshop organization, participant and expert selection, validation procedures, and coverage analysis methodology. Below we respond point-by-point to the Reviewer's observations and list the manuscript insertions that we have made.

Comment 1: Workshop organization Reviewer's comment: "*how were the workshops organized…*" Response: Thank you for highlighting the need for more detail on the co-design workshops. This initial phase was a complex, multi-stakeholder process that warrants a more thorough description. We have expanded the Methods section to provide comprehensive details on the workshop structure and process. The participant composition and synthesis process are now fully detailed. Changes made to manuscript: [*Section: Methodology, Subsection: Phase 1: Initial co-design process*] "The co-design phase represented a deliberate departure from expert-driven approaches to learning outcome development. Rather than beginning with technical specifications derived from learning theory, we initiated a collaborative process across the four OpenPass4Climate consortium institutions. Each institution assembled carefully balanced stakeholder groups: (1) at least three educators from formal education (university faculty at UniLaSalle, NOVA, and University of Valladolid; vocational trainers at CSCI Novara); (2) at least three practitioners from non-formal settings, recruited from corporate sustainability professionals engaged in the project's 'Work Package 5 - Impact evaluation, enlargement & policy recommendations'); and (3) at least five learners representing different educational levels, such as vocational and A-level students (CSCI Novara), Bachelor's and Master's students (UniLaSalle, NOVA), and doctoral candidates (University of Valladolid). Learner participants were volunteers selected via a convenience sampling approach from those involved in the prior surveys and focus groups of the project's 'Work Package 3 - Nature & assessment of engagement' (Martín-Ramos et al., 2025). By bringing together these diverse perspectives (spanning educational levels, professional contexts, and implementation settings), we ensured the resulting learning outcomes would be meaningful across the full spectrum of contexts where GreenComp might be applied. The co-design process unfolded through a series of structured workshops conducted over three months. Each institution hosted four workshops (one per GreenComp competence area) online via Microsoft Teams and Miro collaborative platform, conducted in local languages without time constraints to facilitate nuanced discussion. Participants worked in interdisciplinary groups to translate abstract KSA statements into concrete learning outcomes. To structure the KSA translation process, we employed Bloom's revised taxonomy (Anderson & Krathwohl, 2001) as a heuristic device rather than a rigid framework. Participants were encouraged to consider how each competence might manifest at different cognitive levels, from basic comprehension to creative synthesis. However, we found that many sustainability competencies resisted easy categorization within Bloom's framework, particularly those involving affective dimensions or systems thinking. This led to iterative refinement of outcomes that attempted to capture the holistic nature of competencies while maintaining sufficient specificity for assessment purposes. The learning outcomes were formulated according to the Centre Européen pour le Développement de la Formation Professionnelle (CEDEFOP) guidelines for defining, writing and applying learning outcomes (CEDEFOP, 2022), ensuring they were observable (describing a behavior or product that can be observed), measurable (assessable using

specific criteria), and student-centered (focusing on what the learner will be able to do). Each outcome was designed to integrate relevant knowledge, skills, and attitudes from the GreenComp framework, translating the abstract KSAs into concrete statements of what learners should demonstrate. Following the institutional workshops, a cross-consortium synthesis process was undertaken by project staff (without participation from learners or non-formal trainers) to consolidate the proposals. Translation of outputs from the local languages into English was validated by bilingual consortium members to preserve conceptual accuracy. Similar outcomes were merged, and internal Delphi surveys were used to rank and select the top three learning outcomes for each of the 12 competencies. The initial co-design phase produced 36 learning outcomes, three for each of the 12 GreenComp competencies."

Comment 2: Expert demographics and selection Reviewer's comment: "*who were the experts (as demographics) and how were they selected…*" Response: We agree that providing more information on the expert panel enhances the credibility of the validation phase. We have added details about expert panel composition and selection criteria. Changes made to manuscript: [*Section: Methodology, Subsection: Phase 2: First expert validation round*] "The expert validation phase employed a modified Delphi approach designed to balance quality assurance with practical constraints, such as the project timeline and expert availability. Our expert panel comprised 12 specialists (8 women, 4 men) selected based on demonstrated expertise in sustainability education and familiarity with European competence frameworks. Selection criteria included authorship of GreenComp-related publications or reports, active engagement in the GreenComp Community, and participation in EU sustainability education projects such as TWIN-IN, ASSESS, EduC3, GrowLearnOut, GreenScent, GreenAtYou, and Entrepreneurship4All. The resulting panel represented diverse institutional contexts: five from higher education institutions, five from NGOs focused on sustainability education, one independent researcher, and the GreenComp Community manager. This institutional diversity proved crucial during the validation process, as experts brought culturally and contextually specific insights that challenged the universalist assumptions embedded in our initial formulations. […]"

Comment 3: Validation process details Reviewer's comment: "*how was the validation conducted…*" Response: We appreciate the reviewer's suggestion for greater specificity, as this detail strengthens both the credibility and reproducibility of the process. We have clarified the validation methodology, including tools, timelines, and analysis procedures. Changes made to manuscript: [*Section: Methodology, Subsection: Phase 2: First expert validation round*] "[…] The validation was conducted asynchronously using anonymous Microsoft Forms following an initial briefing via Teams. One form was created per competence area, with experts evaluating each learning outcome through a binary choice: 'valid as is' or 'not valid/requires improvement'. Selection of the latter option triggered a text field for detailed feedback and improvement suggestions. Forms remained open for four weeks to allow sufficient time for thoughtful evaluation. Each learning outcome was assessed against four criteria:

- Alignment: Clear relationship to the target GreenComp competence
- Measurability: Use of clear, assessable verbs and specific performance indicators
- Student-centricity: Focus on learner capabilities rather than teaching activities

- Observability: Potential for demonstration through observable behaviors or products

Analysis followed a conservative protocol: any learning outcome marked as 'not valid/requires improvement' by at least one expert was flagged for revision, regardless of overall approval rates. This approach ensured that all expert concerns were addressed. Qualitative feedback was analyzed thematically to identify recurring concerns and suggestions for improvement, with particular attention to cases where experts disagreed on validity judgments." [*Section: Methodology, Subsection: Phase 4: Second expert validation round, second paragraph*] "[...] The second validation round followed a more focused protocol. Unlike the anonymous first round, experts received personalized documentation packages via email containing:

- Detailed rationales for each proposed modification or addition
- Explicit mapping of how changes addressed prior comments or coverage gaps
- Comparison between the original and revised formulations

Experts provided direct, non-anonymous feedback within two weeks, enabling iterative clarification where needed. This approach facilitated deeper engagement with contentious additions, particularly learning outcomes challenging anthropocentric perspectives or addressing resource conflict dynamics. Experts were asked to evaluate not only the technical quality of these outcomes but also their appropriateness within the GreenComp framework and potential implementation challenges."

Comment 4: Coverage analysis methodology Reviewer's comment: "*coverage analysis (for example), what did that entail?*" Response: Thank you for this question. The coverage analysis was a systematic verification process. Its purpose was to ensure our set of learning outcomes comprehensively addressed every single KSA statement outlined in the official GreenComp framework document. This step was critical to prevent any inadvertent omissions and to guarantee that our operationalization was faithful to the original framework's complete scope. We have added a clarifying sentence to the first paragraph of the "Phase 3: Coverage analysis" section to make its purpose explicit. Changes made to manuscript: [*Section: Methodology, Subsection: Phase 3: Coverage analysis, first paragraph*] "Following the first validation round, we conducted a systematic coverage analysis to assess how comprehensively the learning outcomes addressed all aspects of the GreenComp framework. The primary goal was to verify that our 36 proposed learning outcomes collectively operationalized every individual KSA statement in the official GreenComp publication, ensuring no competence element remained unaddressed. [...]"

Competing Interests: No competing interests were disclosed.