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INTEGRATING THE EUROPEAN GREEN COMPETENCE FRAMEWORK IN ENGINEERING EDUCATION: A REVIEW OF PROJECTS AND APPROACHES

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Abstract: *The engineering profession faces increasing demands to address global sustainability challenges, necessitating the integration of sustainability competencies into engineering education. The European Green Competence Framework (GreenComp) provides a comprehensive structure for defining these competencies. This paper reviews the relevance of GreenComp for engineers, highlighting its four competence areas and their applicability to engineering practice. It further examines European initiatives, such as the Greenversity project and the application of the GreenComp Evaluation Roadmap, that aim to embed sustainability skills in higher education curricula. The discussion emphasizes the importance of fostering systems thinking, ethical considerations, and practical application of GreenComp competencies to equip future engineers for a sustainable job market and a resilient future.*

Keywords: *Green Competence Framework; GreenComp; sustainability competencies; engineering education; curriculum integration; sustainability skills*

1. INTRODUCTION

The engineering profession is at the forefront of addressing global sustainability challenges, necessitating a fundamental shift in the skills and competencies required of future engineers. [1,2] The urgency of climate change and environmental degradation demands that engineers move beyond traditional technical expertise to embrace a holistic understanding of sustainability principles. [3] This evolution requires the integration of sustainability not as a separate discipline, but as a core component of engineering practice across all specializations. [4]

The European Union has developed the European Green Competence Framework (GreenComp) to provide a comprehensive reference for sustainability learning. [5] GreenComp outlines twelve key competencies across four interconnected areas: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability. [5] This framework offers a valuable structure for higher education institutions to equip engineering graduates with the necessary skills and mindset to drive sustainable innovation and solutions. Employers increasingly recognize the importance of these competencies, seeking engineers who can integrate environmental, social, and economic considerations into their work. [6]

This paper aims to provide a concise review of initiatives focused on integrating the GreenComp framework into engineering education. It will highlight the relevance of GreenComp competencies for engineers and discuss projects and approaches aimed at fostering these skills in higher education.

2. THE RELEVANCE OF GREENCOMP COMPETENCIES FOR ENGINEERS

Engineers play a pivotal role in designing, developing, and implementing solutions to complex sustainability challenges [7]. The GreenComp framework's competencies are highly relevant to the engineering profession, providing a roadmap for the skills and

knowledge engineers need to contribute to a sustainable future.

- **Embodying sustainability values** is crucial for engineers to make ethical decisions and prioritize environmental and social well-being in their designs and projects. [5] This includes valuing sustainability, supporting fairness, and promoting nature.
- **Embracing complexity in sustainability** equips engineers with the systems thinking and critical thinking skills necessary to understand the interconnectedness of engineering solutions with broader environmental and societal impacts. [5] Problem framing allows engineers to define sustainability challenges effectively.
- **Envisioning sustainable futures** fosters the innovative and forward-thinking mindset required to develop sustainable technologies and solutions. [5] Futures literacy, adaptability, and exploratory thinking are essential for engineers in a rapidly changing world.
- **Acting for sustainability** empowers engineers to take initiative and work collaboratively towards sustainable outcomes. [5]â Political agency, collective action, and individual initiative are vital for implementing sustainable engineering practices.

The integration of these GreenComp competencies ensures that engineering graduates are not only technically proficient but also equipped with the broader skills and perspectives needed to address the sustainability challenges of the 21st century. [8]

3. METHODOLOGY

This study employs a qualitative research approach to systematically review European-funded projects that integrate the GreenComp framework into higher education. The methodology is designed to ensure a rigorous selection of relevant projects, followed by an analytical assessment of their objectives, implementation strategies, and impact on sustainability education. By adopting a document analysis approach, the study examines official project reports, policy documents, and academic literature to identify key initiatives that promote GreenComp competencies among students and educators.

The selection criteria for the European-funded projects included in this review were established based on relevance, funding source, and alignment with the GreenComp framework. First, projects had to explicitly focus on sustainability education within higher education institutions, ensuring that they contribute to the development of green skills and competencies among students and educators. Second, only projects funded by recognized European funding programs—such as Erasmus+, Horizon Europe, or other EU initiatives supporting education and sustainability—were considered. This criterion ensures the reliability and institutional backing of the selected projects. Third, projects were required to demonstrate a clear connection to the GreenComp framework by incorporating its competencies into their curricula, training programs, or pedagogical strategies. Projects that only indirectly referenced sustainability education without explicit alignment with GreenComp were excluded from the analysis.

Data sources for this review included official European Commission databases, such as the Erasmus+ Project Results Platform and CORDIS, which provide detailed information on EU-funded research and educational initiatives. Additionally, reports from participating institutions, academic publications, and project websites were analyzed to gather comprehensive insights into each initiative's objectives, methodologies, and outcomes. A content analysis approach was applied to examine how the selected projects operationalize the GreenComp framework, identifying common themes, challenges, and best practices in their implementation. This analytical approach allowed for a structured comparison of projects, highlighting their contributions to sustainability education and the potential for replication or scaling across different educational contexts.

By systematically reviewing these projects, the study aims to provide a comprehensive understanding of how GreenComp is being translated into educational practice at the European level. This methodological framework ensures that the findings are grounded in empirical evidence, offering valuable insights

into the effectiveness of different pedagogical approaches and institutional strategies in fostering sustainability competencies in higher education. The analysis also serves to highlight the role of initiatives such as GREENVERSITY, which exemplifies best practices in integrating GreenComp into academic programs and student engagement activities.

4. RESULTS

The implementation of sustainability competencies in European education systems has been supported by various European-funded projects that align with the GreenComp framework. These projects contribute to fostering sustainability literacy, equipping educators and students with key green skills, and embedding sustainability principles within institutional and community settings. The selected projects—GAMECOMP, GREENHIVE, the GreenComp Project, GREEN SCENT, NEMOS, Green Schools Alliance, and Eco-Schools—adopt diverse approaches to sustainability education, ranging from gamification and digital learning to institutional transformation and community-based initiatives. Their methodologies and impacts vary based on their scope, target audiences, and engagement strategies, but they collectively advance sustainability education across different levels.

A comparative analysis of these projects reveals three primary categories of intervention: training programmes for students and educators, institutional integration of sustainability education, and community engagement with applied learning. Training programmes focus on equipping learners and educators with sustainability-related knowledge and skills through structured curricula and experiential learning activities. Institutional integration efforts seek to embed sustainability competencies into educational policies, curricula, and operational practices. Community engagement projects emphasize participatory learning and real-world applications of sustainability principles, often through collaborations between educational institutions, businesses, and local organizations.

A synthesis of the approaches, methodologies, and impacts of the selected projects is presented in the table 1.

Table 1

Comparative Analysis between European-funded projects that align with the GreenComp framework

Project	Approach	Methodology	Impact
GAMECOMP (gamecomp.eu)	Uses gamification as an innovative educational tool for teaching sustainability.	Develops interactive digital games aligned with GreenComp competencies to engage students and educators.	Enhances learner engagement, making sustainability education more interactive and accessible.
GREENHIVE (greenhiveproject.eu)	Creates a collaborative digital platform for sustainability education and innovation.	Uses co-creation workshops, digital collaboration tools, and participatory research methodologies.	Strengthens interdisciplinary collaboration and fosters stakeholder engagement in sustainability initiatives.
GreenComp Project (greencomp-project.eu)	Focuses on structured competency development for students and educators.	Provides training materials, professional development workshops, and assessment tools based on GreenComp.	Increases sustainability literacy and supports the institutional adoption of sustainability competencies.
GREEN SCENT (green-scent.eu)	Promotes sensory and experiential learning to enhance environmental awareness.	Uses immersive learning experiences such as virtual reality and real-world applications.	Encourages behavioral change and fosters a deeper understanding of sustainability challenges.
NEMOS (nemosproject.com)	Focuses on nature-based solutions to address climate change and sustainability challenges.	Combines fieldwork, case studies, and digital learning tools for hands-on engagement.	Provides real-world problem-solving experience and fosters student empowerment in environmental actions.

Project	Approach	Methodology	Impact
Green Schools Alliance (greenschoolsalliance.org)	Engages schools in a global sustainability network.	Uses peer-led initiatives, workshops, and digital resources to promote sustainability practices in schools.	Encourages institutional transformation and promotes sustainable policies within educational settings.
Eco-Schools (eco-schools.org.uk)	Provides a structured certification programme for schools adopting sustainable practices.	Implements a seven-step methodology to integrate sustainability projects into school operations.	Facilitates long-term environmental impact by embedding sustainability into curricula and infrastructure.
Greenversity (greenversity.eu)	Integrates the GreenComp framework into higher education programmes.	Framework integration, educator training, student engagement initiatives, accreditation protocol development.	Comprehensive coverage of all four areas of GreenComp.

4.1. Spotlight on Greenversity: A Key Initiative for GreenComp Implementation

The Greenversity project, a three-year Erasmus+ initiative, is dedicated to integrating the European Green Competence Framework (GreenComp) into higher education. Its primary goal is to empower universities, educators, and students with the necessary skills and knowledge for sustainable transformations. Greenversity aims to achieve this through a structured framework focusing on four key areas: integrating GreenComp into curricula, providing training and resources for educators, engaging students in sustainability initiatives, and developing an accreditation process for green skills. Coordinated by the University of Valencia, this collaborative project seeks to establish green skills as a core component of higher education across Europe, thereby equipping future graduates to contribute to a sustainable future.

5. DISCUSSION

The integration of the GreenComp framework into engineering education is crucial for developing engineers who can lead the transition towards a sustainable future. The reviewed initiatives demonstrate various approaches to achieving this, including curriculum updates, educator training, and the development of evaluation tools. [9]

The development of systems thinking skills, a key component of GreenComp, is particularly important for engineers as they grapple with complex interconnected systems in their projects. [10] Problem-based learning and project-oriented approaches, which have been identified as effective pedagogies for sustainability education [11–14], can be valuable tools for fostering these skills in engineering students.

Moreover, the emphasis on embodying sustainability values within GreenComp aligns with the growing ethical considerations in engineering practice related to environmental and social impacts. [5] Integrating case studies and real-world projects that highlight these ethical dilemmas can help engineering students develop a strong sense of responsibility towards sustainability.

The increasing demand for green skills in the job market [15] underscores the importance of these efforts. Engineering graduates equipped with GreenComp competencies will be better positioned to contribute to a wide range of sectors, driving innovation in renewable energy, sustainable infrastructure, and environmental protection. [6,16,17]

6. CONCLUSION

The European Green Competence Framework provides a vital framework for integrating sustainability into engineering education. By focusing on the twelve key competencies outlined in GreenComp, higher education institutions can equip future engineers with the knowledge, skills, and attitudes necessary to address the complex sustainability

challenges facing the world. [5] Initiatives like Greenversity and the application of the GreenComp Evaluation Roadmap demonstrate the ongoing efforts to embed these competencies within engineering curricula. [2,9,18–21] As the demand for green skills continues to rise, the integration of GreenComp is essential for ensuring that engineering graduates are prepared to lead the transition towards a more sustainable and resilient future. [16]

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Integrarea Cadrului European al Competențelor Verzi în Educația inginerească: O analiză a proiectelor și abordărilor

Profesia de inginer se confruntă cu cerințe tot mai mari de a răspunde provocărilor globale legate de durabilitate, ceea ce impune integrarea competențelor de durabilitate în educația inginerească. Cadrul European al Competențelor Verzi (GreenComp) oferă o structură cuprinzătoare pentru definirea acestor competențe. Această lucrare analizează relevanța GreenComp pentru ingineri, evidențiind cele patru domenii de competență și aplicabilitatea lor în practica inginerească. De asemenea, sunt examinate inițiative europene, precum proiectul Greenversity și aplicarea Foii de Parcurs pentru Evaluarea GreenComp, care urmăresc integrarea competențelor de durabilitate în programele universitare. Discuția subliniază importanța dezvoltării gândirii sistemice, a considerentelor etice și a aplicării practice a competențelor GreenComp pentru a pregăti viitorii ingineri pentru o piață a muncii sustenabilă și un viitor rezilient

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