Journal website: https://publishing.mindseurope.com/index.php/ijetm
ISSN: 3104-3143

International Journal of Emerging Trends in Management

Volume 2 / No 1 / March 2026 / 20-32

MINDSEUROPE
Institute for Research Excellence and Technological Advancement

Research note

Learning gains in green vocational training: Preliminary cross-country evidence from the IMR sector

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ABSTRACT

This research note examines preliminary evidence on learning gains associated with a structured green vocational training programme implemented across five European countries in the Installation, Maintenance and Repair (IMR) sector. Using a pre-post self-assessment design, participants completed four modules covering sustainable materials, organizational sustainability practices, climate change mitigation, and green technologies. Learning outcomes were assessed across three dimensions: knowledge, competence, and skills. Descriptive analyses indicate consistent positive improvements across all modules. While the organizational sustainability module (Sustainable Materials and Resources) displayed comparatively higher average gains, cross-module differences were not statistically confirmed and should be interpreted cautiously. The findings suggest that integrated digital and workplace-embedded green training may support competence development in vocational contexts. Further research employing larger samples, objective performance indicators, and advanced modelling techniques is required to clarify differential content effects and long-term transfer. The study offers exploratory insights relevant for both sustainability education and management-oriented workforce development.

ARTICLE INFO

Received February 26, 2026
Revised March 25, 2026
Accepted March 25, 2026
Published online March 30, 2026

Keywords:
learning gains; sustainability training; competence development; green skills; installation, maintenance and repair (IMR) sector.

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INTRODUCTION

The green transition has fundamentally reshaped the skills requirements of European industries, particularly within the Installation, Maintenance and Repair (IMR) sector, which encompasses activities related to the installation, servicing, maintenance, and repair of equipment, infrastructure, and technical systems across sectors such as energy, construction, manufacturing, and building services, where operational practices directly affect resource efficiency, emissions reduction and environmental performance. European policy frameworks such as the European Green Deal and the European Skills Agenda explicitly emphasize the integration of sustainability competences into vocational education and training (VET) systems to support a low-carbon and circular economy (European Commission, 2020a, 2020b). However, while sustainability training initiatives are increasingly implemented across sectors, empirical evidence regarding which types of sustainability content generate the strongest learning gains remains limited.

Training effectiveness literature consistently demonstrates that structured training programmes produce measurable improvements in knowledge and skills when learning objectives are clearly defined and evaluated through pre-post assessment designs (Arthur et al., 2003; Salas et al., 2012). Moreover, research suggests that contextually embedded and practice-oriented learning approaches generate

Published by Minds Europe Institute for Research Excellence and Technological Advancements, Novi Sad, Serbia.

Doi: 10.65984/ETM2.1.3

stronger competence development than purely theoretical instruction (Burke & Hutchins, 2007; Blume et al., 2010). Within sustainability education, studies highlight that applied organizational sustainability training enhances employees' readiness to implement environmental practices at the workplace level (Jabbour, 2015; Daily et al., 2007). Integrative learning represents a huge benefit and a challenge for VET programs, especially when it comes to sustainability and green competences. Recent research highlights integrative learning as one of the important teaching approaches in modern education. Green and sustainable skills require knowledge acquired by integrative learning, learning that involves several fields and extends beyond one branch. This could be achieved through a curriculum that encourages integrative learning, as well as through various trainings and seminars (Milanković Jovanov et al., 2022).

Despite this growing body of literature, comparative cross-national evidence on green vocational training effectiveness remains scarce, particularly within technical sectors such as IMR. Existing research often focuses either on environmental awareness or technological adoption, without distinguishing between different sustainability content types (organizational practices, materials, climate mitigation, and green technologies). Consequently, there is a need to examine whether organizationally oriented sustainability training, which emphasizes workplace integration, operational procedures, and corporate sustainability strategies, produces stronger competence gains than more technology- or material-focused modules.

This research note addresses this gap by evaluating a structured green vocational training programme implemented across five European countries (Italy, Cyprus, Greece, Serbia, and Spain) within the IMR sector. Using a pre–post self-assessment design grounded in Kirkpatrick's Level 2 learning evaluation framework, the study measures learning gains across knowledge, competence and skills dimensions. The central research question explores whether organizationally oriented sustainability training may be associated with comparatively higher learning gains relative to other sustainability content types.

By providing cross-country empirical evidence, this study contributes to the training evaluation literature, advances understanding of green skills development in vocational contexts, and offers actionable insights for designing effective sustainability training interventions aligned with European green transition priorities.

THEORETICAL BACKGROUND

Training effectiveness and learning outcomes: Kirkpatrick's Model

The evaluation of training effectiveness is traditionally grounded in established frameworks within organizational learning research. Among the most influential is Kirkpatrick's Training Evaluation Model, which conceptualizes training outcomes across four hierarchical levels: reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2006). The present study focuses on Level 2 – Learning, which refers to measurable changes in participants' knowledge, skills, and attitudes following a training intervention.

Level 2 evaluation emphasizes the importance of systematic pre–post assessment to determine whether learning objectives have been achieved (Kirkpatrick & Kirkpatrick, 2006; Salas et al., 2012). In sustainability-oriented vocational education, measuring changes in knowledge, competences, and skills represents a critical first step in understanding whether training interventions effectively support the green transition. By operationalizing learning gains as differences between pre-training and post-training self-assessments, the present study directly applies to the logic of Kirkpatrick's learning-level evaluation.

Importantly, research in training effectiveness suggests that the design and structure of training content significantly influence the magnitude of learning outcomes (Arthur et al., 2003; Salas et al., 2012). This provides the theoretical foundation for comparing learning effects across different sustainability modules.

Experiential learning and organizationally embedded training

While Kirkpatrick's framework explains how learning can be measured, Experiential Learning Theory (ELT) explains how learning occurs (Kolb, 1984). According to Kolb (1984), effective learning follows a cyclical process consisting of concrete experience, reflective observation, abstract conceptualization, and active experimentation. Learning becomes more durable and transferable

when individuals can immediately apply concepts within meaningful and context-specific environments.

In vocational education, particularly within the Installation, Maintenance, and Repair (IMR) sector, training that embeds sustainability principles directly into organizational processes and operational routines is expected to generate stronger applied competences. Organizationally oriented sustainability modules align closely with experiential learning principles because they connect environmental concepts to daily workplace practices, decision-making processes, and company-level sustainability strategies.

In contrast, modules focused primarily on materials science, climate theory, or technological innovation may provide important conceptual foundations but may not offer the same degree of immediate contextual application. Prior research on experiential and context-based learning supports the argument that practice- oriented training enhances competence development and application more effectively than abstract instruction (Blume et al., 2010; Burke & Hutchins, 2007). From an experiential learning perspective, this difference in contextualization may result in differential competence development across training content types.

Learning transfer and baseline preparedness

Beyond immediate learning gains, Learning Transfer Theory emphasizes that training effectiveness ultimately depends on the ability of participants to apply acquired knowledge and skills within real work environments (Baldwin & Ford, 1988). Transfer is facilitated when training content is perceived as relevant, practice-oriented, and aligned with workplace realities (Blume et al., 2010; Burke & Hutchins, 2007).

Perceived competence serves as an important proxy for readiness to transfer learning. When participants report increased confidence in their ability to implement sustainability practices, this suggests not only cognitive acquisition but also enhanced likelihood of workplace application.

Learning transfer literature further suggests that baseline preparedness influences the magnitude of learning gains. Participants with lower initial knowledge or competence levels typically have greater room for improvement and may therefore exhibit stronger relative gains compared to those with higher baseline preparedness (Baldwin & Ford, 1988; Blume et al., 2010). This phenomenon reflects marginal improvement dynamics and learning curve effects within adult education contexts.

Hypotheses development

Drawing on the theoretical perspectives outlined above, this research note formulates three exploratory propositions to guide the empirical analysis of learning outcomes within the GreenVET programme.

First, according to Kirkpatrick's Level 2 learning evaluation framework (Kirkpatrick & Kirkpatrick, 2006), structured training interventions that are aligned with clearly defined learning objectives are expected to be associated with measurable improvements in participants' knowledge, competences, and skills. Prior research in training effectiveness suggests that systematically designed programmes evaluated through pre– post assessments typically demonstrate positive learning gains (Arthur et al., 2003; Salas et al., 2012). In line with this reasoning, the present study examines whether structured green vocational training is associated with improvements across sustainability modules.

H1: Structured green vocational training is expected to be associated with positive pre–post improvements in self-assessed knowledge, competences, and skills across sustainability modules.

Second, Experiential Learning Theory (Kolb, 1984) and research on context-based training transfer (Blume et al., 2010; Burke & Hutchins, 2007) suggest that learning embedded within workplace-relevant contexts may facilitate stronger applied competence development. Organizationally oriented sustainability training, which connects environmental principles to operational routines and company practices, may therefore be associated with comparatively higher competence gains than more conceptually or technologically focused modules. However, given the exploratory nature of the present study, such differences are examined descriptively rather than as confirmatory superiority claims.

H2: Organizationally oriented sustainability training may be associated with comparatively higher competence gains relative to material-, climate-, or technology-focused modules.

Third, the Learning Transfer Theory highlights the importance of baseline preparedness in shaping training outcomes (Baldwin & Ford, 1988; Blume et

al., 2010). Participants entering training with lower prior knowledge or competence may have greater scope for improvement due to larger available learning margins, a pattern frequently observed in adult education research (Salas et al., 2012). Within the scope of this research note, the relationship between baseline preparedness and magnitude of improvement is examined as an exploratory pattern rather than through formal moderation modelling.

H3: Participants with lower baseline preparedness may exhibit relatively larger learning gains, reflecting potential marginal learning effects; this proposition is examined descriptively and warrants further analytical validation.

Together, these hypotheses translate established theoretical frameworks into empirically examinable propositions while acknowledging the exploratory scope of the present research note.

METHODOLOGY

Research design and sample size

This study employs a quantitative pre–post evaluation design within a cross-country case study framework. The empirical setting is the GreenVET project, implemented under the Erasmus+ KA2 Cooperation Partnerships in Vocational Education and Training programme. The design allows for the assessment of learning gains across multiple sustainability training modules and national contexts.

As not all participants completed both the pre- and post-assessment for each module, the effective analytic sample differed across modules. The module-specific sample sizes were: Module 1 (n = 29), Module 2 (n = 19), Module 3 (n = 30), and Module 4 (n = 22).

Case description: The GreenVET Project

The empirical context of this study is the GreenVET project, an Erasmus+ KA2 Cooperation Partnership in Vocational Education and Training (VET), aligned with two strategic priorities: (1) adapting VET to labor market needs and (2) addressing the horizontal priority of environment and climate change.

GreenVET was developed to support the green transition of companies operating within the Installation, Maintenance and Repair (IMR) sector. The project responds to the increasing demand for workforce upskilling in sustainability-related competences, particularly among blue-collar workers whose operational practices directly influence environmental performance.

The intervention consisted of a structured digital training programme delivered through an interactive platform incorporating gamification elements. The pedagogical approach combined theoretical instruction with applied, workplace-relevant scenarios. Participants completed four thematic modules:

1. Sustainable Materials and Resources
2. Sustainable Practices in IMR Companies
3. Climate Change Mitigation and Adaptation
4. Green Technologies and Innovations

Upon successful completion of the digital training, participating companies were awarded a GreenVET badge, signaling commitment to the green transition. In addition, apprenticeship placements were organized to facilitate the development of work-based green competences, reinforcing the transfer of learning from digital instruction to practical application.

The project was implemented across five European countries (Spain, Serbia, Italy, Greece, and Cyprus), enabling cross-national comparison of learning outcomes within diverse institutional and labour market contexts.

GreenVET represents an innovative VET intervention due to three core features:

(1) integration of environmental sustainability into vocational curricula,

(2) use of gamified digital learning technologies, and

(3) structured linkage between digital training and work-based apprenticeship practice.

This combination provides a suitable empirical setting for exploring potential differences in learning gains across sustainability content types.

RESULTS

Module-level summary

The table below summarizes the average rating across all Likert-scale questions for each module. Higher scores indicate greater self-reported knowledge and competences

Across all modules, participants reported substantial gains. The largest improvement occurred in Module 2, where the mean score increased by 1.49, suggesting that the apprenticeship particularly strengthened learners' understanding of sustainable practices in IMR companies. Module 1 showed the smallest but still notable improvement (+1.04), indicating that baseline knowledge about sustainable materials was relatively higher before the programme.

The analysis of pre- and post-apprenticeship data indicates notable learning progress among participants in the GreenVET programme. Before the start of the training, the average self-assessment scores ranged between 2.82 and 3.08, corresponding to the scale points Neutral to Agree. These values indicate that learners entered the programme with only moderate confidence in their existing knowledge and competences related to sustainability and green practices. While most participants showed some awareness of sustainability concepts, their responses suggested a lack of depth in understanding and application, particularly in company-specific contexts.

Following the completion of the training, the mean scores increased significantly, ranging from 4.03 to 4.31, aligning with Agree to Strongly Agree on the assessment scale. This pronounced upward shift across all thematic modules demonstrates that the apprenticeship effectively enhanced both theoretical understanding and practical competence. Participants not only acquired new knowledge but also developed greater confidence in their ability to implement sustainable practices in their professional environments. The consistency of improvement across countries suggests that the GreenVET instructional design may have supported learning across diverse contexts.

When examining performance by individual modules, Module 2 – Sustainable Practices in IMR Companies recorded the largest gain. This result suggests that participants were initially less familiar with company-level sustainability strategies and therefore benefited most from the structured, practice-oriented learning approach adopted in this module. In contrast, Module 4 – Green Technologies and Innovations showed a more moderate improvement, likely reflecting that many participants had some prior exposure to technological innovations before the training.

Table 1. Average rating across all Likert-scale questions for each module

Module	Pre-Apprenticeship Mean	Post-Apprenticeship Mean	Difference (Post – Pre)
1 – Sustainable Materials and Resources	2.99	4.03	+1.04
2 – Sustainable Practices in IMR Companies	2.82	4.31	+1.49
3 – Climate Change Mitigation and Adaptation	2.86	4.18	+1.31
4 – Green Technologies and Innovations	3.08	4.28	+1.20

Country-level progress

Participants hailed from five countries. The following charts illustrate average overall ratings by country before and after the apprenticeship for each module.

Module 1: Sustainable materials and resources

The data reveal some country-level differences in participants' progress within the module Sustainable Materials and Resources. Learners from Spain and Greece demonstrated the most significant gains, with average increases of approximately +1.29 and +1.28 points, respectively. Their mean scores rose from around Neutral (2.8–2.9) to well above Agree (4.2). This improvement suggests that the training strongly enhanced their understanding of sustainable material selection and resource management. It also reflects

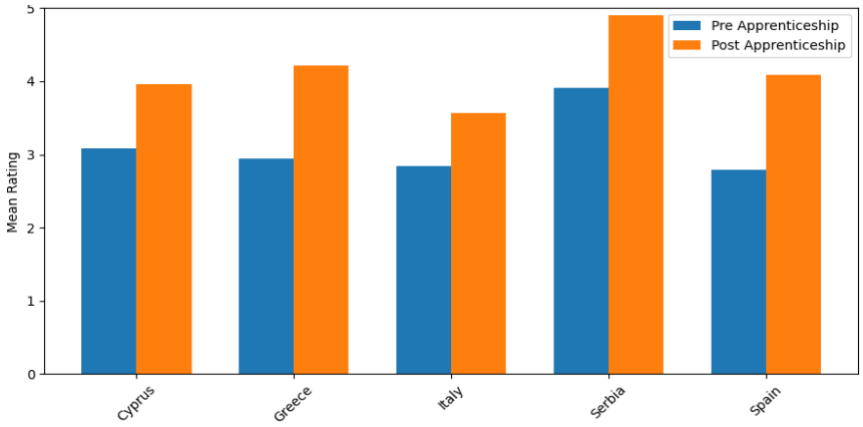

Figure 1. Country Comparison of Module 1 - Sustainable Materials and Resources

effective knowledge transfer within these national contexts, where participants were able to internalize theoretical principles and translate them into practical awareness of sustainability in material use

In contrast, Italy started from the lowest baseline score (2.84) and showed a comparatively improvement of +0.73, reaching an average post-training score of 3.57. This pattern may indicate that Italian participants required more time to adapt to the module's conceptual framework or that contextual factors, such as differences in prior exposure to sustainability topics or varying engagement levels, influenced their learning outcomes. However, the relatively smaller gain nonetheless shows positive movement, implying that the training contributed to building foundational awareness that can be strengthened in future iterations through more localized examples or interactive exercises.

Meanwhile, Serbia began with the highest pre-apprenticeship score (3.92) and still achieved a notable improvement of +0.98, reaching a post-training mean of 4.90, which is close to Strongly agree. This outcome highlights the participants' strong initial familiarity with sustainable material practices and their ability to further consolidate this knowledge through the apprenticeship. The Serbian cohort's consistently high-performance underscores both strong baseline competence and the effectiveness of the GreenVET instructional design in reinforcing advanced understanding of sustainability concepts.

Module 2: Sustainable practices in IMR companies

The results for the module Sustainable Practices in IMR Companies show a strong and consistent pattern of improvement across all participating countries, confirming that the GreenVET training effectively strengthened learners' understanding of corporate sustainability principles. Every country recorded a substantial positive change exceeding +1.1 points, demonstrating that the module successfully addressed key knowledge gaps related to the integration of green practices within industrial and maintenance contexts.

Cyprus and Spain achieved the most remarkable progress, with increases of +1.66 and +1.55, respectively. These gains indicate that participants in both countries significantly benefited from the module's practical focus on workplace sustainability, waste management, and efficiency measures. The training appears to have resonated particularly well in these contexts, where learners moved from moderate levels of prior understanding to high confidence in applying sustainable business practices.

Serbia once again began with a relatively high baseline score (3.79), reflecting strong prior awareness of sustainability issues within corporate environments. Despite this advanced starting point, Serbian participants still achieved an additional +1.11 improvement, reaching an impressive post-training mean of 4.90, close to Strongly agree. This suggests consolidation and refinement of already well-established competences rather than new acquisition of knowledge, reinforcing the programme's ability to enhance existing expertise.

Italy also recorded a substantial gain of +1.55, rising from a lower initial confidence level to a post-apprenticeship mean of 4.28. This demonstrates effective assimilation of the module content, indicating that Italian participants benefited greatly from the hands-on approach and real-world examples used in this module. The notable increase suggests that contextualized, practice-based learning strategies played an important role in improving both comprehension and engagement among learners, further validating the pedagogical design of the GreenVET framework.

Module 3: Climate change mitigation and adaptation

The analysis of the module Climate Change Mitigation and Adaptation highlights significant advancements across most participating countries, confirming that the GreenVET training successfully strengthened learners' understanding of environmental responsibility and climate-related challenges in professional contexts.

Greece demonstrated the most remarkable improvement, with an average score increase of +1.69, moving from 2.78 (Neutral) to 4.48 (Agree to Strongly agree). This substantial gain indicates that the module effectively bridged major knowledge gaps and fostered a deeper comprehension of mitigation and adaptation strategies among Greek participants. The results suggest strong engagement with the module's applied components, such as practical examples of emissions reduction, energy efficiency, and circular economy principles.

Cyprus and Spain also achieved large improvements, each exceeding +1.0 on the five-point scale, finishing with mean post-apprenticeship scores of 4.75 and 3.97, respectively. These results reflect considerable progress in climate literacy and demonstrate that the training content was both relevant and accessible to learners in these contexts. The relatively higher performance of Cypriot participants may be linked to a greater initial awareness

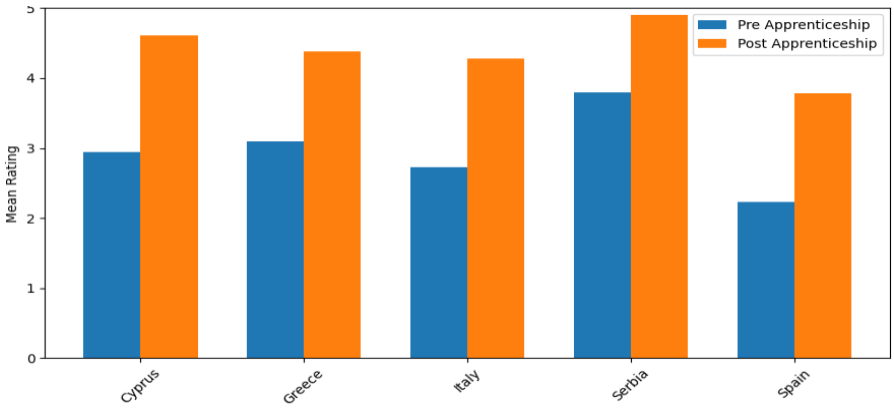

Figure 2. Country comparison of Module 2 – Sustainable Practices in IMR Companies

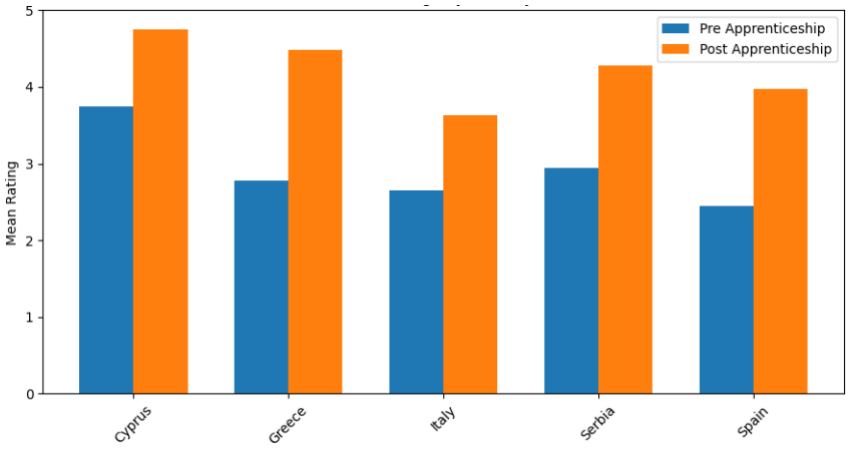

Figure 3. Country comparison of Module 3 – Climate change mitigation and adaptation

of local environmental vulnerabilities, motivating stronger engagement with adaptation and mitigation themes.

Italy recorded also improvement of +0.99, reaching an average post-training score of 3.63. Although this still represents progress, it suggests that Italian participants may have faced challenges in fully assimilating the module's technical and conceptual aspects.

The results confirm that the Climate Change Mitigation and Adaptation module effectively raised awareness and competence among participants, particularly in countries where baseline understanding was lower, demonstrating the transformative potential of applied learning within the GreenVET framework.

Module 4: Green technologies and innovations

The outcomes for the module Green Technologies and Innovations reveal meaningful and positive progress across all partner countries, with particularly strong results in contexts where learners engaged deeply with the technological and innovation-oriented aspects of sustainability.

Serbia achieved the most substantial improvement, with an average increase of +1.69, moving from 2.88 (Neutral) to 4.57 (Agree to Strongly agree). This significant leap indicates that Serbian participants enthusiastically embraced the module's focus on digital tools, renewable energy technologies, and eco- innovative solutions.

Spain and Greece also displayed notable gains, with improvements of approximately +1.48 and +0.99, respectively. In both cases, participants transitioned from moderate baseline scores to post-training levels that reflect high satisfaction and increased confidence

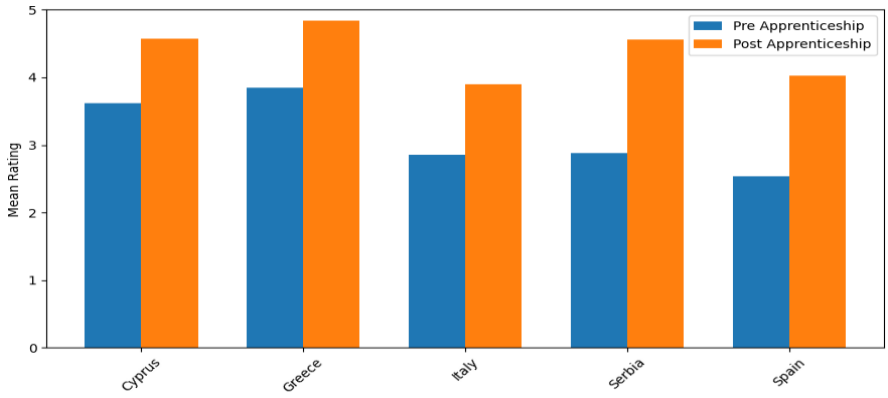

Figure 4. Country comparison of Module 4 – Green technologies and innovations

in applying green technology concepts within their professional settings. The Spanish results, in particular, point to a growing familiarity with innovation-led sustainability strategies, aligning with the country's broader vocational education reforms aimed at integrating environmental technologies into work-based learning. Italy showed an increase of +1.04, rising from 2.85 to 3.89.

The analysis confirms that the Green Technologies and Innovations module was effective in enhancing learners' awareness and competences across all countries, particularly in fostering enthusiasm and applied understanding of emerging technologies that support the green transition. The results further validate the GreenVET framework's ability to blend technical content with practical learning approaches, empowering participants to envision and implement sustainable technological solutions within their future workplaces.

Cross-comparison of modules and countries across knowledge, competence and skills

In Module 1 (Sustainable materials and resources), Spain achieved the largest improvement in competence (≈ +1.62 points), while Greece led in knowledge (+1.21) and skills (+1.39). Italy and Cyprus recorded moderate progress (≈ 0.55–1.04). Serbia had an increase of 1.04. These results suggest that foundational topics on materials and resources effectively strengthened both conceptual understanding and applied competence, particularly among Spanish and Greek participants.

Module 2 (Sustainable practices in IMR Companies) generated the highest overall gains. Cyprus reported the strongest increase in competence (+2.00), while Spain and Italy also showed significant growth (≈+1.58–1.62). Knowledge gains were led by Spain (+1.81) and Greece (+1.67), and skill improvements were most evident in Italy (+1.63), Cyprus (+1.56), and Spain (+1.46). These consistent, cross-category advances confirm that the applied nature of Module 2, focused on sustainable organizational practices, was particularly effective in supporting competence development.

In Module 3 (Climate change mitigation and adaptation), performance was more balanced across countries. Greece and Spain recorded the largest improvements in competence (+1.64 and +1.73) and skills (+1.97 and +1.61), showing strong engagement with climate-related content. Italy and Serbia had comparable competence growth but smaller skill gains. Knowledge progress was moderate, led by Serbia (+1.19) and Italy (+0.92).

Module 4 (Green technologies and innovations) produced smaller but still meaningful gains. Spain showed the greatest competence increase (+1.86) and solid gains in both knowledge and skills. Serbia excelled in skills (+1.96) and competence (+1.39), while Italy achieved its highest knowledge growth (+1.10) in this module. Cyprus and Greece recorded also improvements across all areas. The results highlight the potential of innovation-focused content to boost both technical and problem-solving skills, especially in Spain and Serbia.

Module 2 displayed the highest average gains across countries; however, these differences should be interpreted descriptively and require further statistical validation. Modules 3 and 4 also produced strong results, though their impact varied by country and baseline performance.

The following figures visualize the average improvement (Post – Pre) by module and country for each category: knowledge, competence, and skills.

Overall trends

The overall results of the GreenVET apprenticeship programme demonstrate consistent positive improvement in participants' self-assessed knowledge and competences across all four modules and all participating countries. The aggregated data show that the project successfully achieved its primary educational objectives, enhancing green and sustainable skills among learners in IMR sector, while also providing insights into how learning outcomes vary according to baseline preparedness, content focus, and national context.

A clear pattern of universal progress was observed throughout the analysis. Every participating country recorded positive post-apprenticeship gains across all modules, and importantly, there were no instances of decline in any of the measured indicators. This consistency underscores the overall effectiveness of the GreenVET instructional design and pedagogical framework, confirming that the blended learning model, combining theoretical understanding with work-based application, successfully enhanced both knowledge and competence acquisition

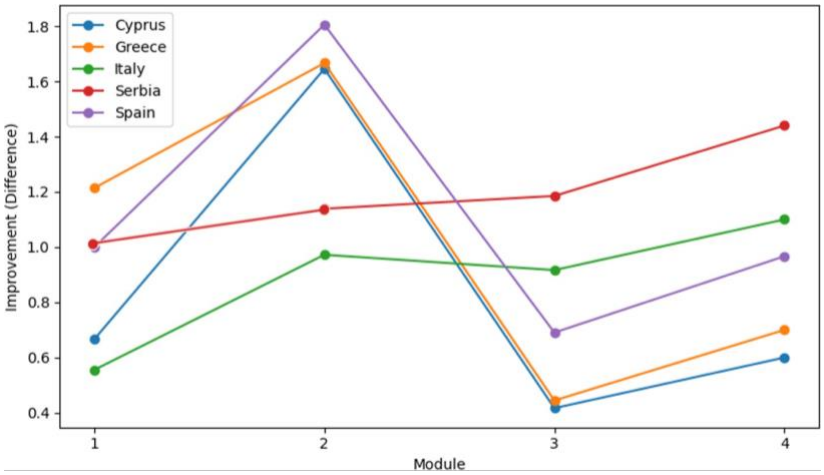

Figure 5. Improvement in knowledge scores across modules (horizontal axis) for each country
Note. A higher value indicates a larger gain from pre- to post-apprenticeship.

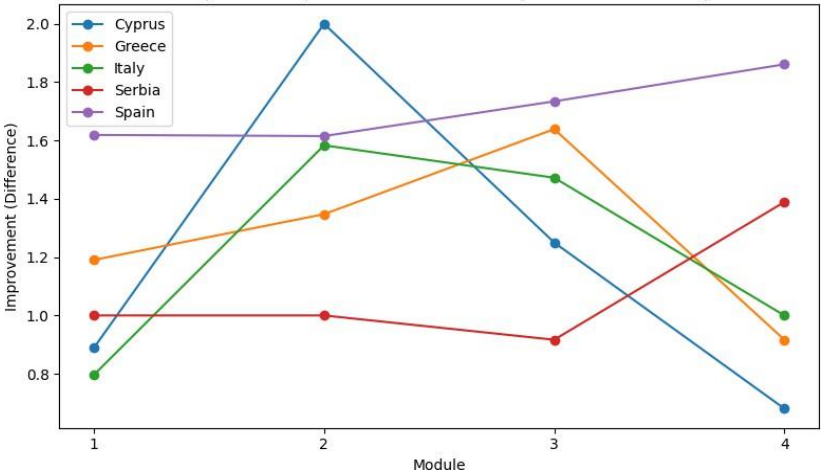

Figure 6. Improvement in competence scores across modules (horizontal axis) for each country
Note. A higher value indicates a larger gain from pre- to post-apprenticeship.

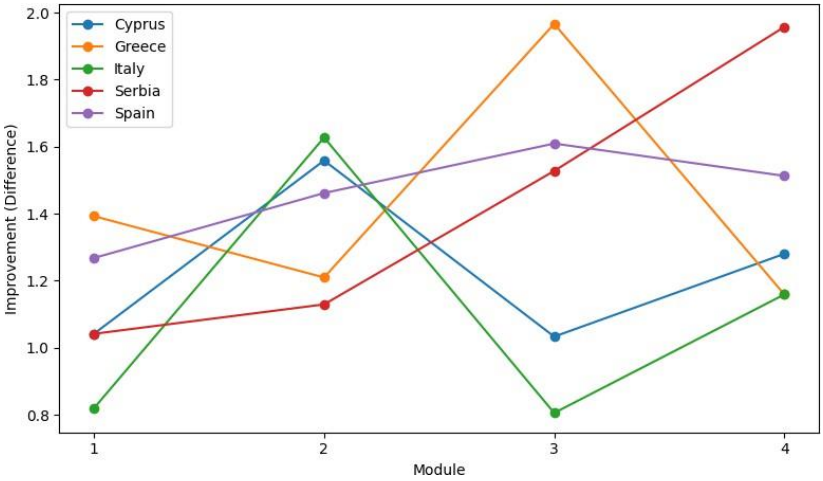

Figure 7. Improvement in skills scores across modules (horizontal axis) for each country
Note. A higher value indicates a larger gain from pre- to post-apprenticeship.

The data further reveal that participants who began with lower baseline scores tended to demonstrate the most substantial growth. This finding is particularly visible in modules and countries where pre-training confidence was moderate or low, suggesting that the GreenVET methodology effectively filled existing knowledge gaps. The structured combination of digital learning, and applied tasks provided a balanced environment that allowed participants with less initial familiarity to build solid conceptual and practical foundations in sustainability.

From a thematic perspective, the analysis shows that modules emphasizing organizational practices and climate-related content (Modules 2 and 3) generated higher post-apprenticeship improvements than those focused on materials and technology (Modules 1 and 4). This pattern suggests that practical, application-oriented content, especially where learners could directly relate concepts to workplace experiences, proved more effective in facilitating knowledge retention and skill development. Learners responded most positively to scenarios that linked sustainability principles with real-world operational challenges, reinforcing the value of experiential learning in vocational education.

The GreenVET apprenticeship delivered measurable learning outcomes, promoting green competencies and sustainable thinking across diverse European contexts. The findings provide preliminary support for the value of combining digital pedagogy with hands-on approaches, and they point toward future refinements that can further increase inclusivity, contextual relevance, and long-term impact within the Erasmus+ vocational training framework.

DISCUSSION

The findings of this cross-country evaluation provide preliminary evidence that structured green vocational training is associated with positive learning gains across knowledge, competences, and skills within the IMR sector. Consistent with Kirkpatrick's Level 2 learning evaluation framework (Kirkpatrick & Kirkpatrick, 2006), participants reported measurable pre–post improvements across all four sustainability modules. These results suggest that systematically designed sustainability training interventions may support green competence development in vocational contexts. Although the module on Sustainable Practices in IMR Companies displayed comparatively higher average gains, differences between modules were not statistically confirmed and should therefore be interpreted descriptively. This lack of statistical confirmation should be interpreted cautiously, as the preliminary character of this research note and the modest, uneven module-specific sample sizes limited the statistical power for reliable between-module comparisons. Rather than indicating the superiority of a particular content type, the results point to the potential effectiveness of the overall instructional design. The integration of digital learning with work-based apprenticeship practice may have contributed to learning gains across all thematic areas.

From the perspective of Experiential Learning Theory (Kolb, 1984), the observed improvements may reflect the benefits of contextualized and practice-oriented instruction. The modules were structured to connect conceptual sustainability knowledge with operational workplace scenarios, which may have facilitated the application and consolidation of learning. However, given the absence of statistically significant differences across modules and the limited statistical power associated with the modest module-specific samples, the present findings should be interpreted as exploratory rather than confirmatory with respect to differential content effects.

The pattern of stronger relative gains among participants with lower baseline preparedness aligns with insights from learning transfer and adult training research (Baldwin & Ford, 1988; Blume et al., 2010; Salas et al., 2012). Individuals entering the programme with limited prior exposure to sustainability concepts may have had greater scope for improvement. Nevertheless, this relationship warrants further analytical modelling to determine whether baseline preparedness systematically moderates learning outcomes.

Cross-country consistency in positive learning gains suggests that the GreenVET training model may be adaptable across diverse VET systems. At the same time, variations in baseline scores and magnitude of improvement indicate that contextual factors. including national vocational structures, prior sustainability exposure, and sectoral maturity. may shape training effects. These contextual influences require deeper multilevel and longitudinal investigation.

While the findings indicate that structured green vocational training is associated with meaningful learning gains, more rigorous designs, including larger samples, objective performance indicators, repeated measures modelling, and longitudinal follow-up, are

needed to clarify causal mechanisms and long-term transfer effects.

Theoretical implications

This study contributes to the literature on training evaluation and sustainability education by applying established theoretical frameworks within a green vocational training context.

First, it offers a preliminary empirical application of Kirkpatrick's Level 2 evaluation logic to green skills development, demonstrating that structured sustainability programmes can be associated with measurable learning improvements (Kirkpatrick & Kirkpatrick, 2006).

Second, the findings are broadly consistent with Experiential Learning Theory (Kolb, 1984), insofar as contextualized and application-oriented instruction appears to support competence development. However, given the absence of statistically confirmed differences across modules, conclusions regarding the relative effectiveness of specific content types remain tentative.

Third, the results are compatible with Learning Transfer Theory (Baldwin & Ford, 1988; Blume et al., 2010), suggesting that perceived competence may serve as a useful proxy for readiness to apply sustainability practices in workplace settings. The observed relationship between baseline preparedness and magnitude of improvement also contributes to ongoing discussions on marginal learning effects in adult education (Salas et al., 2012).

By integrating training evaluation, experiential learning, and transfer perspectives, this note provides a conceptual foundation for future studies examining green vocational training effectiveness.

Practical implications

From a managerial and policy perspective, the findings suggest that structured sustainability training may support workforce readiness for the green transition, particularly when digital instruction is combined with workplace-based application.

Rather than prioritizing a single thematic focus, programme designers may benefit from maintaining an integrated approach that combines organizational practices, climate awareness, materials knowledge, and technological innovation. The absence of statistically confirmed differences between modules indicates that multiple content areas can contribute meaningfully to competence development when embedded within coherent instructional design.

For SMEs and IMR companies, structured green training initiatives may serve as a mechanism for strengthening operational sustainability awareness and enhancing employees' perceived readiness to implement environmental practices.

At the policy level, these findings align with broader European sustainability and skills strategies (European Commission, 2020a, 2020b) and with international calls to integrate green skills into vocational education systems (UNESCO, 2021). The GreenVET case illustrates how digital learning combined with apprenticeship-based practice can operationalize such priorities in practice.

Furthermore, the alignment of the training programme with the European Qualifications Framework (EQF) (Council of the European Union, 2017) Levels 6 and 7 ensures that the acquired competences correspond to recognized European standards for advanced vocational education and professional development. This enhances the credibility, transferability, and labor market relevance of the training, supporting both individual career progression and organizational capacity to implement sustainability practices effectively.

Limitations and future research

Several limitations must be acknowledged. First, the reliance on self-assessment measures may introduce perception bias and social desirability effects. Although self-evaluation is consistent with Level 2 learning assessment (Kirkpatrick & Kirkpatrick, 2006), future research should incorporate objective performance measures, supervisor assessments, or behavioral indicators.

Second, the pre–post design lacks a control group, limiting causal inference. Experimental or quasi-experimental designs would strengthen internal validity.

Third, the study captures short-term learning gains. Longitudinal research is required to determine whether reported competence improvements translate into sustained behavioral change (Level 3) and organizational outcomes (Level 4).

Future studies could employ multilevel modelling, structural equation modelling, and moderation analysis to examine interaction effects between module type, baseline preparedness, and learning outcomes. Such approaches would allow

more definitive conclusions regarding the mechanisms underlying green vocational training effectiveness.

CONCLUSION

This study provides cross-national descriptive evidence that structured green vocational training is associated with positive learning gains across knowledge, competence, and skills dimensions within the IMR sector.

Although organizationally oriented sustainability modules exhibited comparatively higher average gains, cross-module differences were not statistically confirmed and should therefore be interpreted as indicative patterns rather than evidence of content superiority.

Descriptive trends suggest that participants with lower baseline preparedness may have experienced relatively larger improvements. However, this relationship was not formally modelled and requires further analytical validation using moderation or multilevel approaches.

Importantly, the alignment of the training programme with the European Qualifications Framework (EQF) Levels 6 and 7 enhances the transparency, comparability, and formal recognition of the acquired competences across European vocational education and training systems.

The GreenVET case indicates that integrated digital and apprenticeship-based sustainability training may support workforce readiness for the green transition. Future research employing larger samples, objective performance measures, and longitudinal designs is needed to clarify causal mechanisms and long-term transfer effects.

Funding: This paper was produced within the Erasmus+ project GreenVET – Green Transition for VET (KA220-VET), co-funded by the European Union

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