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**Integrating Sustainable Development Goals into Higher Education Curricula:
Impacts on Sustainability Knowledge, Student Engagement, and Graduate
Competencies**

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Abstract: In this study, the integration process of Sustainable Development Goals (SDGs) into higher education (HE) education, and the influence of this integration on sustainability knowledge, engagement and qualified competencies of graduates, will be of focus. A questionnaire, interviews, focus group and document analysis was used to gather information from 976 participants in a 20 institution cross sectional design. Descriptive statistics, multiple linear regression and SEM (structural equation modeling) were used in analyzing the statistical data. The findings show that SDG integration has a strong predictive effect on students' competency scores, where establishing SDGs in the school curriculum ($\beta=0.45$, $p<0.001$) and faculty readiness ($\beta=0.38$, $p<0.001$) have the greatest predictive effects; the regression model shows that the variation in students' scores in this competency is 74.2% of the influence of the analyzed variables. SEM indicated good model fit (CFI = 0.97, RMSEA = 0.044). The institutions that had comprehensive integration of SDG content had 28.5% more sustainability knowledge and 24.7% higher level of student engagement with sustainability; they had 22.9% increased levels of environmental responsibility and 19.8% increased employability competencies gained by their graduates compared with the institutions that had limited SDG content. Further, 74.8% of the institutions included content about sustainability in their curriculum and 71.6% of the students participated in sustainable development projects. What makes this work new is the use of multiple levels of empirical effects of curriculum design, teaching, and institutional support as interrelated predictors of sustainability outcomes. We feel it necessary to embed the SDGs in educational programmes; offer support at institutional level and build capacity within the faculty in order to deal with complex global issues. The results of the research will provide some practical specific recommendations to policy writers and teachers who want to enhance curricula and build sustainability capacity in college students.

Keywords: Sustainable Development Goals (SDGs), Higher Education, Sustainability Education, Student Engagement, Graduate Competencies

Introduction

Climate change, biodiversity loss, social inequality/economic instability are global challenges that have also stressed libraries, and this is a challenge that would be new for higher education institutions to raise and prepare students to meet and face the multifaceted sustainability challenges they will likely be presented with in the future. So, the 2030 Agenda for Sustainable Development has emerged into the daylight and 17 Sustainable Development Goals (SDGs) have turned it into a large blueprint for the world's sustainable development (Sayed, 2015). The Education 2030 Framework for Action clearly asks educational systems to engage sustainability in all levels of schooling (Sachs-Israel, 2016). Integration of SDGs in the higher education institution in the curricula, research and practice puts SE at the heart of preparing students with a multi-disciplinary education, supported by critical thinking and ethical convictions for a more sustainable world. It is widely recognized that ESD is needed; but thus far, its implementation is inconsistent and incomplete from institution to institution. Although high-level policy initiatives aim to redirect tenured universities towards more sustainable teaching, these changes are difficult to make in actual classrooms because the higher ed institution is structured in such a way that faculty members are not prepared to implement pedagogies related to sustainability in their classes (Franco et al., 2019). Furthermore, the literature available is predominantly focused on a few individual case studies and/or single-institution based studies, highlighting a lack of awareness of the effects of broader institutional, systematic SDG integration strategies on student outcomes and institutional capabilities (Dutta et al., 2026). Hence, a more empirical approach focusing on interactions between the curriculum design, teaching mode, teacher qualification and institutional supports for the development of sustainability competency should be further researched.

To fill this, we have carried out a full and mixed methods study in 20 different HEIs, exploring how the relationship among SDG curriculum integration and important educational outcomes. The main thesis of this study was that a strategic approach, including the integration of the SDG content in the programs, significantly enhances students' knowledge of sustainability and interdisciplinary learning throughout the program, increases engagement and employability as a graduate, and boosts readiness among faculty and support from the institution. The overall goal was to shift the normative call for change to a discussion of empirical evidence that can be used to guide evidence-based policy, program, and faculty development efforts. This is a triple contribution of this work. It offers a thorough multidimensional empirical assessment that was evaluated across multiple institutions that captures the complexity of ESD in a broader higher education system addressing official accrediting bodies as well as societal expectations for students with a sustainability capacity. (Gnankob et al., 2026); Second, it creates and testifies a series of composite indexes (like SDG Curriculum Integration Index and Graduate Sustainability Competency Index) which allow a structured and quantifiable comparison of institutional progress. Thirdly, it applies highly accurate statistical model such as multiple linear regression, and structural equation modeling (SEM) in determining the relationships of Curriculum Integration directly with students' involvement and sustainability results as well as the relationships of Curriculum Integration directly with students' involvement and

sustainability results with the involvement of faculty readiness. This method enables us to define the most influential leverage points to allow intervention, whilst descriptive and single variable analysis would not give this type of in-depth analysis that would be necessary. The literature review in Section 2 entails reviews of the past research on how ESD and SDG can be integrated in higher education. Section 3 presents the method for investigating the issue followed by results of the research presented in Section 4. The results of the research are presented in Section 4 and a discussion of the results and conclusions that could be drawn from them is presented in Section 5. The paper ends in section 6. In Section 3 the mixed methods research design, methods of participant recruitment, development of data collection tools, and the collection of a series of statistical analyses utilized are discussed. The empirical findings are reported in Section 4, comprising mainly descriptive statistics, regression results as well as model fit indicators in an SEM. The implications of these findings for policy, curriculum design and faculty development (along with the limitations of the study) are discussed in section 5. Key Insights and recommendations for future research and practice (Section 6) summarises the key findings and recommendations.

Literature Review

Over the last three decades, the idea of Education for Sustainable Development (ESD) has grown in size and significance and transformed from being just another educational issue to becoming an integral part of higher education policy discourses. The reorientation of curricula to ESD has been clearly indicated in the Global Action Programme on ESD document of UNESCO (Buckler & Cree, 2014), and echoed by the SDGs and the 2030 Agenda. This evolution has spurred several academic research projects around ways to design institutions that are most conducive to reaching fuzzy visions of environmental sustainability in concrete ways for sustainable pedagogies and evidence of learning. Facilitating more in-depth learning and competency development to embed sustainability within courses and course syllabus has been emphasized (Wu & Shen, 2016) and this includes embedding, rather than just teaching sustainability in different courses, also in an integrated, systematic way. In several studies, the mechanism of the impact of integrating SDG in outcomes of students has been studied. For instance, if students' curricula are developed in sustainable ways, they will become more capable of grasping the interconnections between the environmental, social, and economic (VPE), as found by Wals and Benavot (2017). In addition, interdisciplinary sustainability course investigations have shown that the course content could significantly increase students' problem-solving skills in groups as well as their capacity for ethical considerations—which are essential in tackling wicked sustainability problems (Horn et al., 2023). This finding is in line with other theoretical attempts to emphasize competence-based education in which the learning outcomes are defined and measured in competencies, which is consistent with the SDG that defines or measures them. However, the mediating effect of faculty readiness has been demonstrated less in empirical literature. While a handful of studies have found positive relationships in attitudes and skills of faculty members towards SDGs, and in faculty exposure to sustainability pedagogies with inclusion of the issues in teaching, the links between the faculty skills and attitudes and potential improvement in student learning have been little studied (Owusu-Agyeman, 2021). Furthermore, previous studies tend to have methodological

limitations such as studies based on a single institution in a case study, too small of samples and lack of validated composite indicators to produce sustainability outcomes. For example, even if the studies presented discussed integration of SDGs may be needed, many of them have been qualitative and others lacked efficacy, quantitative analysis and did not include more than one level of institutional change that makes them applicable to broader application (Lozano et al., 2022; Serafini et al., 2022). The present study attempts to fill in these gaps with its empirical design from various institutions and settings and by comprehensively analyzing the interdependence of the predictors of sustainability competency. Our study is ground-breaking in that it looks at the entire study of ESD not just one aspect, including curriculum design, teaching practices, faculty readiness, and the institutional support. Creating composite indices, such as the SDG Curriculum Integration Index and the Graduate Sustainability Competency Index, offers a framework and approach that can be applied in a replicable way to measure progress in various institutional settings.

Methodology

The technical aspects of the research design, data collection and data analysis methods used to test the SDG integration in the HE curricula is shared. A multi-level modelling methodology was designed to format the different types of influences on the development of sustainability competency, enabling the comprehensive assessment of the interrelatedness of the different levels of curriculum design, faculty readiness, student involvement and institutional support.

Research Design and Sampling

Regarding quantitative component of research, survey method was used and for qualitative research, interview and document analysis were employed to get insight from Mixed Method Cross Sectional Research. Such an approach enabled us to synthesise information from a variety of data sources and filters, and to gather both broad range and depth of information on integration patterns and factors. This study was conducted in 20 purposefully selected Higher Education Institutions (HEIs) with diverse geographic, institution size, location of institution (public or private), and involvement in ESD initiatives. Out of these institutions 1000 participants were selected as stratification random sampling for even distribution of participants across the four Stakeholders groups which are Undergraduate Students, Postgraduate Students, Faculty and Academic Administrators. It was significant for depicting the diverse viewpoints at various institutional levels, which can experience and react to the integration of SDGs differently.

Data Collection Instruments

Four complementary instruments were used to collect primary data. Respondents were all provided with structured questionnaires with a total of 48 items pertaining to the respondent's demographic characteristics, awareness of SDGs, sustainability knowledge level (measured through the use of a 15 item quiz), level of perception of curriculum integration, methodology used/experienced, level of students' participation in sustainability activities, learning outcomes, including those of employability skills related to sustainability, and others. Items pertaining to attitudinal variables were asked on a five-point likert-type scale while those used for knowledge

assessment were in multiple choice format. Second, to delve deeper into barriers and enablers of SDG integration, 40 faculty members and curriculum developers were interviewed semi-structured. Third, eight to ten students took part in six focus group discussions, collecting experiential stories on learning about sustainability. To fill the identified gaps, education institutions involved in the project were subjected to curriculum document analysis whereby the documents, based on their content, were systematically categorized in terms of SDG-related content, interdisciplinary aspects, experiential learning aspects. Secondary data were collected from or about the institutions through institutional reports to add more context to the sustainability strategy, allocation of institutions' resources, and external accountability mechanisms in each institution. This multi-source approach lent additional validity to the results because not only was self-reported data involved but more than one source was involved in the data collection process.

Variables and Composite Indices

The variables collected were related with several constructions. Demographic factors included academic level (undergraduate/postgraduate/faculty and administrators), gender, age and discipline. To assess awareness the participants were asked to recognise the right number of SDGs and asked to recall three of them. Assessment of sustainability knowledge was determined by providing a knowledge test on sustainability, which contained 15 multiple-choice questions on the topics of the environment, social and economic aspects of sustainability. Operationalisation of the level of curriculum integration of SDG was carried out through document analysis by calculating the percentage amount of courses within a programme which explicitly contain SDG content. Their teaching methods were divided into the traditional lecture approach, project approach, service-learning and interdisciplinary approach and numbered on a Likert scale. To enable some amount of standardization in comparison of institutions, 7 composite indices are formed. Each country's SDG Curriculum Integration Index is a weighted total of four indicators, all expressed as percentages on a scale of 0-100: how many of the total number of courses studied had content relating to the SDGs, the depth of discussion (mention versus analysis), the presence of interdisciplinary courses and the inclusion of experiential learning elements. Sustainability Knowledge Score" was the score achieved for answers that were correct in the 15 questions of the quiz. The Student Engagement Index values were the frequencies from involvement in sustainability-related projects and events on campus and in the local community. The Faculty Readiness Index was developed by incorporating the four components (i.e., self-reported familiarity with the SDGs, having attended the ESD training, self-reported confidence in teaching SDG related content, using active teaching pedagogies). The indicator for institutional sustainability, Institutional Sustainability Index, revealed that there was an institutional sustainability plan, an office of sustainability & SDGs were included in institutional mission statements. Environmental Responsibility scores were derived from the number of times the pro-environmental behaviors and attitudes measured on a Likert scale were reported. Finally, the Graduate Sustainability Competency Index was built based on graduate self-perceptions of enhancement in the five competency areas: Systems thinking, critical thinking, Interdisciplinary collaboration, Ethical reasoning, Employability, which were supported with employer feedback where possible. All

the indices were assessed for their internal consistency by Cronbach Alpha reliability analysis with the $\alpha \geq 0.70$ as the desired cut-off point. The alpha scale obtained is acceptable with values between 0.74 (in FRI) and 0.89 (in GSCI).

Data Preprocessing

The data were systematically preprocessed. The responses that were not completed were excluded (24 of 1000, 97%) and any missing responses on a continuous variable were imputed with the median to maintain a large sample size without compromising the results of the data analysis. The data was coded and checked for categorical variables in special fashion to prevent any errors in the coding. No value was identified as an outlier: The interquartile ranges (IQR) method was used to detect the outlying value of the cases, any values below $Q1 - 1.5 \times IQR$ and above $Q3 + 1.5 \times IQR$ were marked and checked for data entry error but no value was excluded from the data as an outlier.

Statistical Analysis

The following analytical approach was used and each of the research questions was addressed: Descriptive statistics comprised of means, standard deviations, frequencies and percentages were used for summarizing the sample characteristics and institutional integration. Secondly, a Pearson correlation analysis was carried out to explore the associations between the composite indices and to check for possible multicollinearity issues. After that a multiple linear regression analysis was used to determine the predictors of the graduate level of Sustainability Competency with the four indices listed below being inputs. Four indices listed above were then used in a multiple linear regression analysis to identify the predictors of Sustainability Competency at the graduate level. This regression model has been defined as:

$$GSCI = \beta_0 + \beta_1 SCII + \beta_2 FRI + \beta_3 SEI + \beta_4 ISI + \epsilon$$

Linear relationship: $\epsilon = b + \beta_1 * GSCI + \beta_2 * SCII + \beta_3 * FRI + \beta_4 * SEI + \epsilon$ where "GSCI" is the Graduate Sustainability Competency Index, "SCII" is the SDG Curriculum Integration Index, "FRI" is the Faculty Readiness Index, "SEI" is the Student Engagement Index, "ISI" is the Institutional Sustainability Index, b is the intercept, and ϵ is the error term, with the regression coefficients β_1 , β_2 , β_3 , and β_4 . Standardized beta weights were used to measure (relative) strength of predictors. The model was assessed by examining the R^2 and adjusted R^2 values and to determine if there were any multicollinearity issues, variance inflation factors (VIF) were valued with < 2.5 . To assess for differences in groups (institutions with different levels of SDG integration: comprehensive, moderate, limited and between undergraduate and post-graduate students, science disciplines versus humanities disciplines), AnaVotest (one-way ANOVA) and independent sample t-tests were used. Last but not least, the hypothesized causal relationships between the study variables (institutional support, curriculum integration, faculty readiness, student engagement, and sustainability competency) were tested using Structural Equation Modeling (SEM) in AMOS. Both direct paths from each predictor to GSCI, and indirect paths via student engagement were included in the SEM. Model fit was examined with regard to Chi-square/df ratio, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA) with acceptable

fit being defined as Chi-square/df ratio ≤ 3.0 , CFI ≥ 0.95 , TLI ≥ 0.95 , and RMSEA ≤ 0.06 . All the statistical analyses were performed by SPSS 29 for descriptive and regression analysis, AMOS for SEM and R (Version 4.3) was used to ensure the visualisation of the data along with further diagnostic testing. Basic setup and management was done in Microsoft Excel. Both parametric and non-parametric methods allowed for strong inferences found depending on data type and distribution. Table 1 shows the key composite indices and the measure of reliability.

Table 1. Composite indices and their internal consistency reliability

Index	Number of items	Cronbach's Alpha
SDG Curriculum Integration Index	4	0.82
Sustainability Knowledge Score	15	0.78
Student Engagement Index	5	0.76
Faculty Readiness Index	4	0.74
Institutional Sustainability Index	4	0.85
Environmental Responsibility Score	6	0.80
Graduate Sustainability Competency Index	8	0.89

Results

Following all these data quality assurances, there was a total of 976 valid responses which were used for analysis. The results are first given in terms of the personal characteristics and background experiences of the participants, followed by results related to the outcomes of curriculum integration, observed gains from an SDG-oriented curriculum, and inferences made that have implications for predicting SDG competency. The feedback and synthesis of summarised results is the same as above from different institutions and subsequently different targets.

Participant Characteristics and SDG Familiarity

A well described subject sample helps to serve as an background for later results in analysis. The 976 valid responses were given by four types of stakeholders. The majority of participants were undergraduate students (61.8%, n=603), followed by post-graduate students (24.5%, n=239), faculty (10.7%, n=104) and academic administrators (3.0%, n=29). This distribution is the "natural" random distribution found in a higher education community, and allows for the analysis to include the perspectives of both learners and educators or institutional decision makers. To truly grasp the many layers of influence on sustainability education, a multi-stakeholder approach is necessary, given that the field of sustainability education requires top-down institutional policymaking coupled with bottom-up students' involvement and engagement in order to implement it (Franco et al., 2019). In the baseline SDG awareness assessment 79.6% (including the non-participants) said they heard about SDGs. Detailedly,

82.3% of faculty stated that they knew about the system; 77.1% and 85.4% of the undergraduate and postgraduate students stated that they knew about the system. At 89.7% the administrators demonstrated the highest. Resultantly, while the general level of awareness is high, 20.4 % of participants were not aware of these values which can be considered as an important issue because the SDGs are present in the discourse of higher education agenda all over the world (Sayed, 2015). This discovery highlights the importance of integrating SDG in the curricula and setting a base level of awareness would be required, either by doing orientation sessions or general education. This difference between the stakeholder groups is also reflected in the greater awareness of the undergraduate students about SDG in comparison to their post-graduate student or administrator colleagues which is also confirmed with the results of previous studies done in the literature (Dutta et al. 2026). Disaggregation by academic discipline of students' awareness revealed that the students' awareness had the highest rate of 88.4% in the environmental sciences group and the moderate rate of 83.7% in the social sciences group, followed by pairs of 74.2% in the engineering group and 68.5% in the humanities group, respectively. This disciplinary gap is one example of the disparate levels of exposure to SDG – the themes of sustainability are not as developed in some disciplines as in others and are not as advanced in any other. This will further strengthen the need for interdisciplinary approaches to ensure access to sustainable learning for all academic disciplines equally (Horn et al. 2023). The sample was comprised of females (54.8%), males (45.2%) aged 18 – 62 years with mean age of 23.4 years for students and 41.2 years for faculty. Students' distribution in the study area reveals a higher predominance of higher education students compared to students at primary or secondary schools, which can be seen in the distribution of the respondents (62.7% public institutions; 37.3% private institutions).

SDG Curriculum Integration Findings

Going deep into the raw data and the extent to which institutions are not only triggering awareness of the SDGs, but also bringing them into the curriculum. Based on different data sources like curriculum document analysis, faculty self reporting and student surveys, the analysis aims at triangulating the level of integration housed in the 20 participating institutions. Overall institutional integration. Several institutions have worked towards integrating SDG related learning into their programs, and a large proportion of these are doing this now. In detail, 74.8 per cent of the surveyed institutions said that they contained SDG related topics in their academic programs. This is further corroborated by recent reviews which have indicated that a greater number of universities worldwide are starting to take up SDGs in some manner in recent times, albeit at differing extents and levels of commitment (Dutta et al., 2026). The content of the SDG was found within certain programmes at various degrees of granularity as follows: 43.2 % of the programmes had SDG content included as a module or a course, 38.7 % of the programmes had themes which included content on SDG(s) in several, and 18.1 % of the programmes had SDG(s) content inserted into some introductory sessions. Many of the institutions addressed the SDG's superficially, an orientation that could be an issue for the transformative potential of ESD (Franco et al., 2019). Inclusion of sustainability topics in the curriculum for research. 69.3 % of all individual teachers reported teaching about sustainability. But when speaking with a qualitative interview it was found that the nature of this integration

was quite different. About a third of faculty (35.1%) reported occasional and event driven topical integration, which involves considering topical integration as it was related to one event during the semester, such as one lecture devoted to a topic such as climate change, or inequality. 34.2% said it was integrated early, but throughout the semester. The other 30.7% of faculty members reported that they don't use any of the sustainability content, mostly because it was hard to fit into existing curriculum, lacked discipline relevance and/or was lacking in quality or training. This aspect of faculty readiness as mediator relates to this reluctance of a considerable percentage of faculty is very prominent in the subsequent regression analysis (Owusu-Agyeman, 2021). Sustainability participation of students. The sustainable actions were also pretty positive stuff that I learnt. Success rate is found when the student population replies that they have participated in at least one project concerning sustainability during their course of studies which was confirmed through the results with 71.6% of them stating that they have participated in at least one of these projects. These ranged from initiatives that focused on campus with a recycling theme to saving energy, service learning which were service projects for a community, and interdisciplinary research projects that had a local SDG theme. The direct experience of participating in these projects indicated an increase in student's perceptions of relevance and motivates them to join careers in sustainability related fields, as revealed in focus group discussions. The relatively high participation percentage indicates that experiential learning opportunities are increasingly gaining a more prominent place in the practice of higher education in line with a pedagogical recommendation for active, problem-based learning as a method in ESD (Horn et al., 2023). Courses that run in several disciplines on which sustainability is covered. For the holistic implementation of the SDGs, one of the key elements is the courses with interdisciplinary focus on sustainability options. Of our sample, 65.4% of institutions indicate that they teach at least one course in which there are sustainability themes that pervade the disciplines, and some of these courses are called "Sustainability Science", "Global Challenges: An Interdisciplinary Perspective" or "Social and Environmental Justice". Nor was its frequency the same when integrated into all of the courses, nor was it the same with students taking all of such courses. These institutions on average added 2.3 interdisciplinary sustainability courses per academic year, suggesting that—away from the average—sustainability courses do exist, but are not yet a regular feature of courses available to all students. In addition, sustainability was listed as an integral component of students' academic programmes in only half of these programs – due to the inclusion of studying sustainability as a graduation requirement. In addition, only 22.7% of programs mandated taking at least one of the interdisciplinary sustainability courses as a graduation requirement. The findings indicate that the availability of interdisciplinary sustainability education is not fully matched with its institutionalization since most graduates are still not using interdisciplinary sustainability education as integral part of their programmes. Support and infrastructure from institutions. Eleven percent of the institutions had a dedicated team of PhD researchers focusing their work on ESD and 27.1% had established a budget for ESD-related activities, as found in the institutional sustainability index, capturing as it does the presence of a sustainability office or sustainability coordinator in the institution and an explicit institutional sustainability plan. Only 31.4% of them had worked out regular spending plans for activities outside of the project budget. Furthermore, the low funding for integration probably weakens

integration efforts to become scalable and sustainable since interpersonal meetings, and training integration faculty, require regular funding for integration curriculum development and engagement programs for both faculty and students (Gnankob et al., 2026).

Educational Outcome Improvements

To evaluate the measurable impact of SDG integration on education, the researcher compared measures before and after SDG implementation—or, for cross-sectional data, differences in perceived educational outcomes before and after SDG implementation when compared to other learning experiences that did not integrate SDG activities. Items chosen for this analysis were parts of the student questionnaire that are retrospective measures, meaning that they asked participants how their knowledge of SDGs, participation in the SDGs, thinking about sustainability, interdisciplinary learning, or effectiveness in applying their sustainability skills to their careers changed since they began the program(s) that included these elements. Student cohorts parallel items were used for faculty and administrators to determine the perceived changes over time. There appeared to be significant and consistent gains in all areas scored. The top gains identified were for domain knowledge of sustainability with gains of 28.5% over baseline. A 15 item quiz was used to measure the Sustainability Knowledge Score. The average performance for the students with explicit SDG modules was 73.6%, while the student with limited integration of SDG was 45.1%, hence, the student achieved a large knowledge gap. Also noteworthy is the improvement of sustainability knowledge, indicating that an emphasis on providing basic knowledge of the concept of sustainability is the key cognitive objective of ESD; this is related to the emphasis on fostering conceptions around the environment, society and the economy in this discipline (Wu & Shen, 2016). It can be seen that the outcome of the quiz can be compared to other research, which found it possible to achieve a high magnitude of knowledge gains for the single student if the knowledge to be acquired was contextually relevant and actively acquired by the student (Wiek et al., 2011). The involvement of students also rose considerably from previous by 24.7% The 3 key parts of the Student Engagement Index (SEI), which measure student engagement across the areas of participating in sustainability activities (projects), campus outreach and community engagement, were used to assess it. This improvement was especially seen among students who had completed interdisciplinary sustainability modules (mean engagement score = 81.2 out of 100) as against those who hadn't (mean = 56.5). Qualitative context was captured in the discussion that occurred during the focus groups; in many cases, students related how a sustainability project affects them – that they felt they had a purpose and that it relates to real-world issues, which inspires them to be more involved in their study and daily activities. This finding was quite similar to study findings that experiential learning in sustainability has a powerful effect on student engagement and affective learning outcomes (Horn et al., 2023). There was an increase in student performance on sample group to 21.6% in Critical thinking skills. The dimension was measured by providing a subjective response to the items on the Graduate Sustainability Competency Index for the ability to analyze complex problems, to consider a wide range of perspectives and to incorporate information from a range of sources. It was a notable enhance for pedagogies such as project and problem-based pedagogies. Participants in such programs frequently have said they learned to think in an iterative way about a problem with several

"right" answers, properties of a wicked problem. When participating in such programs, students frequently have reported the development of an Iterative way to reason with a problem with several "right" answers, which have properties of Wicked problems. The improvement is representative of the nature of SDGs which are not only related by domain but also overlap each other in 4 domains of environmental science, economics, sociology, ethics and political science. It is obvious that the institutions which actively operated curricula which break the boundaries of disciplines were very helpful in supporting deeper integration of various types of knowledge. This is in line with literature in support of transdisciplinary approaches in sustainability education in which problems are presented across different academic departments (Horn et al., 2023). The moderate but significant improvement (19.8%) experienced by graduate employability skills placed third on the list. Improvements were also seen within the strand on Graduate employability skills of 19.8% which was a more moderate improvement. Students and graduates (as appropriate) received an average rating on the Graduate Sustainability Competency Index for the following subscores when provided with internship feedback: Communication, Team work, Ethical Reasoning, and Adaptability. The overall increase of 19.8% suggests that integration with SDGs is motivated by a need to boost the Knowledge of sustainable Development Goals, and that this SDG integration-related knowledge has transferable skills that are also required on the labour market. The research provides a missing piece on the puzzle of the concerns of the job market and students about the linkages between sustainability education and being job ready. The data also suggest that the experiential and collaborative qualities of sustainability projects contribute to development of generic skills, like problem solving and interpersonal relations, which are sought by jobs beyond environmental and natural resource management sectors (Wiek et al., 2011). The relative smaller scale of improvement from SDG courses compared to knowledge and engagement, may be due to the fact that employability skills are more likely to be gained over longer duration and through diverse experiences, not just through SDG-related courses. But good, positive changes are there to be seen and shows the value of ESD as a career preparation. Overall, the positive impact on educational outcomes mentioned constitute robust evidence related to the measurability of the systematic integration of SDGs in a multitude of academic and personal skills. The improvements in knowledge and interdisciplinary learning were the highest rated in percentage; limited but sufficient improvements in critical thinking and employability. The commonalities found throughout all five dimensions indicate that the benefits do not just impact one cognitive area and are more broadly a child's enhancement and capability boost. The pattern is in line with the student learning outcomes (SLOs) of sustainable development as the goal of learning, which contains cognitive, affective, and behavioural learning outcomes, all can be valuable and worthwhile (Wu & Shen, 2016). We investigate them in the next section, discussing the regression analysis that sheds light on the conditions that lead to strong sustainability competency.

Predictors of Sustainability Competency (Regression)

To find what factors contribute most to the Masteries of Sustainability competency, dependant variable Graduate Sustainable Competency Index (GSCI) was fed into Multiple linear regression analysis with the other factors fed into it simultaneously as independent variables.

The SDG Curriculum Integration Index (SDG-Curriculum-Index) (SCII), Faculty Readiness Index (Faculty-Readiness-Index (FRI)) and Student Engagement Index (Student-Engagement-Index (SEI)) and Institutional Sustainability Index (Institutional-Sustainability-Index (ISI)) were taken as independent variables. This methodology allowed for systematic examination of the different factors' relative contribution while accounting for other factors in a way that provided a deeper examination of how SDG integration is related to Students' outcomes (Serafini et al., 2022). The overall regression model was significant, $F(4,971)=702.38$, $p<0.001$, and accounted for a large amount of variance in GSCI, as determined by R^2 (0.742). We were able to account for a large effect size (74.2%) of the difference in sustainability competency between the students when using a combination of the predictors. The $R^2 = 0.741$ showed that the model does not have any other variables that impact the model but are not statistically significant. Also, variance inflation Factor (VIF) scores for various predictors ranged between 1.42 and 1.89, indicating low level and in general no VIF was close to the 5 cut-off level, therefore suggesting no detrimental multicollinearity and resulting in no unreliable coefficient values. SDG Curriculum Integration proved to be the strongest and most significant predictor with the standardized beta coefficient of $\beta=0.45$ ($t=14.27$, $p<0.001$), out of the four predictors. This finding highlights the importance of curriculum design to a curriculum's sustainability outcomes. This coefficient tells us that, other things being equal, an increase of one standard deviation in the SCII will be accompanied by an increase of 0.45 std dev in the GSCI. The outcome is hence in line with theoretical ideas suggesting that a stand-alone integration of SDGs in the educational program creates background knowledge structures that facilitate the development of competences (Wiek et al., 2011). It is also supported by empirical research that substantiates that key curriculum areas can be integrated in reading and students learning outcomes will benefit (Wu & Shen, 2016). The second most influential predictor was Faculty Readiness with standardized $\beta=0.38$ ($t=12.04$, $p<0.001$). This form of assertiveness in speaking directly to a direct impact indicates high competency development of students as a result of the faculty's knowledge of the SDGs, their engagement in SDGs faculty development and faculty confidence in introducing SDGs to their students. The discovery aligns with the existing research that focusing on the central role of faculty in the implementation of ESD, even the best curricula can't succeed if faculty is unable to execute them successfully (Owusu-Agyeman, 2021). Relatively high beta values suggest that faculty readiness was not just a “facilitating” factor, rather it is a predictive and important factor in students' success. The interaction with material of the students was also found to be significantly affecting the students, with a β of 0.33 ($t=10.41$, $p<0.001$). The results of the outcome clearly demonstrates the value of active involvement in sustainability projects and in campus and community activities was significant to students. The coefficient of engagement implies a change of 0.33 in Sustainability competency for each change of 1 SD in engagement. This is in line with the experiential theory where they proposed that promoting critical learning occurs when students understand how theory and knowledge can be applied to real-world issues or problems (Horn et al., 2023). It also revealed that the participants did not only need to focus on content of the curriculum, but that there should be spaces to engage both in co-curriculum and in extra-curriculum activities. However, the standardized β value of institutional sustainability support was relatively small but significant (0.29; $t = 3.12$; $p = 0.002$). Favorable

institutional policies and adequate resources, in addition to an institutional sustainability office, create an environment where integrating sustainability into the curriculum and preparedness of faculty is possible. This result may be interpreted to indicate that institutional support to curriculum integration and teacher readiness may be indirect since the teachers do not involve themselves directly in teaching, but are involved in creating arrangements that can facilitate effective teaching and learning (Gnankob et al., 2026). Its status as a significance is actually a mark of the importance of a supportive system which pours down from top to make ESD a success. The overall level of explanatory power of the model ($R^2=0.742$) shows that the four predictors explain the most of the variance in sustainability competency. This discovery supports the multi-level perspective of educational change where a diverse array of action at the curriculum, faculty, student and institutional levels is required for effective ESD. The relative weights of the weight factors, the curriculum integration, faculty preparedness, the students' preparedness and support from institutions, clearly suggest the relative ranking for policymakers and teachers for allocating resources. Interestingly, when combined the standardized betas suggest they have a much greater impact than the two other themes (a curriculum and faculty are required for each), which would suggest that both should be the focus of interventions. The regression results are also applied in the creation of professional development activities. There was high effect of faculty readiness, suggesting that efforts in faculty training around sustainability content and pedagogies are likely to have high pay-off in student outcomes. Likewise, the importance attached to student engagement encourages institutions to encourage and support student involvement in sustainability-related activities, in both the formal and co-curricular aspects. Moderate beta for institutional support, seems to have the highest impact on those areas of curriculum design / faculty capacity, but not when it is seen working independently of those other areas of support.

Correlation and SEM Analysis

Next, a Pearson correlation analysis was conducted to examine the interstructural relationships among the constructs and Structural Equation Modeling (SEM) was conducted to test the hypothesized causal pathway and interstructural relationships among the constructs of institutional support, curriculum integration, faculty readiness, student engagement, and sustainability competency. This PCA feature has positive attributes, as one can gain more insight from the possible interplay of the different phenomena considered in the higher-education sector in order to reach sustainability outcomes than with the mere associations / relationships. From Pearson correlation analysis, being involved in SDG integration with curriculum ($r=0.82$, $p<0.001$) positively associated with students competence in sustainability. This finding does not contradict that of the previous regression, finding a positive correlation between the level of systematic embedding of sustainability knowledge in academic programmes and graduates' knowledge of sustainability, with $r = 0.76$ and $p < 0.001$. In addition, the correlations between each pair of the composite indexes were as expected positive and were significant. Specifically, correlation between SDG Curriculum Integration Index and Faculty Readiness Index ($r=0.61$, $p<0.001$) and around the SDG Curriculum Integration Index & institutional Sustainability Index ($r=0.59$, $p<0.001$) were found to be moderate. This indicated that there was a positive relationship between SDG Curriculum Integration Index

with the Faculty Readiness Index and the Institutional Sustainability Index respectively. Positive correlations were found between the use of Sustainable curriculum integration and Student Engagement Index ($r = 0.54$ for curriculum integration and $r = 0.52$ for faculty readiness, both were $p < 0.001$), indicating the relationships between students' student engagement in sustainability activities and institutional and pedagogical inputs. The correlations expected indicate the mutual dependence of the different factors of sustainability competency development (Wu & Shen, 2016). This complexity of the relationships prompted the adoption of SEM for developing a more complicated model; that is, the institutional support and curriculum integration antecedents of faculty readiness and student engagement, which in turn directly influences the level of staff competence in sustainability. Four latent variables were identified for the SEM model: Faculty Readiness (measured by the Index of Faculty Readiness), Student Engagement (measured by the Student Engagement Index), Curriculum Integration (measured by the SDG Curriculum Integration Index) were identified as latent variables and Institutional Support (measured by the Index of Institutional Sustainability) was identified as Goal of the Graduate Sustainability Competency Index, the outcome variable. Direct paths (solid arrows) were seen between each predictor and outcome, while dotted arrows and solid arrows were for direct and indirect paths, respectively, links the Institutional Support to the Faculty Readiness, and the Curriculum Integration to the Student Engagement. There were no issues with the SEM fit, with all prespecified criteria for good fit having been met. The model fit was good according to the Mahalan-Ward Statistic (Chi-square-CDF), which was 2.09 and well below the standard of 3.0. CFI = 0.97, the Tucker-Lewis Index (TLI) = 0.96; both values are greater than the recommended value of 0.95. The Root Mean Square Error of Approximation (RMSEA) was 0.044 indicating good fit ($RMSEA < 0.06$). As the results in all of the indices of fit revealed, there is good support for the hypothesized structural model shape, and it can be assumed that the proposed causal paths are valid (Wals & Benavot, 2017). The RMSEA is 0.044, which is quite close suggesting the model does not need major changes to close up the gap between the model-generated and observed data. The direct path coefficients of the SEM model support and extend the results of the regression results. In the direct pathway, the standardized regression coefficient (β) in the regression model: Curriculum Integration-Sustainability Competency was 0.42 ($p < 0.001$); and 0.45 ($p < 0.001$) in the direct pathway. The direct path from Faculty Readiness to Sustainability Competency also was important ($\beta = 0.35$, $p < 0.001$), underscoring the important link between faculty preparedness and sustainability competency. Interestingly, the SEM model also showed an indirect effect of Curriculum Integration on Sustainability Competency via Faculty Raise, ($\beta = 0.18$, $p < 0.001$), suggesting the improvement of curriculum designs not only directly helps the students but also improve faculty capacity which further contributes to an improvement in students. This is an indirect pathway, which shows that the investment of personnel by the faculty in developing curriculum can influence faculty professional development and thereby create a virtuous circle of enhancement (Owusu-Agyeman, 2021). Likewise, the indirect pathway from Institutional Support to Sustainability Competency via Faculty Readiness was moderately strong ($\beta = 0.13$, $p = 0.004$), indicating that the impact of institutional-level policies and resources on faculty readiness is a key pathway that leads to sustainability competency and not the student directly.

This offers further comprehension of the smaller direct impact of the ISI reported from the regression analysis, and the indirect impact of the ISI.

Table 2. SEM path coefficients and model fit indices

Path	Standardized Coefficient (β)	p-value
Curriculum Integration → Sustainability Competency	0.42	< 0.001
Faculty Readiness → Sustainability Competency	0.35	< 0.001
Student Engagement → Sustainability Competency	0.30	< 0.001
Institutional Support → Sustainability Competency	0.18	0.012
Curriculum Integration → Faculty Readiness	0.43	< 0.001
Curriculum Integration → Student Engagement	0.32	< 0.001
Institutional Support → Faculty Readiness	0.37	< 0.001
Institutional Support → Student Engagement	0.21	0.008
Model Fit Indices	Value	Criterion
Chi-square/df	2.09	≤ 3.0
CFI	0.97	≥ 0.95
TLI	0.96	≥ 0.95
RMSEA	0.044	≤ 0.06

The findings that there are associations between level of curriculum integration and sustainability competencies as well as a strong SEM model fit, provide strong evidence that supports the central hypothesis of this research: systematic incorporation of SDG in the curriculum of higher education institutions makes a significant contribution in the development of sustainability competencies of higher education graduates. This result is corroborated by the SEM analysis result which reported that the interaction and development between institutional support and curriculum design in the main components as faculty preparedness and student engagement were found in several ways. integration to provide further evidence on the benefits of implementing SDG comprehensively.

Comparative Findings

To further strengthen the empirical relationship between SDG integration and educational outcomes the 20 institutions that constituted the sample were further divided into two groups: the Top quartile and the Bottom quartile institutions (based on the SDG Curriculum Integration Index scores). Institutions had their scores sorted into quartiles – those in the bottom quartile were classified as having limited integration and those in the top quartile as comprehensive SDG-focused curricula. This dichotomous classification allowed for a direct comparison of the principle educational outcome measures and was a very good illustration of the practical size of the integration effect. This study indicated positive and significant difference for institutions that have a more comprehensive approach in integrating SDGs in all dimensions measured in the methodology used in the composite indices. The pupil who participated in an institution that integrated the most SDGs on a pedagogical level achieved an average score on the Sustainability Knowledge Score which was 28.5% more than the pupils who participated in an institution that integrated the least SDGs on a pedagogical level. comprehensive integration group as well as the 24.7% increase from the limited integration group. The finding makes a strong link between an active, participatory approach to learning and to research and inquiry and a strong SDG course. Among the findings is that a well-developed SDG curriculum fosters learning and enquiry through actively involving learners in seeking and engaging in projects related to sustainability issues both within and beyond the context of the formal curriculum. The gap amount refers to 24.7% that can be interpreted as the middle level of spillover effect on co-curriculum through curriculum integration that impacts the culture of the campus, which in turn fosters students' active involvement. The particular result that was of concern was the student's Environmental Responsibility Score which, at the comprehensive level, came out to be 22.9% more. Self-reported pro-environmental attitudes and behaviour (e.g., promoting environmental justice, recycling, energy saving). The affective and behavioral aspects of sustainability – the interest students demonstrate in sustainability and the action they take as result – also are positively influenced, as reflected in a 22.9% advantage. This aligns with the broader learning outcomes of the ESD that focuses on the change of attitude and disposition (Wu & Shen, 2016) as this is beyond thinking. Comprehensive integrated: Critical thinking skills got an advantage of 21.6%. The following items from the Graduate Sustainability Competency Index were used for this assessment: Words of complex problems, review and critique of arguments coming from multiple sources, and informed evidence used to build coherent arguments. Based on SDG goals, the improvement of 21.6% proves that problem-based and interdisciplinary curricula helps to develop higher order thinking skills more effectively. The 'trade in trade-offs' and uncertainties that learners are expected to deal with inherently in sustainable problems, as described in the theory literature, directly contributes to the development of the learner's capacities of critical reasoning (Wals & Benavot, 2017). Finally, the graduate employability competencies (in the Graduate Sustainability Competency Index) were 19.8% higher in the comprehensive integration group. This more moderate but nevertheless real difference suggests that rather than working on transferable skills and attributes of employability, sustainability education might be more effective in fostering sustainability-specific skills. It is striking, however, that the difference is 19.8 %; clearly, there seems to be a correlation between the employer's willingness to pay attention to creative thinking, a system-to-activity perspective, and ethical considerations, among others skills

fostered by the SDG education as well as cooperative skills (Wiek et al., 2011). The means and the percentage change on the two groups of institutions for the various outcome measurements are presented in Table 3.

Table 3. Comparative educational outcomes by level of SDG curriculum integration

Outcome Measure	Comprehensive Integration Mean (SD)	Limited Integration Mean (SD)	Percentage Difference	<i>p</i> -value
Sustainability Knowledge Score	74.1 (12.4)	45.6 (15.3)	+28.5%	< 0.001
Student Engagement Index	81.2 (10.8)	56.5 (14.2)	+24.7%	< 0.001
Environmental Responsibility Score	78.3 (11.5)	55.4 (13.6)	+22.9%	< 0.001
Critical Thinking Score	72.8 (12.1)	51.2 (15.8)	+21.6%	< 0.001
Graduate Employability Competency Index	73.9 (10.4)	54.1 (13.2)	+19.8%	< 0.001

This gradient of growing sustainability knowledge-levels and the significant but lower increase in employability-competencies suggests a cascading effect of higher knowledge resulting in higher skills; the result pattern supports this idea. The regularity of all five differences points strongly to the results that comprehensive SDG integration can be multidimensional and beyond just content achievement and content engagement, includes attitude and transferable skills. When combined with the regression and SEM results, it can be argued that systematic curriculum reform is a potent tool to improve the quality and relevance of Higher Education in the context of sustainability issues in the world (Serafini et al., 2022).

Discussion

In the multi-institutional study, the interplay of co-development between SDGs and the curriculum of Higher Education provide useful insights into the multi-faceted understanding of 'integration' as a tool to contribute to the development of graduate competences. The integration of SDGs in Higher Education is a goad for developing graduate competencies—conclusion of a multi-institutional study. Strong predictive power from curriculum integration to their peers' readiness to become teachers as seen from the regression model and the SEM paths supports the multi-level framework to understand SE on a theoretical level. Remarkably, the SEM analysis puts forward a systemic comprehension of the effect of institutional support on student outcomes. Namely, the evidence shows that institutional support is more likely to be experienced and contributes to student outcomes indirectly (through an increase in faculty readiness). The result of this study contributed to a deeper understanding of the models which dominate up to now (Gnankob et al., 2026) that suggest that institutions are variables separated from each other, as all the factors that make up an institution have to be channeled through

faculty's human capital, and have to be transferred through willing students to be engaged in the process of teaching and learning. The indirect effect between curriculum and competency, through faculty readiness, also notes a symbiotic relationship, as a school's investment in curriculum reform also helps to support faculty's capacity to engage in discourse and development. The relationship between the farmers and the under-privileged milk wholesaler has been speculated on, in the past (Owusu-Agyeman, 2021), but seldom been divided experientially at this level. With these results and practical implications there will be an action item for consideration by policymakers, institutional leaders and educators. First, based on the SDG Curriculum Integration Index as a predictor, the main thrust of any ESD strategy should be curriculum reform ($\beta=0.45$). There is a need to not only provide individual training courses and out-of-classroom experiences, but to establish structures in which to integrate SDG content into the main degree programs, in such a way that an educational element focused on sustainability is offered for all students, irrespective of topic. The units of sustainable infrastructure, or the concepts of a circular economy, for example, can be taught within Engineering programs, while in Humanities the concern over social justice and ethical questions around goals of the global economy may be addressed. Second, the impact of Faculty Readiness on the dependent variable was significant and high ($\beta=0.38$) which means faculty development programs are to be invested concurrently. It is important that Institutions organize SDGs focused training workshops, not merely as a standard SDGs awareness but to apply active learning teaching pedagogies that are particularly effective in developing capacity on how to think critically and understand and build interdisciplinary skills and competencies, which include project-based learning and problem-based learning. Moreover, curricular development was significant ($\beta = 0.33$), suggesting that curriculum development should include mandatory capstone projects or opportunities for learning through the community – where students are engaged in the real world and can work collaboratively in teams to solve issues facing sustainability. Policymakers could also require accreditation or funding that would tie in with including such experiential elements, which would give a structural incentive to deeper and more extensive integration. This increase in sustainability knowledge (28.5%) and increase in participation in comprehensive-integration institutions (24.7%) provides a good evidence-based foundation. However, it is important to recognize some of the caveats that call into question the meaning of these findings. The disadvantages of a cross sectional research design are inconclusive cause and effect conclusions and in the SEM model there are presumed causal arrows, but the data collected was at one single point in time. A selection effect may occur there if more competent and/or motivated institutions implement SDG curricula as they are more likely to participate and these may be more strongly correlated than others. Greater confidence in establishment of causality would require longitudinal studies that would compare cohorts of students before and after curriculum change. The relatively high level of SDG awareness (79.6%) as well as the high percentage of public institutions (62.7%), which might be of limited applicability in less institutionalized SDG use in the national education agenda, such as other countries, are certainly of relevance for the institutional characteristics. Therefore some future research lines emerge naturally from this work, due to the aforementioned restrictions. Furthermore, there is a need for a multi-country longitudinal study to track cohorts across the academic path, including their subsequent careers in the workplace, and measure the

long-term impact of integrating SDGs in career outcomes and the sustainability practices they bring to their career. A quasi-experimental approach, involving the matched comparison of institutions engaging in varying extents of curriculum reform would be a way to improve causal inferences in such research. Future studies should also investigate the pathways to attain faculty readiness to teach courses on sustainability in relation to their field of instruction, such as how best to provide faculty with professional development to do this. These can be also be qualitative in terms of the case study approach. Relatively smaller effect of institutional support indicates that the quality and type of institutional support is more important than just its existence. Another under-researched area is on the effects of disciplinary culture on the relationship between the curriculum and outcomes.

Conclusion

In sum, this research confirms that systematic incorporation of SDGs into HE curriculum is associated with measurable impacts on students' competencies, engagement and learning gains regarding sustainability. We tested our multi-level model with an empirical analysis with primary data collected from a sample of 20 institutions and 976 participants and found strong evidence for high effectiveness of both curriculum integration (x1) and faculty readiness (x2) as the most powerful factors influencing sustainability competency outcomes; they accounted for 74.2% of the variance in V7 outcomes. Analysis of the SEM results also revealed that institutional support is mostly indirect in the form of faculty and students' capacity and participation but not directly related to learning. These are not simply descriptions of the implementation of ESD but offer a statistically sophisticated causal model of how institutional structure, institutional curricula, and human capital are mutually interchangeable and how one causes educational change. The significance and effect over the comparative advantage of comprehensive-integration institutions in where the sustainability knowledge increases in 28,5% and the students' engagement increases in 24,7%, gives a material correlation of the possibilities of sustainability education, which are enormous and not just one, challenging the thinking of less rigorousness and less employment opportunities.

Future research should be longitudinal and multi-country, allowing for the tracking of cohorts through their school years and into their careers, in order to be able to conclude causality and the impact over the long-term on sustainability practices in the workplace. The strong influence of faculty readiness also highlights an imperative to encourage qualitative research on what professional development might work best to help faculty members in each discipline become ready to teach about sustainability in their classrooms. The statistically significant differences we found in SDG awareness also show that there is an urgency to find pedagogical approaches that can help overcome resistance to SDGs with the aim of bringing about equitable access to sustainability education. Finally, actions at several layers within the institution have to be coordinated and taken in parallel to achieve the best possible outcomes in boosting graduates' readiness to address world challenges, in particular these two factors – curriculum and faculty capacity – being central components.

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