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# Incorporating vertical collaboration to address sustainable development goals: the Monarch Route Project

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Higher Education Institutions in their societal transformative role need to effectively integrate the UN's Sustainable Development Goals (SDGs) and the 2030 Agenda into their curricula. Our goal is to inspire and trigger the discussion in the academic community on learning environments for education for sustainable development. We report *The Monarch Route* (MRP), a project conducted at *Tecnológico de Monterrey* and awarded with the 2018 *Premios Latinoamerica Verde*. Engaging all the students enrolled in the different semesters of the Sustainable Development Engineering (SDE) program, it adopted a research-based learning methodology, which is highly flexible at setting the final deliverables and due dates. It also implemented horizontal (intra-class), vertical (inter-class), and interdisciplinary (multiple courses) student collaboration. In partnership with a non-governmental organization, the MRP aimed to reverse the extinction threat to the monarch butterfly while benefiting rural communities along the butterfly's migratory route. With an exploratory action research approach, we analyzed the data gathered 2 months after the end of the courses: A survey on the perceived learning outcomes (87% confidence level) and a letter for future classes sharing their experience on the MRP, both optional. The analysis included a mixed methodology, i.e., quantitative and qualitative, including text mining, which evidenced that the participants strengthened both, transverse competences (collaboration, citizenship, communication, and critical thinking) and disciplinary competences (subject matter). The MRP is innovative for its dynamic structure that resembles the interconnectedness of real professional practice, scientific research, and environmental conservation efforts. In addition to the disciplinary application and societal relevance, the instructional design of MRP reflects that contributing to 2030 Agenda requires a multi-faceted approach, involving educational institutions, community partnerships, and interdisciplinary collaboration. Traditional education no longer fulfills our needs to face environmental challenges; academics, institutions, and governments are encouraged to implement policies and strategies to educate for a sustainable and better future for humanity and the planet.

## KEYWORDS

vertically integrated project, research-based learning, sustainable development goals in higher education, sustainability competence, sustainability learning, education for 2030 Agenda, higher education

# 1 Introduction

The urgency needed to accelerate progress toward the Sustainable Development Goals (SDGs) (UNESCO, 2015) is undeniable. Global Sustainable Development Report 2023 states that the required transformations are possible and inevitable and invites us to embrace them. Since the Global Sustainable Development Report was published in 2019, challenges have multiplied and intensified, causing the world to fall short of achieving the SDGs. Despite the progress made in areas such as the deployment of zero carbon technologies, several factors, such as the ongoing Ukraine–Russia conflict, inflation, cost-of-living crisis, and environmental, economic, and societal distress, have disrupted overall progress toward the 2030 Agenda and the SDGs (United Nations, 2023).

Our future relies on multiple securities, including geopolitical, energy, climate, water, food, and social security. Thus, strategies to embrace transformations should uphold the principles of solidarity, equity, and well-being, harmoniously with nature. As the world rapidly evolves, there is an increased urgency to build momentum, solidify solidarity, and speed up progress on the SDGs (United Nations, 2023).

The scope of Sustainable Development expands beyond the environmental aspect. It includes economic, social, and political dimensions well identified by the wide variety of topics included in the SDGs. In this regard, achieving the 2030 Agenda demands the collaboration of different societal entities, including governments, non-governmental organizations (NGOs), civil society, and educational institutions (United Nations, 2023). Education is, in fact, a fundamental component represented in SDG 4, quality education (UNESCO, 2015). Then, far from a mere environmental education, educational institutions must integrate sustainability into all levels and forms of education, influencing curriculum design, teaching methodologies, learning environment, and the entire educational experience (UNESCO and UNESCO Global Independent Expert Group on the Universities and the 2030 Agenda, 2022).

Higher education institutions (HEIs) should lead society and invest time and resources as effectively as possible, taking a systematic and strategic approach to drive and accelerate transformations. HEIs must design learning environments to build sustainability concepts and practices from the whole curricula (UNESCO and UNESCO Global Independent Expert Group on the Universities and the 2030 Agenda, 2022). Including real-world contexts and societal impacts in those environments will encourage intellectual cooperation and cross-disciplinary collaborations. This cooperation can accelerate the generation and sharing of knowledge, cultivate understanding of the SDGs, and inspire innovation in strategies for sustainable development (UNESCO and UNESCO Global Independent Expert Group on the Universities and the 2030 Agenda, 2022). Additionally, by integrating SDG-related research and teaching into their curricula, HEIs can shape students with the necessary skills and knowledge to become citizens who contribute effectively to sustainable development in their future career and life (Mazur and Walczyna, 2022; Acevedo-Duque et al., 2023).

The *Premios Latinoamerica Verde* (Green Latin America Awards) is one of the most significant environmental awards in the Latin America region. Launched in 2013 in Ecuador, the awards aim to recognize, promote, and encourage best practices and innovative

projects related to environmental sustainability and social responsibility in Latin American and Caribbean countries. The awards offer a platform for the sharing of knowledge and ideas, promoting regional integration and cooperation toward a common goal: the development of a more sustainable and environmentally friendly Latin America. This is the way to encourage and motivate individuals, communities, and organizations to consider and act upon the environmental challenges facing the region (Premios Verdes Team, 2023).

The Monarch Route (MRP) was a university project awarded with the *Premios Latinoamerica Verde* in 2018 (Latinoamerica Verde, 2018). MRP followed a research-based learning (RBL) methodology and implemented a vertical collaboration with the entire student body enrolled in the Sustainable Development Engineering program of the Tecnológico de Monterrey, Campus Santa Fe, in 2017. It was conducted in conjunction with the *Fundación Nacional para la Conservación del Hábitat Boscoso de la Mariposa Monarca*, A.C. (FUNACOMM). It aims to stop and reverse the disappearance of the monarch butterfly by focusing on the development of agroecological gardens along its migratory route in Mexican territory. This was done to increase the availability of food and rest of the areas that directly aid in the conservation of the species. The project heavily relies on the use of technologies for monitoring and promoting environmental education within the communities located along the butterfly's migratory route.

Since the year 2000, various researchers and institutions interested in the subjects that have proposed different strategies for the conservation of the species, such as expanding the protection zone including conservation incentives (Anderson and Brower, 1996; Andrade and Rhodes, 2012). However, by 2017, the population of butterflies arriving in Mexico had decreased by 95% (Agrawal, 2017). The main threats have been identified as follows: deforestation due to illegal logging in various areas of the migratory route and the reserves located in Mexico; reduction in breeding areas due to land use changes in some places; decrease in the primary food source, known as *Asclepias* or *algodoncillo*, for the butterfly larvae due to the use of herbicides; and finally, climate change (Brower et al., 2002, 2012).

From its instructional design, the MRP aimed to impact several SDGs and provide students with firsthand experience in activities focused on achieving 2030 Agenda and the SDGs in Mexico. The MRP sought to give undergraduate students the opportunity to understand, design, and implement actions in support of the SDGs. It aimed to guide them on their path to becoming global citizens, enhancing their understanding of global and local problems, and inspiring them to continue implementing actions for a more sustainable future.

The goal of this study is to trigger the discussion among the academic community on instructional design and learning environments that actively contribute to achieving the 2030 Agenda. We present an instructional practice implemented in the Monarch Route Project MRP, an award-winning university initiative that engaged students from the sustainable engineering program in a research-based learning experience. We describe an educational setting involving interdisciplinary cooperation, incorporating both horizontal (peer-to-peer, same classes) and vertical (students from different classes) collaborative work, and addressing environmental

and productive challenges for a Mexican community. By analyzing the framework of the MRP, activities, and the perceptions of the participants, the current study highlights the effective strategies and pedagogical practices that contributed to the success of the project in fostering real-world impact and increasing the students' competences for a sustainable future.

## 2 Pedagogical framework

### 2.1 Education for sustainability

Ecological disasters highlight that the education and traditional programs we currently offer are not up to the social and environmental challenges we face in this era (Frisk and Larson, 2011; Fernández, 2023). There is an urgent need to adopt measures to address the increasing environmental risks of this era; our main problem is not the lack of solutions but the perspective from which current crises are gestated and understood (Fernández, 2023). We assume that knowledge automatically leads to action; however, we must go beyond ecological knowledge when educating for true transformation (Frisk and Larson, 2011; UNESCO and UNESCO Global Independent Expert Group on the Universities and the 2030 Agenda, 2022).

Education for and of the future must avoid depriving millions of species of their right to flourish, impoverishing future generations (Kopnina, 2020); such education for sustainability must be imparted now. Throughout history, education has played a crucial role in solving social problems, but in the Anthropocene, it is not only responsible for disseminating information but also for developing sustainability competence in students, reshaping their cognitive paradigms (Fernández, 2023). Ecopedagogy, ecocentric and indigenous learning, is a response to the educational needs of the Anthropocene (Kopnina, 2020).

In the Anthropocene, education must develop effective approaches for transformative actions, which implies that alternative ways of competence strengthening are essential for effectively educating for sustainability (Frisk and Larson, 2011; UNESCO and UNESCO Global Independent Expert Group on the Universities and the 2030 Agenda, 2022). A critical and enhanced education for sustainability involves developing deep competences, as Wamsler (2020) asserts that it is an internal transformation. This explains the interconnection between education for sustainability and human development (Agbedahin, 2019) and the urgent need for interdisciplinary, systemic, and comprehensive pedagogical approaches (Wamsler, 2020). We cannot face the Anthropocene with the same educational, social, and economic tools we applied in the preceding era.

### 2.2 Research-based learning

The current study assumes that the transformative actions required in Education for Sustainability are attainable through research-based learning (RBL). It is a teaching and learning strategy that takes the student from traditional passive learning to a leading role in what is to come (Boyer Commission on Educating Undergraduates in the Research University, 1998). The student goes from being a receiver of information to becoming a promoter and

producer of knowledge. This change takes place gradually over time because RBL allows the student to learn by means of discovery until they can generate and transfer knowledge by themselves.

Among the competences developed by RBL, we can identify open-mindedness, creative and critical thinking, research strategies, information analysis, and information source valuation. To obtain these, the instructor must design activities that allow the student to identify, analyze, and solve problems (Boyer Commission on Educating Undergraduates in the Research University, 1998). In addition, the relationship between research and teaching generates immediate learning benefits in students due to their mutual complementarity (Nehme, 2012; López-Gómez, 2015).

According to the Self-Determination Theory (Ryan and Deci, 2000), there are four RBL strategies that foster student motivation as follows:

- **Choice:** Empowering students with the opportunity to make decisions enhances their ownership of the learning process. Choice has been linked to increased effort, improved performance quality, and a higher likelihood of project completion, making it a key component of successful learning.
- **Challenge:** Engaging students with demanding tasks, even those that push beyond their perceived abilities, can heighten their involvement. However, this strategy requires careful management. A challenge with an adequate level of complexity encourages students and overcoming it can enhance their sense of competence and satisfaction. Conversely, an excessively difficult or unattainable challenge may discourage student interest.
- **Collaboration:** Humans are inherently social, and collaborative work can stimulate learning. Through interaction, students can learn by discussing, clarifying ideas, and receiving feedback, thereby collectively constructing knowledge. Collaboration is most effective when students undertake parallel or complementary activities that they perceive as relevant to the situation.
- **Control:** Encouraging students to manage their own learning can increase their engagement in the process. Self-directed learners tend to be more receptive and honest about their work, performance, and abilities. They are often more willing to acknowledge their mistakes and demonstrate greater resilience in the face of failure.

### 2.3 Vertical collaboration

For graduates, vertical collaboration is a competence as crucial as horizontal and interdisciplinary collaboration. Vertical learning is characterized as an educational experience that fosters a community of learners from diverse academic levels—ranging from bachelor's to master's degree students. This community-based learning model encourages peer feedback, learning from mentors and industry liaisons and sharing of thematic interests (Gómez Puente and Doulougeri, 2022).

A related concept, known as Vertically Integrated Projects (VIP), is a multidisciplinary, multi-semester, team-based learning structure that engages students in hands-on projects, which are applicable to

various contexts (Coyle et al., 2006; Sonnenberg-Klein and Coyle, 2022). VIP teams are composed of students from diverse academic disciplines and levels, from sophomores to PhD candidates, and these teams work on long-term projects, with undergraduate students having the opportunity to participate in a project for multiple semesters (Coyle et al., 2006).

VIP fosters the development of several key skills, including teamwork, interpersonal communication, public speaking, personal responsibility, time management, and problem-solving (Coyle et al., 2006; Morini et al., 2022). Coyle et al. (2006) underscore the significance of coherence, skill-based labor distribution, team-based problem-solving, successful collaboration, and the ability to work with individuals of diverse backgrounds and styles.

Notably, the VIP model emphasizes personal responsibility as a crucial complement to teamwork. Students in VIP settings have recognized the value of taking initiative, exceeding expectations, exhibiting self-discipline, and demonstrating responsibility. This finding is particularly significant as it addresses the limitations often associated with team-based instruction, as documented in the literature (Coyle et al., 2006).

### 3 Learning environment

The Monarch Route Project (MRP) was proposed as an innovative research-based learning strategy. Its uniqueness lies in its interdisciplinarity, horizontally and vertically integrated collaboration, social relevance, alignment with 2030 Agenda, and partnership with a non-governmental organization (NGO).

Initially, the MRP was chosen due to the relevance of its subject matter, making it a large enough project which allowed for the participation of different classes, courses, and semesters. Due to the scope of the MRP, it included several different areas of each participating class and course curricula, making it a relevant part of the students' graded academic work within their courses.

The MRP encouraged interdisciplinary collaboration, mirroring real-world work environments, where professionals from diverse fields and expertise collaborate to solve complex problems. The project involved 181 Sustainable Development Engineering students from Tecnológico de Monterrey, Campus Santa Fe. These students, from various classes and courses, collaborated closely during the August–December 2017 and January–May 2018 periods. Throughout the year-long project, the students worked in teams within their courses (horizontal) and, at the same time, in collaboration with other teams in different courses (interdisciplinary) and even different classes (vertical).

In an initial session, we introduced the project to all participants and assigned objectives based on their academic years (i.e., freshmen, sophomores, juniors, and seniors), informing the students of the weight of the project in their final grade.

The instructional design of the MRP focused on societal relevance and real-world impact. The undergraduates collaborated with FUNACOMM, an NGO dedicated to conserving the monarch butterfly, and several rural communities along the butterfly's migration route. This partnership brought real-world impact and applications to the MRP.

The project was built on three main objectives, aimed to address specific SDG:

- Developing a technological platform for easy monitoring of the species and the implementation of conservation tools (SDG 13: Climate action and SDG 15: Life on Land).
- Creating a teaching resource to raise environmental awareness among communities along the butterfly's route and contribute to broader conservation efforts (SDG 4: Quality Education, SDG 15: Life on Land and SDG 17: Partnerships for the Goals).
- Identifying the Mexican states most affected by conservation issues related to the monarch butterfly and establishing a network of agroecological gardens in these areas. (SDG 2: Zero Hunger, SDG 8: Decent Work and Economic Growth, SDG 12: Responsible Consumption and Production and SDG 15).

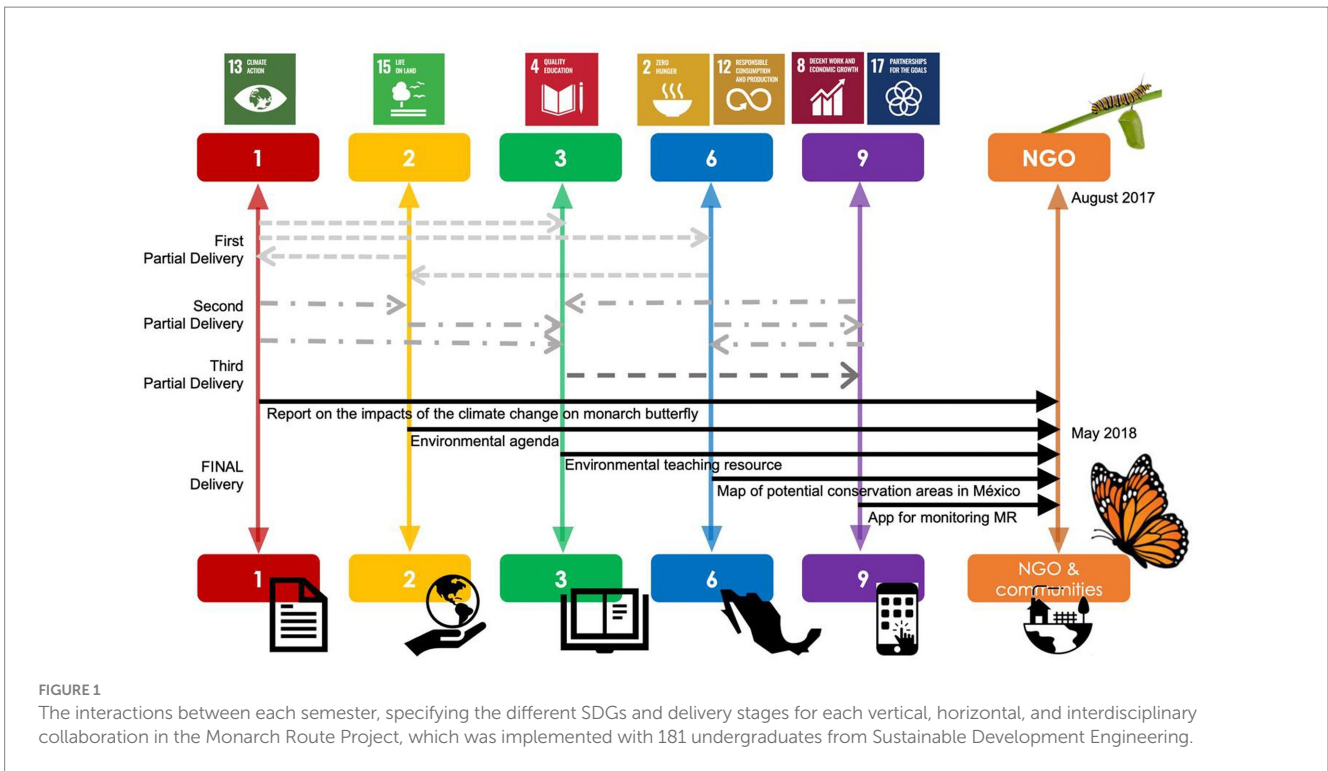
Despite being a requirement for the courses' final grade, the students were responsible for setting their own project deliverables and deadlines, with the purpose of fostering their project management skills and self-directed learning. The collaboration interactions and their relevance to each Sustainable Development Goal (SDG) are presented in Figure 1. This figure describes the collaboration among students of each class and course. The deadlines for partial and final project submissions were determined in agreement among teams from different classes and courses. Therefore, the details in the implementation and evaluation of this RBL instructional design will vary, depending on the issue to be addressed, the objectives of the project, the disciplines involved, the societal partnership (NGO), and the student's approach to achieve them.

### 4 Results

The instructional design of the Monarch Route Project (MRP) aimed to foster interdisciplinary, horizontal, and vertical collaboration under a research-based learning strategy for the understanding of Sustainable Development Goals (SDGs) and acting to enhance 2030 agenda. To analyze the students' perceived learning outcomes of this project, we conducted exploratory action research using a mixed methods approach.

Data were collected 2 months after the end of the courses using an optional survey and written final remarks within a "Letter to your classmates." The instrument, administered via Google Forms in Spanish and shown in Table 1, included five closed questions (0–4 Likert scale) and three open questions. Forty-five students responded to the survey, providing a confidence level of 87% with a 5% margin of error (García-García et al., 2013). The survey introduction informed students about the research purpose, the optional participation at any time along the instrument, the confidentiality of their responses, and the lack of impact of their answers in their evaluations and courses. In addition to requesting their informed consent to participate in the research, it is important to note that no personal data were collected in the survey.

According to gathered data, participation in the MRP led to students' perceived learning outcomes related to both transverse competences (collaboration, citizenship, communication, and critical thinking) and disciplinary competences (subject matter). Figure 2A illustrates their perceptions of the most significant learning outcomes from the MRP, with citizenship being the most frequently mentioned competence and project organization the least. In other words, students recognized the MRP as relevant from both a field of study



perspective (disciplinary competence such as sustainability) and a broader perspective (transverse competences such as human spirit, ethics, and citizenship). Figure 2B shows the students' perceptions of the extent to which their competences were strengthened through their work on the MRP. Notably, most competences were impacted "very much," with modes and medians of 4 for all competences, except for 'entrepreneurship' and 'leadership,' which had modes of 4 and medians of 3.

The perceived learning outcomes of the MRP were not only significant but also transferable to other contexts. Answers to questions Q3, Q4, Q6, and Q7 had modes and medians of 4 (very much). These results evidenced that students felt able to apply their learning outcomes in different contexts (Q3), highly recommended the MRP (Q4), found it valuable for the community (Q6), and felt empowered to act in favor of the environment (Q7).

The MRP was a motivating challenge for undergraduates from the characteristics of a Research-Based Learning (RBL) instructional design. Motivation is fundamental for significant self-managed learning outcomes; a motivated student maintains interest and commitment to the work, ensuring the achievement of the project's objectives. The MRP managed to maintain participants' motivation for an entire year, driven by the need for monarch butterfly conservation. Analyzing the MRP's characteristics from Ryan and Deci's Self-determination Theory (Ryan and Deci, 2000), we identified that motivation might be related to the following characteristics:

- The MRP gave students the opportunity to choose. The project's implementation instructions were broad, setting a clear and well-delineated objective without specifying the procedure or means. For instance, third-semester teams were asked to generate any

teaching resource related to environmental education that fostered the conservation of the monarch butterfly.

- The MRP presented students with a real, global challenge. This was due to the link with the social context surrounding the issue and its professional relevance.
- The MRP facilitated vertically and horizontally integrated collaboration, mirroring workplace environments. This meant students had to work with mates from their own class, other classes, and people in rural communities and FUNACOMM.
- The MRP allowed students to take control of their learning process. They could control the means and, in some cases, the final product to achieve the specified objective and the deadline submission.

Evaluating the project as a whole, over 95% of the students considered it useful for the community (Q6) and recommended it to others (Q4). The reasons for this recommendation are shown in Figure 2C, where the subject matter and the citizenship competence are the most mentioned.

The MRP's learning environment not only facilitated the participants, evidencing their sustainability competence, but also engaged them in continuing to act in favor of 2030 Agenda 2 months after the final submission. We categorized the answers of the students concerning the actions they were taking to solve the MRP problem (Q8). Our results demonstrate that after concluding the project, 82% of the participants effectively took actions as informed and active citizens by contributing to the monarch butterfly conservation. One of the top actions consisted of being responsible of their consumption (38% of the mentions), addressing SDG 12: Responsible Consumption and Production. Furthermore, 38% of the students tried to impact their close social network by sharing

TABLE 1 Survey used to gather data from the undergraduate participants in the Monarch Route project, 2 months after the final delivery to FUNACOM.

No.	Question	Possible answer	
Q1	Define in one sentence or phrase the most significant learning you obtained from this project.	Open-ended	
Q2	To what extent did the project contribute to the strengthening of your skills or competencies?		
	Problem-Solving	0-Not at all	4-Very much
	Self-directed Learning	0-Not at all	4-Very much
	Collaborative Work	0-Not at all	4-Very much
	Organization and Planning of a Project	0-Not at all	4-Very much
	Awareness of Your Environment	0-Not at all	4-Very much
	Leadership	0-Not at all	4-Very much
	Entrepreneurship	0-Not at all	4-Very much
	Empathy and Sensitivity Towards Environmental Issues	0-Not at all	4-Very much
	Reaffirming Your Career Vocation	0-Not at all	4-Very much
	Taking Action to Solve Problems in Your Environment	0-Not at all	4-Very much
	Oral and Written Communication	0-Not at all	4-Very much
Global Perspective	0-Not at all	4-Very much	
Q3	To what extent can you apply what you learned in this project to other projects?	0-Not at all	4-Very much
Q4	To what extent would you recommend this project?	0-Not at all	4-Very much
Q5	Why would you recommend this project?	Open-ended	
Q6	How useful do you believe this project was for the community?	0-Not at all	4-Very much
Q7	To what extent did this project empower you to participate in activities in favor of the environment?	0-Not at all	4-Very much
Q8	What are you doing today to contribute to the solution of the problem identified in the project?	Open-ended	

Five questions were in Likert scale (0—Not at all, 4—Very much) and the rest of the questions were open-ended.

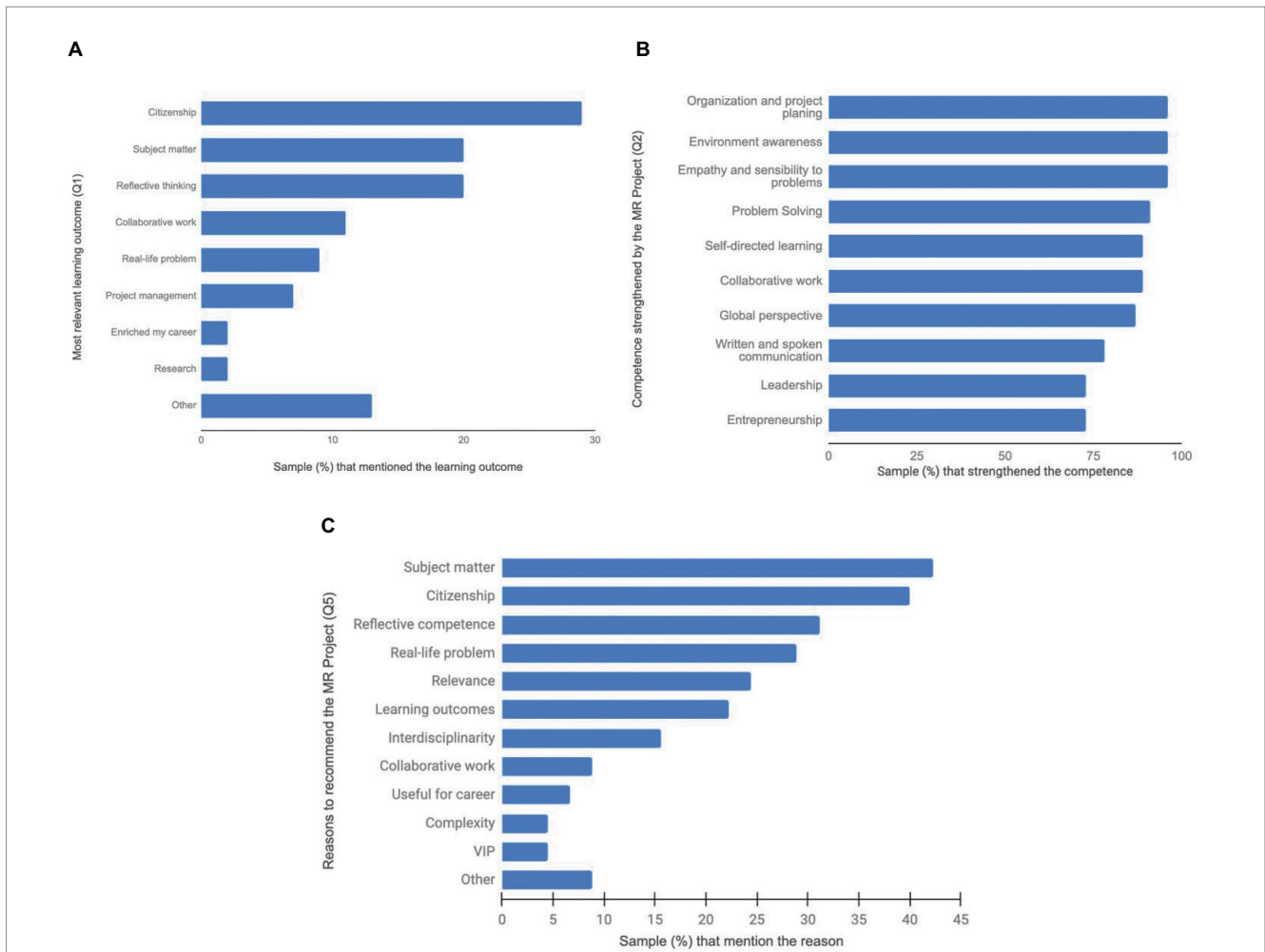
their knowledge and promoting awareness, addressing SDG 4 education. Other SDGs involved were SDG 15: Life on Land (20%), SDG 13: Climate Action (9%), SDG 8: Decent Work and Economic Growth (7%), SDG 2: Zero Hunger (4%), and SDG 17: Partnerships for the Goals (2%).

After 2 months of the end of the course, i.e., after assigning final grades to the project's deliverables and the course, participants were invited to write an optional letter to be shared with students from incoming classes about the MRP. The letters, with no impact on their already registered grades, were collected through email; however, they were informed that disclosing their authorship was also optional. The specific instruction was: 'Write a letter to be shared with incoming classes telling your fellow students about the Monarch Route Project.' We obtained 22 letters and analyzed them using Text Mining, applying Voyant Tools (Sinclair and Rockwell, 2016), and ROBERTuito (Pérez et al., 2022). The text analysis included the average sentence length and word count for each 'Letter to your classmates,' as well as vocabulary richness and sentiment. The final remarks had an average of 243 words, a vocabulary richness of 56%, and an average sentence length of 31 words.

The text analysis of our data reveals the MRP, designed under an RBL framework, develops the research skills of the students while also develops a sense of belonging and their positive attitude

to address related SDGs. Figure 3A presents a word cloud of the 25 most frequently mentioned words in the students' 'Letters to your classmates' about their experience with the MRP. Each term's size is proportional to its frequency. The terms 'project' (96), 'monarch' (70), 'butterfly' (55), 'route' (41), and 'ours' (40) were mentioned most frequently. The first four terms reflect the topic of the project: a project related to the monarch butterfly migration route. The term 'ours' signifies the students' sense of belonging and their commitment to addressing the threat of extinction faced by the monarch butterfly. This demonstrates that the students worked toward SDG 15: Life on Land and SDG 17: Partnerships for the Goals. Figure 3B is a diagram illustrating the 18 most frequently mentioned words and their interrelationships. The diagram's links reflect the concepts' articulation as mentioned by the participants. The nodes reveal subgroups related to disciplinary and transverse competences. For instance, the terms 'ours' and 'Mexico' relate to the MRP's region of analysis and the students' sense of belonging and awareness of the issue's impact. The term 'how,' which is associated with the students' ability to generate knowledge, strategies, and solutions independently, confirms the success of the RBL implementation.

The correlations between terms indicate that the students recognized improvements in their collaborative work, the RBL



**FIGURE 2** Participants in the Monarch Route Project (MRP) and their perception on (A) their most relevant learning outcome (Q1, open ended), on (B) the strengthening of specific competencies, (Q2, Likert scale), and on (C) the reasons to recommend this project (Q5, open ended). Answers to Q1 and Q5 were categorized by the authors while only answers 3 and 4—“very much” to Q2—are reported.

methodology, and their sustainability competence through the MRP. The vertically integrated collaboration is demonstrated by the term pairs ‘activity-collaborate’ and ‘collaborate-primary’ (Correlation Coefficient,  $R=0.9883$ ). The students perceived the relevance of the RBL methodology when they mentioned ‘research’ in sequence with ‘quality,’ ‘reliable,’ ‘source,’ and ‘fieldwork’ ( $R>0.9874$ ). The students’ significant learnings concerning the SDGs are evidenced by the word pairs mentioned in sequence, such as ‘establish-reserve’ ( $R=0.9688$ , SDG 13 and SDG 15) and ‘citizens-ecosystem’ ( $R=0.9444$ , SDG 13 and SDG 15), ‘establish-town’ ( $R=0.9688$ , SDG 12 and SDG 17) and ‘collaborate-primary’ ( $R=0.9883$ , SDG 17), ‘aware-economy’ ( $R=0.9456$ , SDG 8 and SDG 12), and ‘knowledge-ecosystem’ and ‘disseminate-ecosystem’ ( $R>0.9444$ , SDG 4).

Sentiment analysis of the respondents’ “Letter to your classmates” reflected to be mostly positive and neutral. We carried out sentiment analysis for “Letter to your classmates” with the pre-trained language model for user-generated text in Spanish RoBERTuito (Pérez et al., 2022), which is able to perform sentiment analysis, emotion analysis, irony detection, and hate speech detection. RoBERTuito categorized each answer to be positive, neutral, and negative, the prediction of

each category for each answer adds to one. Considering the category with the maximum probability, RoBERTuito labeled the “Letter to your classmates” to be 45% positive ( $0.002 < \text{Probability} < 0.970$ ), 32% neutral ( $0.017 < \text{Pr} < 0.661$ ), and 23% negative ( $0.004 < \text{Pr} < 0.980$ ) (see examples in Table 2). The positive text shown focuses on the valuable learning experiences of the collaborative research work on a societal relevant project, and at the same time, the student’s motivation and engagement can be perceived. The neutral text reflects a description of the activity, highlighting the topic and the RBL strategy. Finally, the negative text can be associated with the students’ perception of the complexity and seriousness of the environmental problem associated with the extinction of the monarch butterfly.

## 5 Discussion

The Monarch Route Project (MRP) won the *Premios Latinoamerica Verde* 2018 award (Latinoamerica Verde, 2018). Its success is also supported by the students’ learning outcomes and transference perceptions, as well as on the high rate of recommendations they give. It was an innovative project from its





TABLE 2 Extracts from "Letter to your classmates," a written text from the participants to the next cohort of students about the Monarch Route Project, the reflected sentiment, and Sustainable Development Goals they mentioned.

Sentiment (Probability)	Extract from the students "Letter to your classmates"	Student	Addressed SDG
Positive (Pr=0.970)	For me, one of the most important things to bring about change in the world is education, and that's why I found this project so interesting. I was really motivated by the approach that the Monarch Route organization took with us and seeing how our work was going to be used in the real world. Also, I thought it was really cool how all of us from different years had a distinct role in this activity.	Student 11	SDG 4, SDG 17
Neutral (Pr=0.661)	Deforestation influences the death of the butterfly since they have nowhere to rest or eat. Because of this, for the Ecosystems and Biodiversity class, we did a project to monitor the route the monarchs follow when they migrate, and we researched their main causes of death to prevent them from dying and help them survive	Student 17	SDG 13, SDG 15
Negative (Pr=0.980)	The Monarch Butterfly project has the main objective of conserving the species of the monarch butterfly, its habitat, and its migration route. Currently, in Mexico there is not enough knowledge about the damage we are causing to the monarch butterfly route. Because of this, nowadays the route of this species is in danger, causing a big negative impact on the ecosystem.	Student 1	SDG 15, SDG 4

the entrepreneurship competence (social entrepreneurship and ecopreneurship) (Schaper, 2016).

- SDG 12: The MRP promoted responsible consumption and production practices by heightening awareness about the repercussions of human activities, particularly in agriculture, on the environment and fostering sustainable practices. Moreover, 2 months after the project's deadline, most of the participants recognized taking effective action in this address.
- SDG 13: The MRP identified the effects of climate change on endangered species and laid the foundation for future action along the entire migration route of the monarch butterfly.
- SDG 15: The MRP additionally contributed to the preservation of terrestrial ecosystems, specifically those vital to the life cycle of the Monarch butterfly. Through education on the significance of these ecosystems and the promotion of conservation efforts, the MRP assists in safeguarding biodiversity and preventing ecosystem degradation and destruction.
- SDG 17: The MRP engaged in collaboration across diverse sectors and stakeholders, including Tecnológico de Monterrey, FUNACOMM, and rural communities. United, students, academia, and civil society will facilitate sustainable development and accomplish shared objectives.

The MRP encompassed species conservation understanding and recognition of its environmental and societal complexity and promoted self-directed learning; besides, students from Sustainable Development Engineering recognized the relevance of the project for their professional life and the strengthening of citizenship. Indeed, the MRP had a direct impact on the environmental issue, as FUNACOMM implemented all the proposals in rural communities along the monarch butterfly migration route. These features are internal learning motivators.

Although the students enrolled in any sustainable development course generally have prior interest in the subject matter, limiting the validity of our conclusions to our sample, it is noteworthy the MRP's instructional design. The current global situation demands the collaboration of different societal agents, highlighting the relevance of fostering undergraduate participation in SDG-related projects, such as the MRP.

The MRP presented a challenge that enabled students to engage in interdisciplinary, horizontal, and vertical collaboration, choose, and govern their own learning process. These characteristics of the instructional design resemble the interconnectedness of real professional practice, scientific research, and environmental conservation efforts. It demonstrates that contributing to 2030 Agenda requires a multi-faceted approach, involving educational institutions, community partnerships, and interdisciplinary collaboration.

Following its implementation and subsequent recognition with the *Premios Latinoamerica Verde*, we prove the MRP as a valuable instructional model for Education for Sustainability. This action research illustrates how higher education can effectively integrate collaboration, real-world impact, and community engagement to empower students toward accomplishing 2030 Agenda. We invite the academic community to discuss on the value and achievements of such effort. The Monarch Route Project incorporated seven Sustainable Development Goals, adhering to a blueprint design for fostering peace and prosperity for both people and the planet, now and in the future.

## Data availability statement

The datasets presented in this article are not readily available because the participants' consent was provided under anonymity and confidentiality of their answers. Requests to access the datasets should be directed to [claudia.camacho@tec.mx](mailto:claudia.camacho@tec.mx).

## Ethics statement

Ethical approval was not required for the studies involving humans because at the moment of collecting the data, our Institution's ethical requirement was to hold the signature of the informed consent from the participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was not obtained from the individual(s) for the publication of any

potentially identifiable images or data included in this article because published data are not individually identifiable.

## Author contributions

MC-C contributed to instructional design and implementation of the Monarch Route Project. MP-B and CC-Z designed the survey and the “Letter to your classmates.” EM-E prepared the corpus and performed sentiment analysis. CC-Z wrote the first draft of the manuscript, elaborated the descriptive statistical analysis, and completed the text analysis (word cloud and graphs). MP-B wrote section 2.1 of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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