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Environmental and Climate Culture for Sustainability: Experiences from Engineering Undergraduate Programs

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ABSTRACT
The educational system should contribute to the resolution of the socio-environmental crises that society faces today. Climate change is one of those problems that affects everyone on the planet. In fact, research is beginning to emerge about the importance of educating for the climate and sustainability; particularly, the identification of some practices and engineering projects related to climate change. However, this issue needs to be included in the teaching-learning processes in all educational programs. This analysis presents the perception of engineering students about climate change and sustainability, as well as its application in climate and sustainable action projects. This research was qualitative, focusing on the 'sustainable development' course delivered at the Tecnologico Nacional de Mexico, from educational practice in seven engineering undergraduate programs. A combination of four exploratory questions and project-based learning were applied to engineering students to identify key elements in the perception and conceptualization of climate change, sustainable development, and climate education. The results show that the students are aware of what is happening with the earth's temperature and global warming; some of them also showed project initiatives to address a climate or environmental problem. Engineering education have great potential to contribute to solving environmental and climate problems.

Key Words: climate education, environment, sustainable development, engineering education, Mexico.

1. Introduction

From an anthropological perspective, culture becomes a set of values, meanings, and attitudes that individuals and social groups possess and transmit to others from generation to generation. As part of a life in society, knowledge and skills are also shared that give a sense of belonging and bond. But culture changes over time, values can change, and others appear, ideas and forms of production change; for this reason, culture is seen as dynamic, because it agrees with the reality that is lived, requiring a transformation and adjustment (Bonfil, 1991c).

In this sense, environmental and climate culture is related to a scale of values and beliefs that are built from experiences and realities within a society or a social group. Sociocultural aspects related to the environment and climate should evolve towards a change of consciousness and mentality in the relationship society-land-existence (Grinberg, 2006). But, many times, the understanding of climatic and environmental events does not depend

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on the lack of information, but rather on the cultural roots and cognitive filters of individuals (Hoffman, 2015). Therefore, the relevance of the cultural issue lies in how people perceive, appreciate, and learn about planet Earth, its climate, environment, and society.
The inclusion of the topic of climate change in education arises from objective 13 of the SDGs (Agenda 2030): 'Climate action' (Unesco, 2017),"*Improve education, awareness and human and institutional capacity regarding climate change mitigation, adaptation, reduction of its effects and early warning*" (United Nations, 2017, p. 33). Meira-Cartea, Gutierrez-Perez, Arto-Blanco and Escoz-Roldan (2018) emphasize that university climate literacy is aimed at knowledge about the causes and physical processes of climate change, but the consequences and actions are not addressed. For this reason, there is a lack of studies on the incorporation, generation of educational proposals and research on climate education in higher education institutions.

Higher education institutions have the great challenge of responding to the awareness and reconstruction of a global environmental and climate culture, which helps the planet to overcome its limits of contamination, high temperature and access to water, through science. But scientific and non-scientific knowledge is required to produce new understandings from multiple perspectives and responsibilities, which generates greater certainty and plurality in the face of new realities. Science alone will not solve serious environmental and socio-ecological problems. So, new ontologies and epistemologies such as critical pedagogy, participatory and transdisciplinary research are indispensable towards sustainability and climate action to produce new knowledge in collaboration with various actors (Caniglia et al., 2020). *Climate change in this way has ontological, epistemological, and axiological elements*; it is about questioning being, knowing and moral valuing (McCowan, 2023).
The objective of this research was to analyze how different engineering students at the Instituto Tecnologico de Merida, perceive sustainability and climate change, as well as to know their knowledge and involvement in application activities in projects towards sustainability and climate action. The intention was to generate a self-reflection and criticism of the current economic model, and whether the hegemony of the modern sustainability paradigm has been able to reduce inequalities, climate change, socio-environmental conflicts, and the loss of natural resources.

2. Theoretical Review

The term 'sustainability' appeared as a way of including ecology and good management of natural resources within the economic study. Various actors began to focus on problems such as the consumption and extraction of resources, pollution, and environmental health; derived from this, the report of 'the limits of growth' arises. Among some indicators that emerged at that time about the seriousness of world growth were the depletion of non-renewable natural resources and accelerated industrialization. Other authors promoted environmental responsibility through tax payments for pollution, the use of resources, and cost-benefit analysis as mechanisms to solve environmental problems. A new field of study then arises called 'ecological economics', which integrates

ethical and environmental elements in the economic value system and the growth of material production (Wheeler, 2012).
Subsequently, the need to add ethical and political aspects to the concept of sustainable development was prevailing. So, new conceptualizations are born as weak, strong, and super strong sustainability. Weak sustainability refers to the fact that the economic valuation of nature in the market is synonymous with good environmental management. This position maintains that a natural capital can be replaced by another form of capital built by the human being. Meanwhile, strong sustainability does not accept artificial substitution. It is necessary to ensure the preservation of ecosystems and species; natural capital is critical and represents both economic and ecological value. Unlike these perspectives, super strong sustainability includes other valuations such as culture and religion on the environment. Therefore, when environmental management is practiced and policies are proposed, this sustainability contemplates citizen participation and the consultation of other knowledge and traditional knowledge (Gudynas, 2011).

Over time, social systems change, take root in human groups, and intersperse. This means that social interactions are important from social ecology, since they are power forces that can influence the functioning of an ecological system. Some factors that are present in social ecology are: a) values, b) knowledge, c) organization, d) technology, and e) environment (Wheeler, 2012). In this sense, to take on the challenge of climate change and sustainability, it is necessary to support these systems to evolve in various ways:

- Improve the education system, helping people think ecologically through critical thinking, active learning, experiential education, and cultural learning.
- Strengthen democracy, keeping people informed and well communicated.
- Improve governance, establishing a multilevel framework with different actions and goals on social and environmental justice (Wheeler, 2012).

The environmental culture for sustainability is an education current that recognizes sustainable development as the way to promote socio-cultural aspects, favor social and economic progress, as well as increase concern for the care of environmental services (Sauvé, 2004). However, to increase educational capacity and respond with knowledge about climate change, an active and critical role is required to face urgent needs, manage risks, and achieve resilience of ecosystems and humans being to climate change (Roberts, 2019). That is, the persons must rebuild themselves in the search for better living conditions that allow them to be actors in their own history (Touraine, 2000). For example, in an investigation carried out by Espino et al. (2015) comments that mechatronic engineering students showed interest in how science and technology contribute to solving environmental problems and the need to incorporate environmental education into educational programs. These students expressed their perceptions about climate change and believe that the challenge of their engineering lies in energy, robotics, recycling, and reuse of products.
The contribution of engineering to sustainability and climate change lies in the development of projects such as integrated waste management, carbon dioxide measurement, circular economy models, noise pollution studies, rescue and recovery of natural ecosystems, studies of socio-environmental impact, among others. Elsaadany &

Helmi (2018) proposed an engineering curriculum based on innovations, emphasizing sustainable design in energy efficiency and complying with the pillars related to social and economic development and environmental protection. Vargas et al. (2021) applied a questionnaire to find out the degree of knowledge and participation on climate change in the engineering area, as well as examined various engineering projects. The results showed that students know about the topic; but they participate very little in activities related to climate change. Likewise, only 16% of the projects addressed environmental issues. Therefore, the opportunity for engineering to contribute to sustainability could be through the promotion of projects and activities that address this type of problem.
Al Bahi et al. (2021) rethought a curriculum that included the implementation of sustainability indicators in engineering education. The authors created a methodology to integrate sustainability indicators and the seventeen sustainable development goals in the academic design of higher education institutions. They identified some factors such as a commitment to continuous improvement, international cooperation, industry ties, and alumni commitment to, as well as philanthropy and volunteerism, community engagement, and the development of financially autonomous universities. This meant a strong focus on socio-cultural dimensions and that addressing most of the seventeen sustainable development goals can be possible through a well-designed engineering education system.

Balza-Franco (2016) mentions that to validate knowledge there must be curricular updates, and in the case of engineering, the teaching-learning process must be based on problem solving. Local experiences and the exchange of knowledge with the community are pedagogical strategies that help teachers and students to live educational experiences in the field and address thematic contents in real cases (Meseguer, 2018). C*limate action depends not only on being taught, but also on self-directed and collaborative peer learning, occurring not only in formal courses, but also in other spaces on campus and beyond in diverse sectors of society* (McCowan, 2023, p. 935). However, there is a lack of information in the academic communities on how they can completely impact and respond to climate change. Therefore, the importance of environmental education for climate change is urgent (Calixto, 2018). Teachers are catalysts for social transformation, and must dialogue with their students to discover, propose, and generate solutions to current environmental or climate problems (Tamayo, 2017). There is not a unique way to teach or learn. In this sense, Stein et al. (2023) proposed a 'climate education otherwise' outline to prepare students with relational, affective, and intellectual capacities to respond current climate justice. This proposal encourages a continuous practice, increasing capacities to face different challenges in a flawed present-day.

3. Methodology

3.1 Research Design and Materials

In this study a qualitative approach was applied, with the intention of knowing the perception of students on sustainability and climate change from a public higher education institution. This implies listening and interpreting their way of understanding reality, but also assessing the possibility towards action and application. For this reason, two data collection methods were used: four open questions at the beginning of the

'Sustainable Development' course, and a practical project, at the end, based on the learning acquired during the entire course and the professor intervention.
Due to the complexity of the concept of sustainability and climate change, as well as the few studies that have been done on this topic in Yucatan, it was decided to elaborate open questions on sustainable development and climate change. At the beginning of the course, both in 2021 and 2022, four open questions were applied to the students to reflect theoretically on the knowledge prior to the development of the topic. These questions were derived from the literature review (strong sustainability, social ecology, and climate education) and considered to explore a general conceptualization, actions, interventions, and education regarding climate change.

- How do you perceive climate change?
- Could you mention if you collaborate or participate together with other social actors in climate education and sustainability activities or actions?
- How would you describe the concept of climate and sustainability education?
- What does sustainable development mean to you?

3.1.2 Project-based learning

At the end of the course, through the interventions of teachers and students during the development of the course, a final team project was requested as evidence of the learning process and social transformation. Project-based learning is a methodology that responds to a real problem, solving a research-action process, mobilizing knowledge, skills, and attitudes. It is an active method where students investigate, learn, and apply what they have learned in social reality or in solving a real problem. Generally, they work as a team to share experiences and analyze the results. This should motivate students because it is a socially useful challenge that contributes to their community. Also, it allows interdisciplinary work and reinforces skills such as critical thinking, collaboration, responsibility, and communication (Secretaria de Educacion Publica, 2022). This project required the application of the knowledge and values acquired on sustainable development and/or climate change. For this reason, it was necessary to address the 2030 Agenda and the 17 sustainable development goals that are not considered in the official syllabus of the course. The students were responsible for planning their project and creating their final product. Below is a checklist that was used to evaluate the project.
Checklist

✓ Various courses are interrelated in an interdisciplinary way in the solution of a real problem.
✓ Contemplates the development of skills, attitudes, and cognitive contents of various courses.
✓ Involves teamwork and collaboration to determine the objectives of the project, the research process and analysis of information.
✓ Creation of a final product (exhibition, infographic, debate, field work, etc.).
✓ Group feedback of the results.

3.2 Participants

The Tecnologico Nacional de Mexico (TNM) has been delivering the 'Sustainable Development' course for more than twelve years in all engineering careers as a transversal and common core subject. This course has had two important updates, its purpose is that students must face serious socio-environmental and economic problems, applying self-reflection, collective and individual awareness. The competencies of the course are a) development of interdisciplinary knowledge and solutions, b) promotion of systemic study and social, environmental, economic, and technological learning, c) environmental values. The course has five parts: Introduction to sustainable development, natural scenario, socio-cultural scenario, economic scenario, and modified scenario.

The Instituto Tecnologico de Merida (ITM) belongs to the TNM; it is in the capital of the state of Yucatan and has eleven engineering undergraduate programs. Some of them are Mechanical, Industrial, Biochemical, Chemical, Environmental, Biomedical, Civil, Computer Systems, among others. Most of the students take the 'Sustainable Development' course between the third and fifth semester. In this study, four groups participated in this research during the years 2021 and 2022. The 2021 group was made up of 16 chemical engineering students, 8 students from industrial, civil and electrical engineering, all in the fourth semester. The three groups of 2022 were divided as follows: one made up of 25 first-semester computer systems engineering students, the second by 15 biochemical engineering students from the third semester, and the third group from the second semester was made up of 26 biochemical engineering students, and 6 civil and environmental engineering students (see table 1 below). In total, 96 students registered in 'Sustainable Development' course, coming from seven undergraduate programs participated in this study. This means that only registered students were considered for research. The ITM receives and integrates students from urban and rural areas, with great cultural diversity and different economic conditions. While the study groups do not attempt to generally represent all students of the institute, they were selected because they reflect multiple cultural and socioeconomic aspects.

Table 1. Participants Summary

Undergraduate program	Number of students	Year	Gender
Chemical engineering	16	2021	7 males, 9 females
Industrial engineering	6	2021	4 males, 2 females
Civil engineering	1	2021	1 male
Electrical engineering	1	2021	1 male
Computer systems engineering	25	2022	22 males, 3 females
Biochemical engineering	15	2022 (third semester)	6 males, 9 females
Biochemical engineering	26	2022 (second semester)	13 males, 13 females
Civil engineering	4	2022	3 males, 1 female
Environmental engineering	2	2022	2 males
Total	96		59 males, 37 females

3.3 Data Analysis

The students' written responses were coded for concepts according to categories that emerge from the data rather than a priori. Initially, the researchers undertook the task of coding the responses independently; then among all the responses that were codified differently were discussed to reach a shared understanding. Using this constant comparative method, the data was pooled and conceptually labeled during this open coding process (Miles & Huberman, 1994). This iterative approach was valuable in highlighting the complexity of the concepts and the inevitable subjectivity involved in interpreting more open responses. The concepts were subsequently categorized and linked to each other. Finally, in the qualitative analysis, verbatim phrases extracted from the original responses are also presented, as they are considered representative of each category analyzed.

4. Results and Discussion

Responding to the objective of the study, the analysis of the information of the students' answers was carried out by means of dimensions, categories, and themes.
In the first question, how do you perceive climate change? Most of the students mentioned their perception of climate change as an environmental and a social problem. For some it is a serious environmental crisis that puts life on earth at risk. Other participants perceive that it is a social crisis due to the lack of education and communication, caused by our actions to affect nature. For other students, climate change is perceived as both a social and an environmental problem, because the activities of human beings have an impact on the environment, altering weather cycles and pollution. Some relevant quotes regarding their perception of climate change were as shown in the following table 1.

Table 2. Perception of climate change

Dimension	Category	Themes	Quotes Examples
Perception of climate change	Social problem and crisis	Poor well-being	"It is a transcendental problem because it not only involves the environment, but also society, the economy and education, it leads to a poor quality of life"
		Diseases	"Human beings pollute and that affects the climate, causing diseases"
		Belief that does not exist	"People are unaware of climate change and in some cases don't believe it, so they don't take it seriously and are uninformed"
	Environmental problem and crisis	Pollution	"In Merida there seems to be a weak ozone layer, there are too many people, cars and pollution due to the emission of greenhouse gases"

		Biodiversity loss Temperature change	"There are changes in the fauna and flora of the region due to the felling of trees and forest fires, causing extremely hot summers" "It is perceived as a change in temperature, more heat, droughts, among the loss of biodiversity"

Regarding the second question, could you mention if you collaborate or participate together with other social actors in climate education and sustainability activities or actions? Most of the students said they had collaborated with other actors, organizations, or with their own families in different actions, from waste separation, beach cleaning, or making compost. For example, a student commented that her family has a mechanical workshop and that they properly recover liquids and oils in containers. However, 18 participants commented that they had not collaborated with anyone in any particular action. Some students who do not collaborate socially with other people said that if they carried out actions, these may be not burning garbage, not throwing away toxic products, and helping at home with watering the plants. Some relevant quotes regarding their collaboration with other actors on climate and/or sustainability actions were as shown in the following table 2.

Table 3. Collaboration and climate action

Dimension	Category	Themes	Quotes Examples
Collaboration in climate action/ sustainability	Environmental campaigns	Cleaning of beaches, parks Recycling, reuse of waste	"I have volunteered to collect garbage on the beaches, collect rainwater and separate garbage" "In the neighborhood where I live, we usually recycle paper, cardboard, pet; We also work with a company that helps us make compost with organic waste" "At home we reuse various materials that are useful"
	Conservation of environmental services	Composting Planting of native plants	"In my family we use organic waste to generate compost naturally and efficiently" "I have participated as a volunteer at my school to create gardens and plant native plants"

		Social marketing	"I participate and collaborate in marketing strategies on social awareness in an NGO to preserve ecosystems"

In the third question, how would you describe the concept of climate and sustainability education? there were similar answers, and some different ones. All the students stated that climate education is very relevant for professional training and as global citizens, without education for sustainability the planet would be worse off. Most referred to climate and sustainability education as the degree of awareness, increasing knowledge about climate and responsible training to improve behaviors and habits. Few students commented that education for sustainability should be taught in basic education, and not in the university. Other students said that adults should be re-educated because they don't understand what climate change is and don't know what actions they should take. The most important quotes on climate education were placed in table 3.

Table 3. Description of climate education

Dimension	Category	Themes	Quotes Examples
Description of climate education/ sustainability	Knowledge	Causes of climate change	"It is a strategy to know the damage we cause, since today we are the largest consumers of resources on the planet, we are exhausting future possibilities" "It is necessary to know in depth why climate changes occur"
		Consequences of global warming	"Teaching the consequences of climate disasters and how to prevent the deterioration of the planet" "Addressing the consequences of global warming to change behaviors"
	Sensitization	Environmental care awareness	"Climate education is intertwined with sustainability, which helps us to be aware of our actions and use our intuition"
		Principles and values	"Help people to be trained so that they can act as agents of change with values and skills."

			"They are principles of life that must be adapted and promoted to affect the environment less"
	Skills	Solutions and actions	"It's important to implement new ideas and strategies and get better results on climate change" "Responsible training through research and innovation of proposals" "Promote a mindset directed at different actions.
		Adaptation	"It improves the skills to assimilate knowledge, calculate risks, prepare for the climate crisis and recover from its effects" "It helps to adapt to a global emergency"

Regarding the question, what does sustainable development mean to you? Many students commented that sustainable development is one that meets the needs of the present without affecting the needs of future generations. However, around 50% of the participants indicated some different aspects of what sustainable development means, which are described in Table 4. It should be noted that most of the students refer to sustainable development as caring for and properly using the natural resources, not waste or exploit them.

Table 4. The meaning of sustainable development

Dimension	Category	Themes	Quotes Examples
Meaning of sustainable development	Balance	Economic, social development and environmental well-being	"Maintain a good balance between economic development and socio-environmental well-being" "Personal, social and emotional stability with prosperity and development of society"

		Protection and caution	"It is a program that avoids the exploitation of natural resources" "Creation of protection initiatives" "Promote justice in general"
		Alternatives	"Generation of positive changes and innovations" "Study how technology can help reduce pollution" "Science that helps to reflect on the damage to the environment and seek solutions to problems"
	Respect and responsibility	Equity	"Respect for life and ecosystems" "Study of values, responsibility and actions towards our environment" "Commitment and citizen responsibility towards social equity and a new culture"
		Actions	"Result of a friendly and concentrated action in a group of people who promote a new development model"
		Feelings	"It is loving nature and caring for the environment" "Enjoy the natural heritage of my region" "Citizens with conscience"

4.1 Effectiveness of project-based learning

Transforming educational practice is a difficult challenge; for this reason, teaching a course with a project proposal has enormous challenges, but advantages, implying a great effort for both the teacher and the students. Small personal transformations through this experience of building better people and professionals together can help educational institutions make a paradigm shift. Therefore, this course had the purpose of making students reflect on the values of sustainability, their social constructions within society and communicate if their decisions and actions are consistent with their own values, which allows them to recognize that this new knowledge is important in their personal and professional life, creating the change that is required.

The planning of the team projects was inclusive when the students were from different educational programs and when they integrated their various courses and themes into the project. Through their insights and collaboration, they were able to identify a real problem; for which, they had to invest in creativity, discussion and reach consensus. Subsequently, the challenge was to design an interdisciplinary proposal that addresses and imagines possible solutions. Problem solving is learned by practicing and collaborating. Therefore,

the students faced the time, the spaces, and the resources they had. For example, one of the teams was made up of an environmental engineering student, a biochemical engineering student, and another computer systems engineering student; these three students together developed a platform that serves as a calculator to obtain a measurement of the institute's carbon footprint for energy consumption. So, they made an inventory of the green area, number of fans and air conditioners in the school to calculate the carbon footprint. Its result was presented and tested to the authorities of the institute. His reflective learning throughout the course is shown below.

We had not seen or heard what the ecological and carbon footprint is, the planetary limits, the 2030 agenda, the water footprint, and other issues. We found it interesting, but at the same time it causes anxiety. It gives anxiety not knowing what to do or not being able to know what to do with pollution, global warming, and other planetary limits, because it does not depend on one, but on everyone. Realize the importance of communicating these issues with all people, especially with older people to create an environmental culture and practice.

Other students of environmental engineering and biochemistry decided to undertake the task of community gardens. They were collaborating with a civil organization in a neighborhood to the north of the Merida city, carrying out civic ecology for the care and recovery of green areas. The intention was to promote citizen participation to generate urban gardens through the planting of native plants in open spaces shared by the residents of the place. The result of this project is shown in the following reflection.

I think that the experience acquired in this activity has been very useful to be able to appreciate how it is that today the effects of the environment caused by man, and despite the consequences generated by climate change, we can still reduce these impacts. This to prolong the health and preservation of natural resources, such is the case of community gardens, with what is sought is that individuals can produce their own inputs for their livelihood and not depend solely on companies that usually generate pollution based on to the ways of producing and distributing products, when one can support the environment through responsible consumption.

Some other student statements based on their reflective learning about the course and capstone project are shown below.

The course fascinated me. I really liked my project, it was good. Thanks to this course (and the research) I opened a small business making handmade soaps, since these are free of surfactants and are friendly to nature at its best. Without a doubt, it was one of the best classes for me this semester, because I liked the debates and learning more about the objectives of sustainable development, which, although I had an idea, was not in my vocabulary.

Thanks to this project I was able to realize how important green areas are in a community, normally these small areas exist in most communities; however, they leave them forgotten and filling them with garbage. Over time I realized that many things we throw away can be useful for the creation of these community gardens, I feel that the phrase "one's garbage is another's treasure" is true.

This project was interesting. Insects are an important element of the ecosystem, they help us regulate pests, pollinate flowers, and even improve soil conditions, and having an insect hotel that can provide enough warmth and protection for these species is very important. It is necessary to keep insects to preserve biodiversity and ecological balance.

5. Climate and sustainability education: practice and policy

To achieve the competencies and objective of the course such as the development of interdisciplinary knowledge and solutions, promotion of social learning, and environmental/climatic values, several activities were structured for students to construct their own meaning of the topic. Some teaching approaches were:

- ✓ Problem-solving exercises that allow students to critically engage with influences in the environment, the economy, or the local community.
- ✓ Concepts and principles of sustainability and development.
- ✓ Case studies for students to integrate and apply their knowledge to real life.
- ✓ Audiovisual material, websites, and readings to develop critical thinking skills.

It is also necessary to reflect on the importance of teachers having their own pedagogy to recognize learning and teaching approaches in the development of the skills required for the 'sustainable development' course. Without a critical reflection on the teaching practice, a teacher can fall into the reductionism of education, and not think that other teaching-learning alternatives are possible. Also, as a reflective practice, students' comments and experiences are relevant factors in creating positive learning environments. As Wheeler (2012) mentions, education for sustainability and climate change requires people to think about ecology from the experience of change, cultural exchange, active and critical learning. For example, in the Stein et al. (2023) climate education otherwise proposal, showed two experiential learning programs, and emphasize that this proposal is a process of pedagogical possibilities, explore new insights and un/learning situations.

Indeed, a pedagogical renewal is discussed by McCowan (2023). This author mentions that universities should be a transformative experience to address questions of values, knowing, and critical pedagogy. Misiaszek and Rodrigues (2023, p. 215) argue critically a teaching for 'Justice-Based Environmental Sustainability' (JBES) education in higher education institutions throughout all curricula, unloading six questions related to this teaching. Three of them are*: 1. Higher education's roles and responsibilities in leading to students' praxis of sustainability; 2. the incorporation, or not, of Southern, Indigenous, and/or Northern epistemologies grounding (un)sustainability taught; 3. and the (non-)anthropocentric groundings in higher education learning.*

For this reason, it is necessary to rethink new study plans in the different engineering study programs, which include indicators of the 2030 Agenda, social ecology, ecological economy, and climate change. As Al Bahi et al. (2021) proposed in their study programs, the implementation of sustainability indicators in engineering education; as well as Balza-Franco (2016) and Meseguer (2018) affirm that there must be updates in the engineering study plans and that the teaching-learning process must be based on the resolution of real problems, local experiences and the exchange of knowledge with other people in the community; that is, to have educational experiences based on a real experience. A transformation in the curricular programs that align with the 2030 Agenda is fundamental, but it is also truly important to include in the study plans of undergraduate programs certain lifelong education skills such as: awareness, empathy, self-management, and social skills, added to a deep understanding of the world through systems thinking. Young people are the ones who can transform living conditions on the planet, and educational institutions, together with teachers, have a role so that these young people are the leaders

of tomorrow, they can reinvent and work collectively on what they are inheriting from their predecessors.

Another reflection of the course is to notice that engineering students are aware of the climate crisis and socio-environmental problems that are experienced not only around the planet, but also in their community. They know that actions towards solving those problems are very vital today. However, there are many interpretations that depend on personal experiences. For example, those students who live in rural areas face different challenges and realities, unlike those who live in urban areas. Some of these rural students have mentioned that they experience floods and loss of crops, giving them first-hand knowledge of how the climate and environment can affect everyday life. Thus, for some it could alter their perception, but not for others. Likewise, the study could present a bias because the projects, as being part of an open and non-anonymous course, do not necessarily represent truthfulness. Some students may lie about their beliefs on climate change, so their grades are not affected. Also, some students could present different learning because they were studying during the COVID-19 pandemic, which means they were not able to develop the projects adequately from their homes. Additionally, a gender analysis could or not have led a different level of perception and consciousness, as this was not conducted in data analysis.

Lastly, if educational institutions do not have policies and pedagogical activities that help to face these problems, it will be difficult to make a social transformation through the course of 'sustainable development'. Institutions are required to promote environmental practice and sustainability, citizen participation, and the dialogue of knowledge in the entire academic community (professors and students) from different disciplines and courses. The issue of climate change is not in the educational programs either, it is an isolated sub-theme within the sustainable development course, which does not motivate some students to propose projects that are oriented towards the mitigation or adaptation of climate change. It is therefore important to promote and develop the capacities of university students so that they may be experts in projects and research with attention to this type of current and real problems. Watson (2019) comments that nature can still be restored in a sustainable way and meet some objectives at a global level, but a transformative change at an educational level is necessary. A reorganization of social and technological factors is required, as well as a change in paradigms, values, and objectives.

6. Conclusions

The purpose of this research was to analyze the perceptions of engineering students on sustainability and climate change, as well as to know their learning application in projects towards sustainability and climate action. Recent studies have shown the low knowledge and awareness that students have of the SDGs (Leiva-Brondo et al., 2022); demonstrating that higher education institutions in developing countries still have a long way to go regarding climate and sustainability education. This study has contributed to the sustainability education literature, through the exploration of open-ended questions and project-based learning, to further understand how students perceive climate change and carry out projects aimed at responding to SDGs. Particularly, this research was relevant for providing information on how this issue is being addressed in some South American

countries. How these higher education institutions should raise awareness and reorient their educational processes towards transformations of knowledge and doing for sustainability; responding to the social place where they are located, but also to the characteristics of each local and global space. Understanding that north- and south-oriented countries have different problems, understandings, and ways of facing climate change. Similar to how Misiaszek and Rodrigues (2023) discussed if it is crucial or not to consider the integration of Southern, Native, and/or Northern epistemologies to achieve a teaching for JBES in higher education.

The perception of sustainability and climate change, as well as the identification of actions and involvement of students in projects should lead to self-reflection and critical thinking. Regarding the opinion of the students, they stressed that it is a social and environmental problem. They are aware of the increase in temperature, the misuse of resources, and the lack of responsibility in the production and consumption of goods and services. However, Hoffman (2015) mentions, it is not due to a lack of knowledge, but rather the way in which people learn and appreciate the environment, the climate, and the society-nature relationship. They also recognize that quality of life is essential, that collaboration and climate action is to prevent further contamination. Nevertheless, Calixto (2018) reveals, there is a lack of information and collaboration to respond to climate change, since some students still do not carry out actions or they do not know what they should do. For this reason, as Caniglia et al. (2020) say that a participatory and transdisciplinary research is needed to produce collaborative knowledge on climate and sustainability, at local and global context. In this regard, McCowan (2023) mentions the importance of learning collaboration with other regional actors and diverse sectors of society.

Climate education was understood by students as knowledge of the causes and consequences of global warming, as well as from the sensitization and awareness for the care of natural resources. Some students mentioned that with education they would hope to gain the skills to adapt to the risks and vulnerabilities that changes in climate bring about. Additionally, other students commented that it is imperative that the education sector promote innovation and generate ideas to find solutions to this global problem that affects locally. However, students have the same knowledge as the general population, when they should have scientific knowledge about what climate change is and how it affects; hence, educational institutions still need to promote and communicate a socio-environmental culture. In this sense, Balza-Franco (2016) says the need for curricular updates to include knowledge about climate, sustainability, and the 2030 Agenda. Particularly, learning in engineering careers should focus on solving problems, through processes of innovation. These processes should also include pedagogical alternatives and experiments, allowing to engage critically on sustainability education, but depends on the geographical, political, contextual, and cultural implications (Stein et al., 2023) of engineering programs towards the solving of local problems.

In fact, some international and national universities are beginning to move towards actions and research on decarbonization and climate neutrality (Olivieri, et al., 2020; Agdas, et al., 2015; Opel, et al., 2017). These authors say that universities should implement transformative agendas and programs such as zero carbon, reduction of their atmospheric emissions and renewable energy generation in their campuses. Mexican public higher education institutions lack planning carbon neutrality and collaboration with external

agents. However, governments have been making efforts to establish policies and programs focused on climate action. The government of Yucatan enacted its climate change law in 2021, and in conjunction with the Education Secretary, they began to train elementary school teachers on sustainability and waste issues. Likewise, they have created a network of sustainable universities where they register their actions towards sustainability. However, the Instituto Tecnologico de Merida (ITM) is not yet part of this network. As a result, its engineering students have little involvement in community projects with socio-environmental impact. This means that much remains to be done, not only at the local level, but also at the international level; particularly in public institutions from developing countries, where the creation of a new curricula, economic resources and new capacities are needed.

The projects that were carried out in the course focused on covering some of the seventeen objectives of sustainable development, and only two teams addressed a problem related to climate change. In fact, Vargas et al. (2021) showed that engineering students only address environmental projects in 16%, despite knowing about the topic and the climatic and environmental problems that are currently experienced. In the different regions of the world, climatic scenarios are experienced that must be addressed. For this reason, it is urgent to have pedagogical strategies and experiential projects within the study programs that address climate change from engineering, since the 'sustainable development' course is not enough to carry out projects that contribute positively to the challenges and complexities that climate and sustainability processes demand today. Climate education in engineering has an enormous opportunity to contribute to solving this socio-environmental problem, although certain skills and an understanding of principles and values are required to achieve climate education for sustainability. Higher education institutions are then in charge of strengthening and rebuilding a global environmental and climate culture, through the application of science and the involvement of professors and students in projects and actions that reduce greenhouse gas emissions or avoid atmospheric pollution.

References

Agdas, D., Srinivasan, R., Frost, K. & Masters, F. (2015). Energy use assessment of educational buildings: Toward a campus-wide sustainable energy policy, *Sustain. Cities Soc.*, 17, 15–21. https://doi.org/10.1016/J.SCS.2015.03.001

Al-Bahi, A. M., Abd-Elwahed, M. S., & Soliman, A. Y. (2021). Implementation of Sustainability Indicators in Engineering Education Using a Combined Balanced Scorecard and Quality Function Deployment Approaches. Sustainability, 13 (13), 7083, http://doi.org/10.3390/su13137083

Balza-Franco, V. (2016). Formulacion y diseno de un modelo de vigilancia tecnologica curricular en programas de ingenieria en Colombia. *Revista de la Educacion Superior*, *45*(179), 55–77, https://doi.org/10.1016/j.resu.2016.04.008

Bonfil, G. (1991c). "Nuestro patrimonio cultural. Un laberinto de significados", en *Pensar nuestra cultura,* México, Alianza Editorial, pp. 127-151.

Calixto, R. (2018). El cambio climatico en las representaciones sociales de los estudiantes universitarios. *Revista Electrónica de Investigacion Educativa*, *20*(1), 122–132. https://doi.org/10.24320/redie.2018.20.1.1443

Caniglia, G. et al. (2020). A pluralistic and integrated approach to action-oriented knowledge for sustainability, *Nature Sustainability*, 4, 93 – 100.https://doi.org/10.1038/s41893-020-00616-z.

Elsaadany, A. & Helmi, A. (2018). Sustainable Development, Technological and Industrial Impacts on Engineering Education. Interdisciplinary Description of complex Systems, 16 (2), 227 – 237, http://doi: 10.7906/indecs.16.2.3

Espino, P., Olaguez, E., & Davizon, Y. A. (2015). Analisis de la Percepcion del Medio Ambiente de los Estudiantes de Ingenieria en Mecatronica. *Formación universitaria*, *8*(4), 45–54. https://doi.org/10.4067/S0718-50062015000400006

Grinberg, S. (2006). Educación y gubernamentalidad en las sociedades de gerenciamiento, Revista Argentina de Sociología, 4 (6), 67-87.

Gudynas, E. (2011) "Ambiente, sustentabilidad y desarrollo: una revisión de los encuentros y desencuentros" En: J. Reyes Ruiz y E. Castro Rosales, editores. *Contornos educativos de la sustentabilidad*, Editorial Universitaria, Universidad de Guadalajara, México, 109-144.

Hoffman, A. (2012). How culture shapes the climate change debate, Stanford University Press, California, USA.

Leiva-Brondo, M.; Lajara-Camilleri, N.; Vidal-Meló, A.; Atarés, A.; Lull, C. (2022). Spanish University Students' Awareness and Perception of Sustainable Development Goals and Sustainability Literacy. *Sustainability*, 14, 4552. https://doi.org/ 10.3390/su14084552

McCowan, T. (2023). The climate crisis as a driver for pedagogical renewal in higher education, *Teaching in Higher Education,* 28 (5), 933-952.

Meira-Cartea, P., Gutierrez-Perez, J., Arto-Blanco, M. y Escoz-Roldan, A. (2018). "Influence of academic education *vs.* common culture on the climate literacy of university students/Formacion academica frente a cultura comun en la alfabetizacion climatica de estudiantes universitarios", *PsyEcology,* vol. 9, num. 3, pp. 301-340, http://doi: 10.1080/21711976.2018.1483569 (consultado: 23 de febrero de 2020).

Meseguer, S. (2018). Educacion Superior Intercultural, Aprender en y como comunidad. En B. Baronnet, J. Mercon, & G. Alatorre (Eds.), *Educación para la interculturalidad y la Sustentabilidad. Aportaciones reflexivas a la acción.* (pp. 139–149). Universidad Autonoma Intercultural de Sinaloa y Universidad Autonoma Indigena de Mexico.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage Publications, Inc.

Misiaszek, G.W. & Rodrigues, C. (2023). Six critical questions for teaching justice-based environmental sustainability (JBES) in higher education, *Teaching in Higher Education*, 28 (1), 211–19. doi:10.1080/13562517.2022.2114338.

Olivieri, L., Caamaño, E., Sassenou, L. & Olivieri, F. (2020). Contribution of photovoltaic distributed generation to the transition towards an emission-free supply to university campus: technical, economic feasibility and carbon emission reduction at the Universidad Politécnica de Madrid. *Renew. Energy,* 162, 1703–1714. https://doi.org/10.1016/J.RENENE.2020.09.120

Opel, O., Strodel, N., Werner, K., Geffken, J., Tribel, A. & Ruck, W. (2017). Climate-neutral and sustainable campus Leuphana University of Lueneburg. *Energy,* 141, 2628–2639. https://doi.org/10.1016/J.ENERGY.2017.08.039

Roberts, D. (25 de 09 de 2019). L*as decisiones que adoptemos ahora son fundamentales para el futuro de los oceános y la criosfera*. Comunicado de prensa del IPCC. Monaco.

Sauvé, L. (2004). Una cartografía de corrientes en educación ambiental, In Sato, Michèle, Carvalho, Isabel (Orgs). 2004. *A pesquisa em educação ambiental: cartografías de uma identidade narrativa em formação*. Porto Alegre: Artmed.

Secretaría de Educación Pública (2022). Metodología del aprendizaje basado en proyectos https://educacionbasica.sep.gob.mx/wp-content/uploads/2022/06/Metodologia-ABP-Final.pdf

Stein, S., Andreotti, V., Ahenakew, C., Suša, V., Valley, W., Huni Kui, N., Tremembé, M., Taylor, L., Siwek, D., Cardoso, C., Duque, C., Oliveira da Silva, S., Kui, H., Calhoun, B., van Sluys, S., Amsler, S., D'Emilia, D., Pigeau, D., Andreotti, B., Bowness, E. & McIntyre, A. (2023) Beyond colonial futurities in climate education, *Teaching in Higher Education*, 28 (5), 987-1004, DOI: 10.1080/13562517.2023.2193667.

Tamayo, L. (2017). *Apreder a Decrecer 2.0. Educando para la sustentabilidad poco antes del inicio de la debacle socioambiental* (Primera Ed). El Colegio de Morelos.

Touraine, A. (2000). *¿Podremos vivir juntos?* México : Fondo de Cultura Económica.

Unesco (2017). *Educación para los Objetivos del Desarrollo Sostenible. Objetivos de aprendizaje*, Paris Ediciones Unesco. Disponible en: https://unesdoc.unesco.org/ark:/48223/pf0000252423 (consultado: 15 de abril de 2022).

Vargas, R., Rolon, J. & Tovar, R. (2021). La enseñanza del cambio climático en la ingeniería: el caso del centro Universitario Sur de la Universidad Autónoma de Tamaulipas, En Rueda, J., Terrón, E. y Gay, C. (Eds.), Epistemología y pedagogía climática en México, Universidad Nacional Autónoma de México.

Watson, R. (2019). Nature's Dangerous Decline 'Unprecedented', The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Wheeler, S. (2012). Climate change and social ecology: a new perspective on the climate challenge. Routledge: Great Britain.