THE LACK OF ENVIRONMENTAL EDUCATION IN THE TRAINING OF ENVIRONMENTAL ENGINEERS IN COLOMBIA

Pedro Mauricio Acosta Castellanos[1], Araceli Queiruga Dios[2], Alejandra Castro Ortegon[3]

[1,3] Universidad Santo Tomás - Faculty of environmental engineering [2] Universidad de Salamanca Universidad de Salamanca · Department of Applied Mathematics.

Conference Key Areas: New Complexity quest in engineering sciences, new notions of interdisciplinarity in engineering education

Keywords: Environmental Engineer, education Ambiental

ABSTRACT

Environmental education has become an important tool for human formation, especially in basic cycles such as primary and secondary school, which tends to transform human actions on nature, based on multidisciplinary knowledge that supports decision-making, generating a change in social behavior achieving recovery, conservation and preservation of the environment. Higher education is more complex to treat environmental education, then, although it is increasingly common to see degree or undergraduate programs that have environmental content academic spaces in their curricula, these develop specific skills of each occupation, therefore, it is almost non-existent observe environmental education immersed in these curricula. In environmental engineering, although its name would be assumed to have introduced environmental education, were found evidence that in general demonstrate the opposite, a lack or nonexistence of this in its formation. Based on an analysis of the curriculum, objectives and graduation profiles, there was a lack of nuclei or academic spaces that involve environmental education in these undergraduate engineering, and it could be related that this deficiency is due to a certain extent that this career evolved in Latin America of sanitary engineering, which sought to address problems related to basic sanitation, product of the economic development characteristics of these countries, then, environmental engineering inherits too much the technique of the

sanitary, leaving little space in the study plans for environmental and ecological issues.

1 INTRODUCTION

The university is defined in many ways, but every definition has within its structure aspects such as enrichment of knowledge for the common good; Salvador Moncada (2008) defines the university as "an academic community that rigorously and critically contributes to the protection and development of human dignity and cultural heritage through research, teaching and several services offered to local, national and international communities" . In universities, graduate programs are the first link in a chain of studies that will train the person integrally and integrates the role of the university from the outset, therefore, to the mission and vision of each institution of higher education.

Today, humanity faces apparent, irreversible changes: the result of bad actions and social development with little or no environmental liability, establishing a series of global challenges such as climate change and the degradation of natural resources [1]. These challenges are also the responsibility of universities and their programs. While wide definitions include and integrate environmental issues in them, Zabala (1999) defined the university as "a place where you should raise awareness about the human being who with his activity promotes social and environmental changes in recent years; It also fully trains people to be able to understand society and intervene in order to improve it." Environmental Education (EE) and Education for Sustainable Development (ESD) have become two currents within the comprehensive training in higher education who are looking for concepts and different ways to protect natural resources for future generations. The EE has a greater historical foothold against ESD, which is why countries like Colombia's find it more relevant compared to ESD [2] [3]. Colombia has opted for a policy focused solely on the EE, the Ministry of Education, as well as the Ministry of Environment and Sustainable Development of Colombia, decreed for this country the "Environmental Education Policy" [4] therefore, has left relegated for now the EDS.

Although EE lacks a single definition or consensus, it can be classified as heterogeneous and diverse and is concerned with basic primary education to independent university education, independent of the knowledge area, with a common, clearly defined core proposing the promotion of some type of change in the way people act towards the environment, outside of the focus or teaching

strategy being employed. UNESCO (1980), at the Conference on Environmental Education, stated that this must respond to the complexity of the environment and its binding between biological, physical, social, cultural and socioeconomic factors. Similarly, it is common to see the EE emphasizing awareness and providing tools to acquire information about environmental sustainability, focusing on promoting ecological behavior and critical thinking against overconsumption [5] [6], Also focuses on providing information for intelligent decisions facing the environment and how to protect it. [7] [8].

At universities, the EE must take the student to know and understand their environment, in terms of both human actions and natural phenomena, and to learn from generating an action strategy to protect the environment. For this to happen it is necessary to teach students practical, theoretical, and innovative actions and tools aimed at improving the environment [9]. In this sense, many universities face a great challenge, because few involve environmental matters within their substantive or adjectival functions. In Latin America, environmental education is seen as something that only affects primary and secondary basic education [3], but not higher education. It involves large voluntary changes in reshaping curricula in graduate and postgraduate programs. Therefore, this change would recognize in the educational system the importance of the environment in people's lives and the development of societies, thus implying the use of EE in curricula and the universities themselves [10].

Based on the previous description, one can infer the importance of environmental education and how it has joined the evolutionary process of universities, as well as the need that exists to demonstrate it in the curricula and training of people who are in these institutions. As previously mentioned, the chain of formal qualifications starts at the undergraduate level and ensures that such training could in some way define the future of the person in a certain job [11]. One graduate degree is environmental engineering, which emerged from the evolution of sanitary engineering and the specification of topics closer to the structure of civil engineering. Both types of engineering address environmental issues in their curricula, on the part of sanitary engineering, the area of environmental health. This area is broadly designed to analyze the effect of the use of toxic elements in the environment on human health [12]. Civil engineering includes issues of water resources [13]. Not much time has elapsed since the emergence of environmental engineering in Latin America: only in the nineties did the first environmental designations in engineering programs in Colombia appear, and in much of Latin America, the original name was sanitary and environmental engineering. Over time, the word "sanitary" disappeared from the discipline, as environmental issues began to carry more weight as countries

with greater progress began to overcome the problems associated with the lack of basic sanitation. But the curricula continued to focus primarily on technique, inclined to this health genesis.

Environmental engineering is therefore based on technique, and its definition given by Engineer's Council for Professional Development - ECDP (Current Accreditation Board for Engineering and Technology - ABET) and found in the book Introduction to Environmental Engineering reads: "The environmental engineering is the profession in which knowledge of mathematics and natural sciences obtained by study, experience and practice is applied with judgment to develop ways to economically use the materials and forces of nature for the benefit of mankind ". So the education of environmental engineers has a very clear curricular core or training areas that meet the definition given by ECDP, as basic sciences, basic engineering, training and applied research and ethical engineering or humanism depending on the approach of the university offering the program; It is unusual to display the EE in the curricula of this type of engineering.

The objective of this research focuses on the lack of evidence EE in the training of environmental engineers in Colombia, based on reviewing the curriculum, objectives, vision and mission of these higher education programs. It was conducted on a sample of six programs of universities in Colombia who have this type of engineering, reviewing the curricula and consulting students about their perceptions, needs and interests focused on the EE. The goal is for the results to serve as input to improve these programs through updating, evaluating the possibility of incorporating the EE in the training/education of future environmental engineers so that they can become an agent of change and transformation in society against social and environmental challenges ahead.

2 METHODOLOGY

2.1 The environment in universities.

One could say that education, in general terms, seeks to provide validated knowledge to people as tools to solve contemporary problems, so it is dynamic and adaptive, able to lead us to generate new knowledge driving changes and improvements in society. In this sense, environmental education emerges as a product of historical context and the uncertainty of the future in social terms and in terms of existence as a human species, which we have faced since the late

twentieth century. Universities are being forced to confront these challenges by applying schools of thought such as AD and ESD. Universities play an important role in the solution to the current socioenvironmental crisis: the medium requires its members to prepare to meet the challenges brought, including climate change, degradation of natural resources, territorial disputes arising from the expansion of the agricultural frontier, solid waste generation, pollution of water sources among many others [14] [15]. Teaching and research should be the main agents of change to address the problems and challenges of society, addressing issues that relate to the environment in any educational context, as; responsible consumption, conservation of biodiversity, and the economy inter alia. This entails the promotion and strengthening of environmental education processes
[16] [14].

It has been observed that higher education is not playing this important role, so the effect that it is having on students and graduates in terms of pro-environmental attitudes and solving these given problems is minimal. [17]. Universities therefore need to increase efforts to permeate all spheres of environmental action; teaching, research, operation and social responsibility [18] [19], acting in accordance with the global guidelines on environmental education as the Talloires Declaration, Bergen, Turin, the University Charter for Sustainable Development and many more [18] [20]. In line with these needs, universities committed to environmental issues have sought to create program participation, implementation, and management of environmental systems , such as ISO 14001 EMS, and create environmental academic lines and undergraduate and graduate programs, among many other things [21] [22]. Some degrees and branches of engineering dedicated to environmental matters are covering more and more space in universities. One of the most common degrees? in Latin America is environmental engineering, which has a wealth of curricular uncertainties that should be investigated to increasingly strengthen its graduates, so they can face the changing environment on a planet increasingly in need of solutions to its environmental problems [23].

2.2 Basis for evaluating the existence of EE in environmental engineering curricula.

To analyze environmental engineering curricula in Colombia, we took the recommendations of the ABET organization for the formulation of these programs and skills that the engineer must have, among them: "*Apply knowledge of mathematics through differential equations, probability and statistics, physics based on calculus and chemistry (including stoichiometry,*

equilibrium and kinetic)" "Master an earth science, biological science and fluid mechanics", "Formulating balances of mass and energy, transport and analysis of target substance in the air components, water and soil and between these", *"Carry out laboratory experiments, analyze and interpret data in more than one relevant area of environmental engineering"* [24].

It also was taken as a premise that the study plan is the materialization of the curriculum and declares what is regarded as valid knowledge, dictating criteria of relevance and validity for the discipline, as well as reflecting the interests of the university or institution of higher education [25]. It is important to note that Colombia has certain peculiarities, which give a different context to this research, because curricular revisions, updating curricula, and the inclusion of innovative topics are rare occurrences, due to the lack of teachers or experts dedicated to these issues, especially in engineering programs [26] [25] [27].

For methodological development, public information was taken from a sample of 6 Environmental Engineering programs in Colombia, selecting recognized universities with high quality accreditation by the Ministry of Education. The environmental engineering program is currently offered at 46 universities in this country, but only 14 are accredited; Universidad Santo Tomás (USTA), University Business School (EAN), School of Engineering of Antioquia (EIA), University El Bosque (UBOSQUE), University of Antioquia (UDEA), Free University (UNILIBRE), Technologic of Antioquia (TDEA) Pedagogical and Technological University of Colombia (UPTC), Universidad Autonomy de Occident (UAO), Universidad de la Salle (USALLE), Universidad de Los Andes (UNIANDES), National University of Colombia (UNAL), University of Medellín (UDEM) Technological University of Pereira (UTP). High quality accreditation for higher education institutions indicates the quality of academic processes, both substantive and adjective, is voluntary and is governed by law, and ensures that both universities and programs meet national and international educational quality standards [28]. Of the programs outside of this list, tradition highlights that which is offered by the University of Boyacá, which is the oldest in this country [13].

Academic or subject areas were reviewed, as was the existence of environmental education in the objectives proposed by each university for environmental engineering. Once reviewed, the information was corroborated with students of these programs through surveys, verifying the inclusion of AD in their training.

2.3 Analysis of environmental education in environmental engineering in Colombia.

In a survey of 300 students in environmental engineering was performed in order to contextualize the respondents, the number of respondents per university was as follows: USTA; 70, UNILIBRE; 25, UNIBOSQUE; 65, UB; 40, UPTC; 70, UNISALLE; 30. It was necessary to disclose the information and definition of the EE by the Ministry of Environment, Housing and Territorial Development and the Ministry of Education of Colombia. This is important because it gives border conditions and frames the survey, since the EE can sometimes be distorted with environmentalism or curricular activities within subjects and only as a secondary or side effect is similar to an EE action. The definition for respondents was in line with the policy of EE Government of Colombia: "Environmental education should be considered as the process that allows the individual to understand the interdependence with its environment, from reflective and critical knowledge of its biophysical, social, political, economic, and cultural reality so that the appropriation of concrete reality can be generate attitudes of appreciation and respect for the environment in him and his community " [29]. Students were asked 18 questions, including 4 control questions to avoid bias. Questions fall into three groups: knowledge in EE, EE training in their curricula, and perception of the importance of environmental education in their training.

The age range of environmental engineering students surveyed is between 16 and 30 years. Of these, 93% are between 16 and 23, with the most representative respondents being 20 and representing 26.7% of those surveyed. This age range is characteristic of the Colombian student population usually finishes secondary education at age 15 and begins university education at age 16; in this case, it is typical for students to graduate as engineers at age 24.

3 RESULTS AND DISCUSSION

Curricula and subjects offered in all semesters were analyzed to determine which directly or indirectly address the principles of EE. Accordingly, some academic spaces were found where it is essential to use EE tools: for example, in the subject waste management, which is common in all programs of environmental engineering. This subject should include issues through environmental education as they are; source reduction, sorting, reuse, recycling and many other tools that seek to minimize the disposal of

solid waste. Other academic spaces do this tangentially, especially in environmental management, through the teaching of ISO 14001, which is equally common in all of the reviewed plans of study. In the same way, subjects such as environmental policy, ecology and environmental impact were found, but on average they represent only 5% of academic spaces in the curriculum, with the Pedagogical and Technological University of Colombia with the most representation, at 8%.

Paritcularities were found in the curricula where there are academic spaces dedicated exclusively to EE and its promotion. Though it is important to note that it is unrepresentative compared to the rest, in this case the Pedagogical and Technological University of Colombia stands out with 4% was also noted, while its counterpart St. Thomas University and the Free University do not have exclusive spaces for training or promotion of EE. The summary of the quantitative analysis of academic spaces that directly or indirectly addressed in its structure the EE is found in table 1. It is important to note that there is an evident breakdown in the training process aimed at promoting EE, but there is remarkable harmony between the programs of all sample universities that focus on the same matters into own attitudes of EE, particularly the case of solid waste management.

Table 1. Analysis of the designated EE programs in environmental engineering sample academic load.

University offering environmental engineering		Number of subjects with a focus on EE	Number of Academic Credits with a focus on EE	% of subjects with focus on EE	Number of exclusive subjects for EE	% of subjects EE
1	USTA	3	12	5%	0	0%
2	UNIBOSQUE	5	15	6%	1	1%
3	UPTC	4	12	8%	2	4%
4	UNILIBRE	2	6	3%	0	0%
5	UB	3	12	5%	1	2%
6	UNISALLE	3	12	5%	1	2%

In contrast to the above, 99% of students think the environmental engineer must be trained with tools that give him the skills to transform the environment that is degraded by human actions through EE. Another question focused on students' futures as graduates: in this question, 94% of

respondents wanted to be part of projects related to EE. In contrast shows that students corroborate the findings in the table two. Where there is evidence of a curricular deficiency is in the training of the environmental engineer based on the principles of environmental education: 72% of students expressed their desire for environmental education become part of the curriculum, while 17% indicated a possible interest or need.

Moreover, students indicate that environmental engineering programs lack tools to help prepare or train in EE: 65% of them think that their engineering programs do not have this, reinforcing this trend 48.9 % of respondents think that they have never been trained in environmental education strategies as part of their education in environmental engineering.

It is noteworthy that 26.6% of students claim to be prepared or trained in EE extracurricularly. They are voluntarily attending academic and non-academic spaces with content dedicated to EE. Among those most frequently mentioned are forums, seminars, courses and conferences representing 29.8% of respondents. Likewise, 69.1% of students in environmental engineering from universities in the sample say they have conducted environmental education activities: among the most frequent are reforestation, recycling days, lectures in schools, and plans for cleaner production. These mostly they relate to activities within subjects such as waste management and environmental management. In some cases, especially at the University of Boyacá, are carried out in a class called "environmental education".

Environmental engineering, like any other profession, must continuously adapt to the challenges of the environment, and even more so for being born in modern times where every decade represents unprecedented leaps in knowledge. This implies that it should evolve with the needs of the environment, but it seems that the processes of contamination and degradation of natural resources are winning. In this situation the environmental engineer must not only respond from its technical base, which is undoubtedly its support and backbone, but also from the ability he must have to prevent pollution by promoting friendlier attitudes to the environment, which seek to conserve natural resources and their sustainability, generating a synergy between a technical solution to the process of contamination and mitigation in magnitude using environmental education to those who generate pollution. A best practice observed in the research was the subject of solid waste management, where students begin learning the strategies for waste generators to minimize the amount they

produce. These tools fall into the categories of behavior change and environmental awareness, which are primarily tools of environmental education. This finalizes the subject more to the technical side, giving the tools for designing structures for the use and disposal of the waste that a human population inevitably produces. In this case the student understands perfectly the importance of human actions to mitigate their impact on an uninhabitable environment (generating waste), but if they do not take actions that are based purely on environmental education, even with the technical tools, the cycle is unsustainable.

In all cases reviewed in the sample, a greater proportion of the curriculum is still related to basic sanitation, which responds to the particular needs of the country in recent years, as the coverage of water and sanitation in urban areas for 1995 was only 86.1% and 90.96% for 2010 [30]. However, according to the trend, it is expected that this stage of the country's history has been overcome, since in 2017 the coverage of drinking water and basic sanitation in urban areas was 98.5% [31] [32]. This encourages the curricula of environmental change, adapting and rethinking engineering for the future characteristics of the country, designed to address an increasingly developed and marked need to protect the natural characteristics and potential, especially biodiversity and national water supply, since Colombia ranks 17th in biodiversity and 3rd in water reserves in the world and owns 50% of our planet's moors, besides owning 53% of the territory in natural forests, among many other environmental riches [33].

Looking at this future perspective raises the need for more EE in the curricula of environmental engineering, putting them more in line with environmental and contemporary problems, perceiving the context of biodiversity and nature as an asset that must be protected by knowledge and education. This need is reflected in the results of environmental engineering student surveys. Undoubtedly, the engineer who is currently studying in Colombia wants to become a dynamic communicator of knowledge, highlighting the importance of proper use of resources, protection and conservation of unique natural areas in the world. This can be done through the implementation of EE in the curriculum, as an instrument immersed in the syllabus. It has been shown that currently, the curricula of this profession does not respond to the needs and demands their own students and will therefore arguably not be entirely relevant. It is necessary to clarify that the intention of this research is not to say that this type of engineering is not fully responding to the needs of medium or that it is not entirely relevant, but that it should incorporate environmental education more in its foundation as a cross-cutting tool to all learning processes taking into

account the aforementioned example of the subject of solid waste , which is taught in the same way in all universities. These results should be compared broadening the spectrum of research of teachers, managers, graduates of environmental engineering universities and employers in order to know their perceptions compared to the information evidenced in this article.

4 CONCLUSIONS

We can say that the curricula of environmental engineering in Colombia are not relevant enough to meet the future needs of the environment or the demands or current tastes of students in this field, because while students and the country's outlook indicate the need for the environmental engineer to know and manage environmental education strategies, curricula incorporate only an average of 5% of space to these topics.

ESD is a type of education that has not been formally explored in Colombia, because the government policy focuses on the promotion of environmental education. Therefore, ESD is non-existent in the revised curricula.

It was possible to show that there are cases of successful environmental education in the training of environmental engineers and common to all universities that were included in this study, the most notable case is waste management and environmental management. Achieving harmony between EE and technique, this case can be studied in form and pedagogy to propose strategies of articulation between EE and other academic technical spaces, substantially impacting the education of these engineers.

It is important to continue research on this topic and streamline environmental engineering curriculum updating, so that it is relevant to Colombia and to be an aid in the process of sustainable development in which it is framed. Through ongoing evaluation and critical self-evaluation of this engineering, people can generate more knowledge and holistic views which foster proper management of natural resources.

It was shown that there is a lack of training in environmental education among students in environmental engineering, because in the curriculum review, only 1% of space in the curriculum was, on average, dedicated exclusively to EE while in about 5% of spaces on average, EE was partially covered, while among the students surveyed, 72% mentioned that environmental education should be part of the curriculum.

In reviewing the syllabi, it was observed that each university projects its mission or goals in engineering education, in some cases in Christian teaching, humanist education, pedagogy, and economics, among others, reflected in 100% the content of the subjects. If the environmental feature formed part of the mission or objectives of universities, this would also be within the syllabus, making it easier for teachers to engage and spend time on EE.

It was possible to generate a breakthrough in research of curricula in environmental engineering in Colombia. There are few, if any, studies like this, since there is no information similar to that raised in a database research. This is due in part to its short history and the lack of momentum to evaluate educational trends such as EE or ESD curriculum with an environmental focus.

REFERENCES

[1] S. B. Sosa, R. I. Márquez, A. Eastmond, M. E. Ayala and M. A. Arteaga, "Higher education and environmental literacy in southeastern Mexico," *Universidad y Ciencia,* vol. 26, no. 1, pp. 33-49, 2010.

[2] J. B. Salgueirinho Osório de Andrade Guerra, J. Garcua, M. De Andrade Lima and S. Borges Barbosa, "A proposal of a Balanced Scorecard for an environmental education program at universities," *Journal of Cleaner Production,* vol. 172, no. 1, pp. 1674-1690, 2018.

[3] E. J. González Gaudiano and J. C. Puente Quintanilla, "El perfil de la educación ambiental en América Latina y el Caribe: Un corte transversal en el marco del Decenio de la Educación para el Desarrollo Sustentable," *Pesquisa em Educação Ambiental,* vol. 5, no. 1, pp. 27-45, 2012.

[4] M. E. Badillo Mendoza, "Environmental education policy in Colombia, 2002-2010," *Revista de investigación agraria y ambiental,* vol. 3, no. 1, pp. 89-96, 2012.

[5] A. Kibbe, F. X. Bogner and F. G. Kaiser, "Exploitative vs. appreciative use of nature – Two interpretations of utilization and their relevance for environmental education," *Studies in Educational Evaluation,* pp. 106-112, 2014.

[6] C. M. Frantz and F. S. Mayer, "The importance of connection to nature in assessing environmental education programs," *Studies in Educational Evaluation,* vol. 41, pp. 8589, 2014.

[7] A. Carleton-Hug and W. J. Hug, “Challenges and opportunities for evaluating environmental education programs,” *Evaluation and Program Planning,* vol. 33, no. 2, pp. 159-164, 2010.

[8] Á. Zsóka, Z. Marjainé, A. Széchy and T. Kocsis, “Greening due to environmental education? Environmental knowledge, attitudes, consumer behavior and everyday proenvironmental activities of Hungarian high school and university students,” *Journal of Cleaner Production,* vol. 48, pp. 126-138, 2013.

[9] R. Lozano, “ncorporation and institutionalization of SD into universities: breaking through barriers to change,” *Journal of Cleaner Production,* vol. 14, no. 9-11, pp. 787796, 2006.

[10] C. P. Ariza and L. Á. Rueda Toncel, “La educación ambiental: una mirada desde el contexto universitario,” *Boletín Virtual,* pp. 116-124, 2016.

[11] A. Alvar Ezquerra, “La universidad en la encrucijada,” *Magriberia ,* pp. 25-44, 2011.

[12] J. Paz Maroto, La medicina y la ingeniería en la salud ambiental, Madrid: Instituto de España Real Academia Nacional de Medicina, 1968, p. 43.

[13] G. García Durán, “Surgimiento y evolución de la Ingeniería Ambiental en Colombia,” *Revista de Ingeniería,* vol. 26, pp. 121-130, 2007.

[14] A. C. Molano Niño and J. F. Herrera Romero, “La formación ambiental en la educación superior: una revisión necesaria,” *Luna Azul,* vol. 39, pp. 186-206, 2014.

[15] H. F. Guerrero Sierra, M. E. Vega and P. M. Acosta Castellanos, Estudios sobre medio ambiente y sostenibilidad: una mirada desde Colombia, Tunja: Universidad Santo Tomás, 2019.

[16] D. Quiva and L. Vera, “Environmental Education as a Toolto Promote Sustainable Development,” *Telos,* vol. 12, no. 3, pp. 378-394, 2010.

[17] A. Meyer, “Does education increase pro-environmental behavior? Evidence from Europe,” *Ecological Economics,* vol. 41, pp. 108-121, 2015.

[18] T. S. A. Wrigth, “Definitions and frameworks for environmental sustainability in higher education,” *Higher Education Policy,* vol. 2, pp. 105-120, 2002.

[19] R. Lozano, “Towards a more effective and efficient SD incorporation into the universities,” *GUNI Higher Education in the World 4: Higher Education's Commitment to Sustainability from Understanding to Action,* pp. 31-35, 2012.

[20] D. Tilbury, “Higher Education for Sustainability: A Global Overview of Commitment and progress,” in *Education in the World 4 Higher Education’s*

Commitment to Sustainability: From Understanding to Action, Barcelona, 2012.

[21] A. Disterheft, S. S. Ferreira da Silva Caeiro, M. Rosário Ramos and U. M. Miranda Azeiteiro, "Environmental Management Systems (EMS) implementation processes and practices in European higher education institutions – Top-down versus participatory approaches," *Journal of Cleaner Production,* vol. 31, pp. 80-90, 2012.

[22] Y. Leon Fernández, A. Gomera, M. Antúnez, B. Martínez Escrich, F. Villamandos and M. Vaquero, "Enhancing environmental management in universities through participation: the case of the University of Córdoba," *Journal of Cleaner Production,* vol. 172, pp. 4328-4337, 2018.

[23] W. J. Mitsch, "What is ecological engineering?," *Ecological Engineering,* pp. 5-12, 2012.

[24] ABET, "Criteria for accrediting engineering programs : Environmental and similarly named Engineering programs.," Engineering Accreditation Commission, Baltimore, 2017.

[25] V. Balza Franco, "Formulación y diseño de un modelo de vigilancia tecnológica curricular en programas de ingeniería en Colombia," *Revista de la Educación Superior,,* vol. 45, no. 179, pp. 55-77, 2016.

[26] F. Díaz Barriga, "Aproximaciones metodológicas al diseño curricular hacia una propuesta integral," *Tecnología y Comunicación Educativas,* pp. 19-39, 1993.

[27] V. Balza Franco, A. P. Caro Ospina and W. Navarro Zúñiga, "Una mirada a la producción académica de investigación formativa de pregrado en el área de operaciones y logística de ingeniería industrial en colombia," *Educación en Ingeniería,* vol. 10, no. 20, pp. 75-87, 2015.

[28] Consejo Nacional de Acreditación, "Lineamientos para la acreditación institucional," Bogotá, 2015.

[29] Ministerio de Eduación Nacional; Ministerio de Ambiente y Desarrollo Sostenible, "Política Nacional de Educación Ambiental," Bogotá, Cooperativa Editorial, 2002.

[30] Comisión de regulación de agua potable y saneamiento básico, "20 años. Regulación de los servicios domiciliarios de acueducto, alcantarillado y aseo en Colombia," Bogotá, 2013.

[31] Contraloria General de la Republica, "Gestión y resultados del sector de agua potable y saneamiento básico con enfasis en los recursos del sistema general de participaciones 1994-2017," Bogotá, 2018.

[32] H. F. Guerrero Sierra, M. E. Vega and P. M. Acosta Castellanos, Estudios sobre medio ambiente y sostenibilidad: una mirada desde Colombia, Tunja: Ediciones USTA, 2018, pp. 215-249.

[33] Ministerio de ambiente y desarrollo sostenible, “Logros y recomendaciones del sector ambiental,” Gobierno de Colombia, Bogotá, 2018.

[34] J. García Carrasco and A. García del Dujo, Teoría de la educación. Educación y acción, Salamanca: Universidad de Salamanca, 1996.

[35] L. García Aretio, M. Ruíz Corbella and D. Domínguez Figaredo, De la educación a distancia a la educación virtual, Barcelona: Ariel, S.A., 2007.

[36] V. Balza Franco, A. P. Caro Ospina and W. Navarro Zúñiga, “Una mirada a la producción académica de investigación formativa de pregrado en el área de operaciones y logística de ingeniería industrial en Colombia,” *Educación en Ingeniería,* vol. 10, no. 20, pp. 75-87, 2015.

[37] Ministerio de Educación - Secretaria de ambiente y desarrrollo sustentable , Educación ambiental Ideas y propuestas para docentes, Buenos Aires : Presidencia de la Republica , 2011, p. 18.