Neuroethics and the Teaching of Ethics in University Engineering Programs*

Neuroética y enseñanza de la ética en los programas universitarios de ingeniería

DOI: https://doi.org/10.11144/Javeriana.iued28.nteu

Andrés Mauricio Ponce Correa [a]
Corporación Universitaria Minuto de Dios sede Bello, Colombia
ORCID: https://orcid.org/0000-0003-4353-9439

Rosa Elvira Correa Gutiérrez
Universidad Nacional de Colombia sede Medellín, Colombia
ORCID: https://orcid.org/0000-0003-2128-384X

Alexander Alonso Ospina Ospina
Fundación Universitaria Católica del Norte, Colombia
ORCID: https://orcid.org/0000-0003-4732-6481

Received: 15 december 2020
Accepted: 06 february 2024
Published: 30 december 2024

Abstract:

This article presents a reflection on the teaching of ethics in engineering programs with a proposal from a neuroscientific approach. Moreover, the main concepts and methodological guidelines that are key for the design of courses and activities related to the teaching of ethics in engineering are described. For this qualitative descriptive study, a systematic review of the literature in scientific databases on the teaching of ethics from 1996 to 2024 was conducted. From this search, the most pertinent articles were chosen, and these enabled us to reflect on neuroethics and the teaching of engineering ethics, ultimately describing the main concepts and recommendations that are relevant for the teaching of engineering ethics.

Keywords: Engineering Ethics, Neuroethics, Moral Reasoning.

Resumen:

Objetivo: este artículo presentó como objetivo analizar la enseñanza de la ética en carreras de ingeniería a través de un estudio documental histórico y con una propuesta neurocientífica. En esta, se describen los principales conceptos y lineamientos metodológicos que son clave para el diseño de cursos relacionados con la enseñanza de la ética en la ingeniería. El estudio aborda diversos estudios sobre la enseñanza de la ética y el estado de los currículos en la ingeniería.
Materiales y Métodos: investigación de enfoque cualitativo tipo descriptivo, diseño de investigación documental, con revisión sistemática de cincuenta y siete artículos en bases de datos científicas sobre la enseñanza de la ética desde 1996 hasta 2024.
Resultados y discusión: los artículos revisados establecen la necesidad de profundizar en la enseñanza de la ética en la ingeniería, innovando con nuevas metodologías, a través de una ética práctica y de una ética aplicada y con apoyo de la neurociencia, teniendo en cuenta no solo los procesos emocionales y motivacionales, sino también los procesos mentales, que incluyen la empatía, la cognición social y el razonamiento moral, siendo importante la incorporación de casos de estudio reales.

Palabras clave: ética en la ingeniería, neuroética, razonamiento moral.

Introduction

This study aimed to analyze research focused on the teaching of ethics in engineering. Through a qualitative, descriptive methodology and a systematic study, fifty-seven articles from 1996 to 2024 were analyzed using the following two categories were established: 40 units of analysis were classified in the category of need for training ethics in engineers, and 17 units were classified in the category of methodology for teaching engineering ethics.

Author notes

[a]Corresponding author. E-mail: andresbremen@yahoo.com

The analysis revealed that some of the studies that have been conducted since 1996, such as the investigations of [1] and [2], refer to problems derived from the lack of ethics in engineering and how these problems derive from the training of engineers in universities.

In other studies from the beginning of the second millennium, such as that of [3], the importance of ethical training in the 21st century was noted as a priority need, especially in the training of engineers, to help them grow into upright professionals who have "convictions that generate a social commitment to their country, promote the ethics of the profession, scientific and civic honesty, as well as the sense of creativity, conservation and enrichment of national values and the best universal traditions" (p. 2).

[4] argued that engineering ethics has several fundamental confusions about what "ethics" means in engineering, what it means to be an engineering professional and what it means to be an engineering professional. Over the years, the confusions involved in the engineering discipline have not been achieved and affect engineers' training.

According to [5], the first important step in addressing the problems of ethics in engineering is to innovate; in his time, this raised the issue of the need to review study plans, which is still imperative today. Relatedly, it suggests addressing the training of ethics in engineering, with case studies, seeking its greatest application to real life.

[6] proposed that both teachers and students have agreed that the teaching of engineering was based purely on technical components, a training totally dissociated from human training, which highlights the need to include a training ethics in the engineering curriculum.

[7] discussed a preventive ethic, which is understood as the set of actions aimed at avoiding public harm, and an aspirational ethic, which refers to the promotion of personal motivation toward human well-being. In the teaching of ethics in engineering, this means that a pedagogy based on the incorporation of rules is not as effective as generating positive actions through motivation.

[8], in a reflection for the Colombian Association of Engineering Faculties (ACOFI), speaking of the deterioration of the moral infrastructure of engineers in Colombia to date, mentioned how the ongoing moral anarchy and morality crisis in engineering have threatened to hit rock bottom. This has led to a continuous questioning of the ethics of the engineer in Colombia due to the permeability of corruption, as an example, (p. 32), and this author noted that engineering ethics should be addressed in universities and not with the study of theory or discussion of codes of ethics, but with the study of situations and specific cases of real life. Additionally, university professors play a central role in the ethical training engineers, as they not only impart science and knowledge but also serve as models and educators.

For his part, [9], on the basis of the list of competencies of the European Higher Education Area (EEES), referred to ethics as a key competence in the technical teaching of engineering, demonstrating how teaching has focused more on training engineers competent from the technical and not from the human and ethical. In this sense, it is emphasized that ethics is transversal for the training of engineers from a purely scientific point of view and that teachers also have to prepare themselves in methodologies for teaching ethics.

[10] proposed an alternative for an ethical formation that is based on three components: alterity, will, and induction in ethics. These must enter the educational model transversally and are linked to the hidden curriculum to strengthen the processes of training in ethics (p. 109). Otherness allows one to put oneself in the place of others and think about their well-being, will or volunteerism; it allows activities to help others; and induction allows the student to incorporate ethical values through academic activities that also strengthen the conceptual part.

[11] explained from the comparative analysis of 120 study plans, that moral education in engineering, still to date, remained absent in the university curriculum. Although the teaching of ethics had gained space in the curriculum, its didactic development was still pending (p. 131). This study highlights the need for more importance to be given to the ethical training of university students in engineering programs.

In their book, Ethics for Engineers, [12] noted that most engineering curricula focus on technical aspects and forget about humanistic content, such as ethics. With respect to this gap, the authors, from the perspective of the Mexican context, which is similar to the Colombian context, emphasized the need for humanistic and ethical training in engineering through renewed methodologies that incorporate a collaborative learning perspective through studies of cases. In this way, engineering professionals should develop skills to solve difficulties with a sense of responsibility that positively impacts the quality of life of the communities.

[13] investigated the social representations of teachers and students in terms of ethics in a higher education institution in Cúcuta, Colombia. In this study, the researchers explained the need for pedagogical reform on the basis of justice and the community. In this sense, ethics is essentially social and aimed at improving the living conditions of the community; moreover, engineering has great potential, so it is necessary to direct students to develop an ethical conscience of their actions so that they can make the most pertinent decisions in their professional practice.

[14], in a review of 135 articles published from 1980 to 2016, reported that education on engineering ethics should include complex ethical reflections, which include risk management and the approach to ethical issues in engineering education.

When examining the teaching of ethics at some universities in the city of Medellín, [15], noted that at the National University of Colombia, Medellín headquarters, ethics training is not evident in the curricular plans as a compulsory or disciplinary subject but is offered as a component of free choice for all undergraduate careers (p. 9).

[16] developed a guide on ethics and professional conduct for managers of engineering projects in Colombia. For the construction of the ethical guide, they conducted a literature review on codes of ethics, in which they identified fundamental values to be followed by professionals who guide their actions toward ethical conduct, such as integrity, honesty, equity, respect and responsibility, that are key in the design of methodologies for the teaching of ethics.

Engineering societies such as the National Professional Council of Engineering (COPNIA) [17] created by Law 94 of 1937 in Colombia, an entity created with the function of controlling, inspecting and monitoring the practice of engineering in Colombia, indicate that ethics in engineering is not an individual matter. Specifically, teachers must join the ethical debate inside and outside the classroom, not turning ethics into a subject, but making ethics have a practical dimension, encouraging coresponsibility between the teacher who teaches it and the professional who applies it (p. 12). Thus, according to COPNIA, ethics is an issue that must be continuously improved "in the academic training and ethical training of human resources, as an irreplaceable factor to recover the ethical culture" (p. 12) because, at the moment, for engineers to practice their profession, "they face ethical dilemmas that force reflection on the moral acts of social groups (p. 11).

According to [18], the commitment and responsibility in the training of engineers materialize mainly in the exercise of their teachers, who must assume ethics and morals as elements of their substantive functions. To guarantee the ethical learning of the profession itself, competent teachers are needed not only in theoretical and technical but also in moral areas (p. 4).

According to [19], the problem of ethics in engineering has existed for decades without substantial advances in its solution. The problems of corruption in various works, which have led to collapses and deaths, have been noted. Ethics is an educational responsibility, the ethical debate must take place inside and outside the classroom, and ethics cannot be allowed to remain a pending issue in engineering programs. It is necessary to innovate in the teaching of ethics in engineering from a practical dimension, which includes the study of cases and moral dilemmas and is based on problems applied to the context.

According to [20], the engineer is currently part of a global vision for sustainable development, which is why it is necessary to include the discussion of sustainable development in engineers' ethical training. This,

in addition to the development of professional ethics, can even improve the solutions to technical and social problems.

[21], also noting sustainable development as a global vision, stated that the integration of certain essential elements in ethical training, such as dignity, the same people, prosperity, the planet and justice as a common good, should be supported. The ultimate goal is that the actions of the engineer benefit all citizens, as well as nature and its various ecosystems.

[22] noted that, with regard to accelerated evolution, the opportunity to reflect on the ethical aspects involved in engineering as a reasonable requirement, which is essential for engineers to learn to identify ethical issues in their workplace before economic accelerationism is imposed, increasingly hinders ethical reflexivity and weakens critical judgment, for which the impulse of the teaching of ethics is needed, which impacts sensitivity, stimulates a significant improvement in moral reasoning skills and leads to decision-making ethics (p. 226).

The abovementioned articles, as well as those by other authors reviewed in this documentary research, highlight the importance of considering the teaching of ethics not as an additional subject but as an element of training that is essential to guarantee upright professionals in training programs (Table 1).

TABLE 1
Other authors who have determined the need for a transformation in the teaching of ethics in engineering over several years

Author	Year	Conclusions
[23]	2010	The formation of values among engineers with commitment from the universities is urgently needed.
[24]	2012	The development of moral reasoning is strongly linked to everyday behaviors; thus, it should be included in the curricula.
[25]	2013	Students should be exposed to as many ethical role models in professional engineering as possible; it can be much more beneficial if modeling of ethical behavior is received by academic engineering staff.
[26]	2015	A subject with bioethical considerations that is necessary for the exercise of the profession should be considered.
[27]	2016	Engineers need to receive ethical training because of the social implications of their work.
[28]	2019	Due to the gaps in ethics education in engineering undergraduate programs, teachers' profiles and training need to be reviewed.
[29]	2019	Engineers need to understand elements such as engineering ethics and work ethics.

Source: Own creation from the documentary review.

Thus, a curriculum with a defined ethical framework that includes ethics teaching methodologies, either through courses, open professorships, diplomas, case studies or other activities, should be established to train ethical engineers.

Ethical Pedagogy in Engineering

The systematic analysis enabled us to observe that the pedagogy of engineering ethics has been developing since the 1970s and began in the United States, moving then in Germany, the Netherlands, Sweden, France, the United Kingdom, Canada, Australia, Japan, Russia and other countries. In China, it has developed since the 1990s. Chinese academics have responded to globalization through discussions of ethics in engineering.

Since this time, the ethical application of practical engineering has been considered; more emphasis has been placed on the practical application of ethics, rather than the ethical theory itself, which "emphasizes the reasonable practice of technology based on moral reasoning" [30].

Through the present study, we were able to observe that there is still a critical gap in the pedagogy of the ethics of engineering aimed at the training of ethical engineers. The codes of ethics, which give a first line of what the ethical behavior of engineering should be, are not sufficient and need to be transcended; ethical skills need to be provided to address the great ethical challenges of our time [31].

Engineering programs that employ innovative methodologies for teaching ethics should include an understanding of ethical and professional responsibility, leading to an understanding of the impact of engineering solutions in a global and social context (Board of Accreditation of Engineering and Technology ABET- EAC, 2003) [30]. Ethics courses in engineering programs cannot be elective and must be taught by engineering professors; they cannot be peripheral courses [31].

[32] argued that "engineering education must instill in its students an early respect and ethical awareness for sustainable development, including an understanding and appreciation of the cultural and social characteristics and differences between the different communities of the world." For example, American education in engineering ethics proposes a series of desirable goals ([30], cited by [1]), such as the ability to recognize ethical problems, analytical skills in key ethical concepts and principles, management of ambiguity, greater ethical sensitivity and better ethical judgment.

One of the most commonly used methods for ethical training in engineering is case studies for understanding particular implications, as well as the needs of engineering students. Many engineering students are not accustomed to dealing with these ambiguities, which often exist in both theoretical and applied ethics. Case studies help students understand the concepts and consequences of ethical decision-making, "how ethical problems can be solved and, in some cases, learn how ethical problems cannot be solved" [5].

Whitbeck [5] described useful case situations for ethical education in engineering, such as the creation of problematic situations, stories of caution in common experiences, and multiple-choice problems to identify morally significant options.

Neuroethics in the Teaching of Engineering Ethics

According to [33], neuroeducation is understood as "the introduction of the neuroscientific study of the brain in learning processes and its possible contribution to teaching". It is a relatively new interdiscipline that was born at the end of the 1990s and is generally called "Mind Brain Education" (MBE) [34]. [34], cited by [33], defined neuroeducation as an interdiscipline and transdiscipline from a greater integration of the sciences of education and the sciences of neurocognitive development. On the other hand, [35], cited by [33], as a transdiscipline of human learning development processes.

Neuroeducation [36] highlights the need to transcend naturalistic and deterministic explanations, which have come to ignore the interdependence between biology and culture. Specifically, according to [37], educational neuroethics aims to adequately bring scientific discoveries to the classroom while keeping in mind the dangers of "neuromyths" that become deterministic and simplistic with respect to reality. Both the "neuroeducational ethics" of [38], cited by [37], and the "educational neuroethics" of [39], cited by [37], seek applied ethics, which is about addressing the potential of education, understanding the importance of neuroplasticity, which can be used from neuroeducation, as the human being is capable of developing an ethics that justifies their conduct, which is not based on "an inherited biological condition but on an ethical justification of another order." In fact, [40], cited by [41], affirms that the objective of neuroeducation is not

only to understand how human beings learn better but also "to determine the way in which they can be teach them to maximize their potential".

In the new approaches to neuroeducation, it is not a question of indoctrinating or training human beings so that they act in a way that the trainer wants but rather an issue of ensuring that the principles of freedom and human autonomy are respected, which constitutes moral neuroeducation, with the goal of the full development of one's personality. Thus, education and, more specifically, moral education are possible because of the unfinished nature of the human brain; owing to its neuroplasticity, the brain is cultivated, and in doing so, it is modified throughout life, which makes the human species capable of directing its own evolution, what [42], cited by [41], has called "coevolution".

Neuroeducation is key for the teaching of ethics, since according to [33], it takes advantage of sensitive periods of learning and takes into account that the preferred learning styles of sensory modalities (VAK) are visual, auditory and kinesthetic, with the help of tests applied to students, who are able to recognize predominant and preferred learning styles [43], cited by [33]. Therefore, the relevance of integrating neuroeducation into the teaching of ethics in engineering students is apparent in the search for a true full human rationality in the moral, beyond interest, prudence and happiness, it is about universal justice and the appreciation of what is valuable by itself [44], cited by [33].

Two key concepts within neuroeducation are neuroethics and neuromorality, which refer to the exploration of the neurological foundations of the processes in the complex and dynamic relationship between the brain and social interaction [45] and have been integrated into social neuroscience, with the potential to align, managing to establish theories and constructions, which provides a better understanding of complex social phenomena [46].

In some studies [47], [48], cited by [49], the cortical and subcortical areas are related in ethical decision tasks. The most recent research on the neural circuit of ethics identified a cortical center of integration related to morale in the ventromedial prefrontal cortex, with multiple connections to the limbic lobe, the thalamus and the brainstem [50], cited by [49].

Multiple studies have shown that limbic regions, such as the left amygdala, work with medial prefrontal and temporal regions, such as the medial prefrontal cortex, the bilateral temporoparietal junction and the posterior cingulate, during moral processing to integrate emotional elements. social and cognitive factors in decision-making [51]. Finally, Gazzaniga, from the perspective of neuroscience, suggests that it is not a question of studying ethics and morals from neural circuits but one of thinking about a universal applied ethics [49] and the importance it has for the teaching of ethics in engineering schools.

In addition, in neuroscience, specifically in the so-called social neurosciences, specific studies on some neurobehavioral aspects of human beings have been conducted. These aspects have also been considered to think, reflect and complement studies from neuroethics and neuromorality and are important for the teaching of engineering ethics. Other aspects include social cognition, theory of mind (ToM) and empathy.

For example, social cognition refers to the cognitive processes used to understand and store information about other people, about oneself, and about interpersonal norms and procedures to adapt efficiently in the social world. This includes understanding the reasons for behavior and dispositions of oneself and other people, social intelligence for attributing the behaviors of others that can be harmful or dangerous, reading the minds of others, and determining the possible thoughts and beliefs of others, which is also known as theory of mind (ToM) or mentalization, a high-level ability [52].

In social cognition, one learns about others through observation, reinforcement and other mechanisms, and impressions about others through social comments. These impressions and attitudes are based on social interaction; they depend on instrumental and conceptual learning and action-result associations, which leads to learning from the responses to these associations [53].

Social cognition is essential for adaptation and social development; it also seeks to understand how the brain processes social information [54] and includes the dimensions of emotional processing, theory of mind

(ToM), social perception, social knowledge, and style or attributional bias. Social cognition allows us to interpret the social signs of others and respond appropriately [55].

The theory of mind (ToM) suggests that human beings are innately predisposed to sensitivity to the subjective states of other people. Likewise, the ability to recognize oneself is implicit with introspective awareness of one's own mental states and the ability to attribute mental states to others [56]. This ability to attribute mental states to others, which is related to moral reasoning, includes the ability to think and feel like others and even imagine being in the other's situation.

Discussion and Conclusions

The analysis revealed that the articles initially focused on the state of ethics teaching from 1996 to 2024, indicating the need to deepen ethical teaching in engineering and make recommendations regarding the need to innovate and implement new methodologies. These are the main themes found in all the articles on teaching ethics in engineering:

1. State of the teaching of ethics in engineering
2. Social problems derived from the lack of teaching ethics in engineering
3. Need to innovate in the teaching of ethics in engineering
4. Need for new methodologies in the teaching of ethics in engineering

On the basis of the present study, the state of teaching ethics in some engineering programs from 1996 to 2024 shows that it is still necessary to implement innovative didactic methodologies and strategies that generate a greater incorporation of behavior ethics in engineering.

Similarly, various studies have proposed ways in which, from universities, the main problems related to ethics in engineering can be addressed and students can be prepared to perform ethically in their professional practice.

The authors conclude that ethical education in engineering must be an applied ethics, which allows a better quality of life for the communities, permeated by an "ethical fabric" (Oscar Diego, cited by [57]), and thus achieves public ethics, the application of ethics as an integral good, which is based on service to the human being and the truth. Since engineers affect the quality of life of all people, the curriculum and study plans of engineering programs need to include training oriented toward collective professional responsibility.

In neuroeducation, knowledge about how the human brain works should be used to make the learning of ethics in engineering more effective, not only from the emotional and motivational fields but also from multiple processes that include sensitivity to others, ethical judgment, cognition and moral reasoning, which include the solution of moral dilemmas, seeking to lead engineering students toward an ethic of sustainable development, which, beyond economic reasons, find survival and well-being in general. An ethic that includes responsibility toward the world and an orientation toward good development and not toward poor development is needed [58], cited by [59].

Thus, ethic's education should lead students to think about the consequences of their own actions for others and for global well-being. As noted by [32], "engineering education must instill in its students an early respect and an ethical conscience for sustainable development".

One of the alternatives that can be effective for the education of engineering ethics is to make use of the different cases presented in the Engineering Ethics Courts, which can be effective, to implement an adequate pedagogy of ethics in engineering.

References

[1] C. E. Harris Jr., M. Davis, M. S. Pritchard and M. J. Rabins, "Engineering Ethics: What? Why? How? and When?", *Journal of Engineering Education*, 85: 93-96, April, 1996.

[2] C. J. Cuartas-Chacón, "Ética, Ingeniería y Universidad", *IyU*, vol. 1, no. 1, pp. 38–44, Dec. 1997. https://revistas.javeriana.edu.co/index.php/iyu/article/view/34100

[3] A. A. Becerra, "Educación en Valores en la Ingeniería Industrial", Conference: Memorias del I Simposio Ing. Industrial I Simposio Internacional de Ingeniería Industrial, noviembre, 2000.

[4] M. Davis, "What's philosophically interesting about engineering ethics?", *Science and Engineering Ethics,* Vol. 9 Issue 3, 353-361, 2003, https://doi.org/10.1007/s11948-003-0032-y.

[5] J. H. Smith, "Topics and cases for online Education in Engineering. *Science and Engineering Ethics 11*, 451-458, 2005. https://doi.org/10.1007/s11948-005-0014-3.

[6] A. I. Del Valle y E. Usategui , "Los valores en la enseñanza de la ingeniería", *Revista de Enseñanza Universitaria*, N. 29, 51-67, 2007.

[7] C. E. Harris Jr., M. S. Pritchard, and M. J. Rabins, "Engineering Ethics: Concepts and cases", Four edition, Belmont, CA, *All Books and Monographs by WMU Authors*. 122. https://scholarworks.wmich.edu/books/122, 200

[8] C. J. Cuartas Chacón and Asociación Colombiana de Facultades de Ingeniería, "Los ingenieros y el deterioro de la infraestructura moral en Colombia", Asociación Colombiana de Facultades de Ingeniería, 2010.

[9] F. Periago Esparza, "La ética como competencia transversal en las carreras de ingeniería: una propuesta pedagógica", *Congreso Internacional de Innovación Docente*, Universidad Politécnica de Cartagena, Cartagena, 6,7 y 8 de julio de 2011. https://www.researchgate.net/publication/277065314_La_etica_como_competencia_transversal_en_las_carreras_de_ingenieria_una_propuesta_pedagogica.

[10] M. del P. Rodríguez Córdoba, M. A. Pantoja Ospina y V. Salazar Gil, "Educación ética en ingeniería. Una propuesta desde el currículo oculto", *Revista Educación En Ingeniería*, 5(9), 104-116, 2012. https://doi.org/10.26507/rei.v5n9.2.

[11] M. E. Guerrero y D. A. Gómez, "Enseñanza de la ética y la educación moral, ¿permanecen ausentes de los programas universitarios?", *Revista Electrónica de Investigación Educativa*, 15(1), 122-135, 2013. Recuperado de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1607-40412013000100010.

[12] E. Chávez Alcaraz y C. S Carbajal Fernández, "Ética para Ingenieros", primera edición, México, Grupo Editorial Patria, 2014.

[13] R. A Pérez Gómez, A. A. Gamboa Suárez y C. A. Hernández Suárez, "La ética en la formación del ingeniero de minas: representaciones sociales de actores educativos, *Revista Tecnura,* 9(44), 201-208, 2015. http://dx.doi.org/10.14483/udistrital.jour.tecnura.2015.2.a15

[14] Y. Guntzburger, T. C. Pauchant and P. A. Tanguy, "Ethical Risk Management Education in Engineering: A Systematic Review", Science and Engineering Ethics, 23(2):1-28, 323-350, April 2017.

[15] S. Valencia Rodríguez, M. Rojas López, y E. Vera Aguirre, "Revisión de Formación Ética en La Universidad Nacional de Colombia, Sede Medellín", *En-Contexto: Revista de Investigación en Administración, Contabilidad, Economía y Sociedad*, Vol. 6, Nº. 9, 2346-3279, 2018.

[16] O. González Ortega y D. González Sanabria, "Elaboración de una guía de ética y conducta profesional para gerentes de proyectos de ingeniería en Colombia", *Revista Investigación En Desarrollo Y Gerencia Integral De Proyectos*, 2(2), 67-93, dec.2019. https://doi.org/10.46659/26191830.v2.n2.2019.134

[17] Consejo Profesional Nacional de Ingeniería COPNIA y Ministerio de Vivienda, ciudad y territorio, "Elementos de Buenas Prácticas en ingeniería, en el sector de agua potable, saneamiento básico", mayo, 2020. https://www.copnia.gov.co/sites/default/files/node/page/field_insert_file/Elementos%20Buenas%20Practicas.pdf.

[18] G. Y. Chávez Arias, A. M. Sarria Palacio y A. Rentería Castro, "Análisis de la aplicabilidad de principios éticos y morales de los docentes en el proceso de formación de ingenieros: una experiencia de investigación en aula para la Universidad Tecnológica Del Chocó, Colombia", *Encuentro Internacional de Educación en Ingeniería ACOFI*, septiembre 2021.

[19] A. M. Ponce Correa, A. A. Ospina Ospina y R. E. Correa Gutiérrez, "Curriculum analysis of ethics in engineering: a case study", *DYNA Rev*., vol. 89, no. 222, Esp, pp. 67-73, september, 2022. Universidad Nacional de Colombia.

[20] M. López Echavarría, "Reflexiones Sobre la Ingeniería y la Formación Ética de los Ingenieros", LÓGOI Revista de Filosofía, No. 44, Año 25. Semestre julio diciembre 2023.

[21] J. J Cubero Marín, "La gestión ética en la Ingeniería del siglo XXI". *Revista Técnica Industrial*, 338: 78-84, julio 2024, doi: 10.23800/10556.

[22] A. L. Terrones Rodríguez y M. Rocha Bernardi, "El valor de la ética aplicada en los estudios de ingeniería en un horizonte de inteligencia artificial confiable". Sophia, Colección de Filosofía de la Educación, (36), pp. 221-245, 2024

[23] L. M. Acevedo Tovar, "Educación, Tecnología y Ética". Investigación educativa. Vol. 14, No 25, enero-junio, 181-208, 2010.

[24] R. Anaya Rodríguez, "El programa de educación en valores y su relación con el razonamiento moral, ideología educativa y liderazgo del centro docente", *Nóesis. Revista De Ciencias Sociales y Humanidades*, Vol. 22, No. 44, 91- 118, 2021.

[25] B. Stappenbelt, "Ethics in engineering: student perceptions and their professional identity development", *Journal of Technology and Science Education. (JOTSE)*, 3(1), 3-10, 2013.

[26] C. Gil R., "El desarrollo sustentable y análisis de su impacto en los códigos de ética ingeniería en dos países latinoamericanos". *Rev. Provincia*, Nº 34, julio – diciembre, 11-24, 2015.

[27] G. L. Capote León, N. Rizo Rabelo y G. Bravo López, "La formación de ingenieros en la actualidad. Una explicación necesaria", *Revista* Universidad y Sociedad, 8(1), 21-28, 2016.

[28] J. A. Olayo Valles, J., E. E. ArmentaVerdugo, Z. I. Castro Borunda y M. A. Caro Dueñas, "Enseñanza de la ética en programas de pregrado de ingeniería: el caso del tecnológico nacional de México". *Ra Ximhai,* Vol. 15, No. 5 Edición Especial Julio diciembre 95-107, 2019.

[29] A. Ban M. Bucur M., "What does engineering ethics involve?", *Scientific Bulletin of the Petru Maior University of Târgu Mureş* Vol. 15 (XXXII) no. 2, P- 31-35, 2018.

[30] G. H. Hong, "Comparison of China-Us Engineering Ethics Educations in Sino - Western Philosophies of Technology", Science *and Engineering Ethics* 21(6), 1609-1635, 2014.

[31] J. Li and S. Fu, "A Systematic Approach to Engineering Ethics Education", *Science and Engineering Ethics,* 18, 339-349, 2012.

[32] J. R. Herkert, "Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering", *Science and Engineering Ethic*, 11(3), 373-385, 2005.

[33] D. Pallarés Domínguez, "Neuroeducación en diálogo: Neuromitos en el proceso de Enseñanza - Aprendizaje y en la educación moral", Pensamiento. *Revista De Investigación E Información Filosófica*, Vol. 72, No. 273, 941-58, 2016.

[34] A. M. Battro, y D. P. Cardinali, "Más cerebro en la educación", Buenos Aires: La Nación, 1996.

[35] H. Koizumi, "Developing the Brain: A functional-imaging based approach to learning and educational sciences", in The Educated Brain: Essays in neuroeducation, A. M. Battro, K. W. Fischer, and P. J. Léna, Eds. Cambridge: Cambridge University Press, pp. 166-180, 2008.

[36] J. De Vos, "¿Dónde está la educación en la neuroeducación? Teoría y crítica de la Psicología Vol. 8, 1-16, 2016.

[37] J. Gracia Calandin, "El fin ético no naturalista de la neuroeducación", RECERCA Revista de Pensamiento y Análisis Vol. 22, 51-68, 2018.

[38] P. Howard Jones, "Introducing neuroeducational research: Neuroscience, education, and the brain from contexts to practice, Paulo Joward Jones, Routledge, 2010.

[39] M. Hardiman, L. Rinne, E. Gregory and J. Yarmolinska, Julia, "Neuroethics, Neuroeducation and Classroom teaching. Where the Brain Sciences Meet Pedagogy?", *Neuroethics,* 5(2): 135-143, 2012.

[40] M. J. Codina Felip, "Neuroeducación en virtudes cordiales. Cómo reconciliar lo que decimos con lo que hacemos", Octaedro Editorial Digital, Barcelona, 2015.

[41] J. Gracia, V. Gonzálvez, "La libertad incorporada como clave para la neuroeducación moral". *Sophia Vol. 26 Universidad Politécnica Salesiana del Ecuador*, 59-82, 2019

[42] J. A. MARINA, José Antonio "Neurociencia y educación". *Participation educative*, (pp. 7-13), 2011.

[43] R. Dunn, and G. E. Price, G. E., "Learning Style inventory", Lawrence: KS Price System; 1984.

[44] A. Cortina, (1998). Hasta un pueblo de demonios: ética pública y sociedad. Madrid: Taurus.

[45] J. Decety, and J. Keenan, "Social Neuroscience: A new journal Social Neuroscience", Psychology Press Ltd. 1 (1), 1-4, 2006.

[46] J. Cacioppo, G. Bernston, and J. Decety, "Social neuroscience and its relationship to social psychology", Social cognition Vol. 28. N. 6, 675-685, 2010.

[47] J. Moll, R. Zahn, R. de Oliveira Souza, F. Krueger, J. Grafman, "Opinion: the neural basis of human moral cognition", Nat. Rev. Neurosci, *6*(10), 799-809, oct., 2005.

[48] J. Moll, R. De Oliveira Souza, y Z. Roland, "The neural basis of moral cognition: Sentiments, concepts, and values", Annals of the New York Academy of Sciences, vol. 1124, pp. 161-180, 2008,

[49] J. A. Álvarez Díaz, "Neuroética: Una introducción", Valenciana *N. 15 ene-junio 2015 Universidad de Guanajuato México*, 157-187, 2015.

[50] D. Marazziti, S. Baroni, P. Landi and L. Ceresoli , "The neurobiology of moral sense: Facts or hypotheses?", *Annals of General Psychiatry*, Mar 6;12:6. doi: 10.1186/1744-859X-12-6, 2013.

[51] S. J. Fede, and K. A. Kiehl, "Meta-analysis of the moral brain: patterns of neural engagement assessed using multilevel kernel density analysis", *Brain Imaging and Behavor*, 1-14, 2019.

[52] F. V. Overwalle, "Social Cognition and the Brain: A Meta-Analysis", *Human Brain Mapping*, 829-858, (2009).

[53] D. M. Amodio, "Social cognition 2.0: An interactive memory Systems Account", *Trensin cognitive Sciences*. January Vol. 23 N. 1, 20-33, 2019.

[54] I. F. Tso, S. Rutherford, Y. Fang, M. Angtadt and S. F. Taylor, "The social branin is highy sensitie to the mere presence of social information: An automated meta- análysis and an independent study". *Plos One*, 1-13. 2018.

[55] D. De Achaval, "Evaluación de la cognición social en pacientes con Esquizofrenia y sus familiares de primer grado no afectados". Belgrano: Universidad de Belgrano, 2010.

[56] J. Decety and P. Jackson, "The Functional Architecture of human Empathy", Behavioral and Cognitive Neuroscience Review. Vol. 3 N. 2 June, 71-100, 2004.

[57] A. J. Rodríguez. "Finlandia: Un modelo ético contra la corrupción". Espacios Públicos, Vol. 20 N. 49 mayo- agosto Universidad Autónoma del Estado de México, Toluca, 1-6, 2017.

[58] J. M. Tortosa, "Mal desarrollo y Mal Vivir: Pobreza y Violencia a Escala Mundial", Esperanza Martínez y Alberto Acosta, editores, Quito, Ediciones Abya-Yala. (2011).

[59] E. Martínez Navarro, "Ética del desarrollo en un mundo globalizado". Veritas, revista de Filosofía y Teología. N. 37 agosto Pontificio Seminario Mayor San Rafael de Valparaiso, Chile, 35-50, 2017.

Notes

* Research article

How to cite this article: A. M. Ponce Correa, R. E. Correa Gutiérrez, A. A. Ospina Ospina, "Neuroethics and the Teaching of Ethics in University Engineering Programs" Ing. Univ. vol. 28, 2024. https://doi.org/10.11144/Javeriana.iued28.nteu