STS in Engineering Education: Contributions From the Engineering, Technology and Society Network

Javier Jiménez Becerra
CTS-LAB FLACSO

Jorge Rojas-Álvarez
University of Illinois

Based on the teaching experience of the Engineering, Technology and Society Network, this paper analyzes the contributions made by STS studies to engineering education. This network offers educational perspectives for engineering students in their first semesters of higher education and has added recently a graduate education approach. This article describes how STS scholarship contributed a comprehensive view of technology, interdisciplinarity and development of critical thinking. Finally, it reviews STS education through active teaching and design in context, and describes the emergence of a graduate certificate program under an engineering, technology and society approach. This program combines engineering, social participation, technological assessment and STS thinking.

Keywords: engineering education, active teaching, design in context, technology social management

INTRODUCTION: STS AND THE ENGINEERING, TECHNOLOGY AND SOCIETY NETWORK

Although engineering may be seen as a bridge between society and technology, there are engineers who are dissatisfied with their social contribution, as they feel that their knowledge is shared inequitably, as they cannot provide it to the less economically advantaged (Baillie, 2022). In many universities and institutions, engineers do not receive the necessary education and training that will support critical thinking, reflective decision making, and the power of action to bring about social change (Riley, 2008). Faced with such dissatisfaction, engineers are looking for an approach that contributes more fully. This is the case with modern infrastructure systems, which are particularly important in shaping society. A failure in a service infrastructure, for example, results in millions of people not having access to the benefits enjoyed by others, usually in developed countries. Engineers such as STS studies play a key role in strategically developing new infrastructure that recognizes the relationship between technology and society, ensuring general access to resources.

In 2002, the Engineering, Technology and Society Network was founded with the purpose of researching and teaching about the role of technology in today's society (Albornoz Barriga et al., 2017). The network has been involved in the development of educational proposals for engineering students in their first semesters of undergraduate education and recently in graduate education. In its origins the network was inspired by the pedagogical developments of a team of Spanish teachers and professors, called the ARGO Educational Group (2003) (Grupo Educativo ARGO). The pedagogical development of the group consists of the study in the classroom of public controversies[1] related to technoscientific issues with social or environmental implications, through which it seeks to understand how various social actors with diverse ideas, opinions or interests intervene (Arribas Ramírez and Fernández García, 2001). The work of the network has given birth to courses such as Technology and Society, Technology and Globalization, Technology and Culture in Latin America, and History of Technology. The network has established collaborations with the Lecture Program Ingenuity, Science, Technology and Society, the Colombian Network of Engineering and Social Development and with several Colombian universities (Gutiérrez Pérez et al., 2018). Through these proposals, RETIS has consolidated "a research and teaching program on the relationships between technological change and social change in Colombia" (Camargo Uribe and García Rozo, 2009, p. 101).

In the case of engineering education, the network considers that this proposal contributes in a significant way insofar as it significantly to the point in which:

> "(…) Today, every engineer must be aware of and understand the processes and dynamics of the technological decisions made within the country. In the same way, it is essential for every engineer to know the effects that such technological decisions have and have had, with the purpose of noticing not only the social importance of his work, but also the importance of the social in it, so that the need to appeal to other formal and non-formal perspectives different from engineering is recognized and stimulated, both in order to promote interdisciplinary work closer to national needs, and to strengthen the social and technological aspects not as mere variables to be taken into account in technological decisions, but as a horizon for the decisions themselves" (Jiménez Becerra et al. , 2003, p. 3).

Other sources of inspiration for the network are the efforts that have emerged worldwide, which some have dominated engineering education, technology and society (Brown et al., 2009; Leydens and Lucena, 2017). For many authors in this field of study, understanding engineering and its professional practice is the path to understanding the role of technology in our society, as it is the profession behind the development and maintenance of technological systems (Hughes, 2005). Furthermore, engineering is deeply linked to innovation processes, as it is the profession in which the physical, organizational and social components that come into play in the innovative process converge (Akrich et al., 2006), and through which we can examine the limits of technical rationality, since what is distinctive about our relationship as a society with technology is engineering materiality (Hynes and Swenson, 2013).

Likewise, as our society becomes more technological, the engineer becomes a central social agent, because his professional practice organizes, designs, creates, manages and implements projects that are changing our society (Claussen et al., 2019). For this reason, the teaching of engineers cannot be decontextualized, since their future work will increasingly have social aspects from which it will be difficult to separate their decisions.

This article seeks to reflect on the contribution of STS studies to engineering education based on the experiences gathered in the general development of courses led by the network. These courses develop an integral vision of technology, interdisciplinarity and generate critical thinking skills. This paper reviews the moment of insertion of the STS theme through active teaching and design in context, and describes how this process led to the proposal of a graduate technology social management approach that puts engineering, social participation and technology assessment in dialogue with STS thinking.

Design of the Courses

The general design of the Engineering, Technology and Society Network courses includes the following elements: objectives, methodology and pedagogical moments.

General Objective

The general objective of the network courses is to analyze the main controversies about a technology in a given context. In this case, for example, the controversies that have arisen around the insertion of the so-called information and communication technologies (ICT) in higher education in Colombia. This analysis, took as a reference the theoretical framework of a systemic view of technology (Pacey, 2014; Vinck, 2012) and as a methodology of social construction of technology (COST) (Bijker et al., 2012).

Through a systemic vision of technology, students contextually problematize ICTs in higher education in Colombia, from the point of view of their main cultural, technical and organizational aspects, inquiring about their identification, mutual influences, and how they prefigure possible characteristics of the technology according to national realities. Additionally, with the methodology of the social construction of technology, we seek to generate discussions on the pertinence and effectiveness of these technologies, as well as to examine each of their relevant actors, identifying their interests, strategies, motivations and major challenges to adopt them in the national context in relation to the conceptualization of the systemic vision initially addressed.

Course Methodology

The course was structured on the basis of two interrelated activities: first, reflection on the context and the problem of the relationship between technology and society; second, the construction of possible scenarios for the implementation of a solution to the technological controversy of the course by means of a contextual design. The general activities of the course are detailed as follows:

- *Theoretical sessions.* They present the field of STS studies, offering examples of the systemic view of technology and methodologies such as the social construction of technology (Gordillo, 2017).
- *Case study.* They apply a methodology that combines the study of the role of ICTs in higher education in Colombia, with a recognition of the relevant social and technological actors by the students. The case is built by means of inquiry in groups of students about the role of each actor, seeking to trace their interests, strategies and motivations, and thus understand how the system works. The case study has dynamics such as discussions, personal and group reflections of what was discussed in the master class.
- *Real-time videoconferences.* Experts in ICT for education present their experiences or non-presential learning sessions are held with observation of videos related to the topic and short writing activities.
- *Writing activities.* They are elaborated based on a problem of higher education in Colombia, online videoconferencing and the systemic vision of technology.

Students identify an aspect to be taken in consideration in order for ICT to contribute in solving the problem of higher education, explicitly referencing the core elements the class materials and linking to a cultural, organizational or technical aspect of their interest (Jiménez Becerra and Rojas-Álvarez, 2015).

Moments of the Course

To achieve the proposed objective, the course is divided into the following pedagogical moments, which include a theme, a specific learning objective, some motivational questions and competencies designed for the students: introduction to the problem of technology and higher education in Colombia, cultural aspects of technology, controversies regarding the case study and organizational aspect.

Introduction to the Problem of Technology and Higher Education in Colombia

In this pedagogical moment of the course, the student is introduced to a systemic vision of technology and the methodology of social construction of technology. In the light of the main concepts and tools introduced in the first part of the course, the panorama of education in Colombia and the role assigned to ICTs are reviewed.

TABLE 1
INTRODUCTION TO THE PROBLEM OF TECHNOLOGY AND HIGHER EDUCATION IN THE COLOMBIAN CONTEXT

Subject	Questions	Target	Competence
The problem of technology and higher education in Colombia	What is technology according to a systemic perspective? What are the differences and advantages of this view versus the traditional one? What elements does the COST methodology propose as relevant to analyze technology? What are the main challenges of higher education in Colombia?	To generate a space for the introduction to a problem and questions about technology and its relationship with society. We start from the personal concerns and experiences of the participants, as well as those raised by scholars on the subject.	The student will develop inquiry and problematization skills in the case of the relationship between technology and society.
Question for real-time videoconferences and video observation: What should be the role of ICT with respect to the challenges facing higher education in Colombia?			

Source: own elaboration

Cultural Aspects of Technology

In this pedagogical moment of the course, we start from the values that tend to be associated with the use of ICT and the demands of the context. The role of ICT in higher education is examined, as well as relevant pedagogical and socio-cultural aspects to be considered.

TABLE 2
RELEVANT CHARACTERISTICS IN ICT DESIGN

Subject	Questions	Target	Competence
ICT: relevant features in their design, pedagogical aspects.	How do teaching processes supported by the use of new technologies can help improve learning practices in higher education? How do ICTs impact learning processes, as well as the goals and forms of teaching? How do ICTs change the traditional way of teaching and learning?	To study a socio-technical system of relevance in the Colombian society, through an active learning methodology.	The student will develop critical thinking based on the relationships between technology and society and the social actors in a given technological system. The student builds a critical reflective view on the role of technology in higher education.
Questions for real-time videoconferencing and video observation: What are the most relevant design features of ICT for higher education? What pedagogies are appropriate for the insertion of ICT in education?			

Source: own elaboration

Controversies Regarding the Case Under Study

A general recognition of ICTs is made, based on the key elements for a reflective evaluation, identifying their characteristics, potentials and limitations. At this point in the course, a systemic vision focuses on the interrelation of the different aspects involved in the insertion of ICTs (a specific context, with clear objectives and relevant actors). Such implementation is feasible if it responds to the elements of the environment, to the cultural, economic, political and social demands of the context in which they are to be inserted.

TABLE 3
ICT: RELEVANT TECHNICAL FEATURES

Subject		**Target**	**Competence**
ICT: relevant features in its design, technical and infrastructure aspects.	What advantages inherent in the design of ICTs can have an impact on improving educational practices in higher education? What opportunities for improvement do these new technologies offer?	To study a socio-technical system of relevance in the Colombian society, through an active learning methodology.	The student will develop critical thinking based on the relationships between technology and society and the social actors in a given technological system. The student builds a critical reflective view on the role of technology in higher education.

Source: own elaboration

Organizational Aspects

This transversal aspect of the entire course includes the relationships between actors as the key to the success of the implementation of any technological tool, since the artifact itself does not educate. If the relevant actors within the educational system, their opinions and interests are not taken into consideration, the implementation will not be successful. The students identify which organizational aspects they consider fundamental for the correct insertion of ICT in higher education in Colombia. It is necessary to focus on the relationships between relevant actors of the technology chosen as a solution to the problem of the technological controversy. For example, in the case of ICT for higher education, key factors such as institutions, professors, students, government, state and civil society are taken into consideration.

REFLECTIONS ON ENGINEERING EDUCATION FROM THE EXPERIENCE OF THE NETWORK

Taking the various evaluative articles it has made to the network throughout its history (Jiménez Becerra et al., 2022; Jiménez Becerra and Rojas-Álvarez, 2016, 2017; Valderrama Pineda et al., 2007), as well as the internal reflections it currently maintains, it can be said that the contributions of the group's activities to the training of future engineers focused on pedagogy, the vision of technology, theoretical foundation, interdisciplinary proposal and the development of critical thinking.

Pedagogical Contribution: Integral Vision of Technology

We understand by pedagogical contribution the contributions of the STS approach that help the student to understand, appropriate and recognize how the relationships between technology and society develop. This also addresses the relevance of the courses for the creation of an interdisciplinary culture and reflection in teaching and university research, which includes both the teaching-learning relationship of the conceptual contents of the courses and the development of skills in the student that will allow him/her, within the academy and in the professional and labor future, to assume a responsible, critical and proactive position in the face of technological and social realities in terms of decision-making and implementation of technologies in Colombia.

Regarding the vision of technology, the experiences of the network members show that having had access to a non-traditional vision or perspective of technology is a critical, contextualized and non-linear approach. Students can identify different approaches by contrast with elements of the traditional view of technology. Students' understanding of these elements can be summarized as follows:

- *Dynamic vs. static vision.* There is a traditional view that shows technological change as the outcome of a series of concatenated events that lead to certain results in a "natural" way. From this perspective, the problem of technology would be mainly how to implement certain advances in certain contexts. On the contrary, the courses show a perspective of technology as a social process in which technology is created by society and it is fundamental that society itself is in charge of its control.
- *Technology as a human phenomenon vs. artifactual vision.* Closely related to the above, the courses broaden the generalized and traditional view of technology according to which technology comprises only artifacts and tools. The courses show technology as an eminently social phenomenon; evidence of this is that nowadays almost all, if not all, of man's activities involve technology or are carried out in relation to it. Man depends on technology and therefore it is essential to reflect on the role assigned to it in society, its limits and scope, as well as to study the ethical, moral and political dimensions of human activities impregnated with technology.
- *Technology as a tool for social construction.* The courses show that the question about technology is also a question about the society that is wanted and the influence that the type of technology used has on the type of society that is being built. For example, depending on the technology a society chooses to supply itself (water), educate itself (Internet), and who is chosen to manage it (multinational companies, the State, communities), aspects such as equality, equity, opportunities and its future development are determined in general terms (Jiménez Becerra and Rojas-Álvarez, 2016).
- *Technology adaptation vs. technology neutrality.* In the courses, future engineers consider that their contents show that not all technology is benevolent nor is it the most adequate. It is necessary to contextualize technology according to the place where it is to be implemented, since technologies that benefit the population in a First World country or in an underdeveloped country may be harmful to the population or useless to solve a particular problem (Fressoli et al., 2013).
- *Technology as a means vs. technology as an end.* Finally, the courses show the importance of assuming technology as a means to solve the different problems of a society if one wants to have a responsible attitude towards it. If one chooses to see technology as an end in itself, one falls into a naive attitude that thinks that social problems will be solved with technological progress (which should never be questioned), and that the solutions to these problems do not depend on people, but on the implementation of the latest technology available for that problem. This implies that the problems of our environment, our city or country are not problems of technological backwardness.

Theoretical Basis

In this aspect, it is considered very important to maintain a clear articulation in the development of the topics, showing their progressive relationship and connecting theoretical aspects that are handled throughout the course.

To this extent, perspectives or theoretical approaches to the topics should be presented in a clear and differentiated manner, as well as concrete information about them. Additionally, the participation of experts, researchers and decision makers in the courses to exemplify how the relationship between technology and society in today's world occurs has awakened the student's sensitivity to the importance of reflecting on the interactions between technology and society, both in macro terms and in everyday life in contemporary society. Therefore, it is necessary to show the how and why of the theoretical foundation and its relationship with the courses.

Interdisciplinary Proposal

One of the central activities of the network is the construction of an interdisciplinary and integrated perspective of the relationship between technology and society. The various reflections cited above consider that this can only be achieved to the extent that the relationship between technology and society as a generic module must include, at least, the following levels of relationship: philosophical-epistemological, dynamic and pragmatic. The first is necessary for the understanding of the others, but especially for the consolidation of solid academic foundations. Here the assumptions and epistemological foundations of why it is important to appeal to a different interdisciplinary and paradigmatic knowledge in contrast to the traditional ways of analyzing and understanding technology and society should be presented.

Secondly, the dynamic relationship is basically about making explicit the difference between a static vision of technology in which it is inert and artifactual, as well as following linear courses of action, and that vision that understands it as a social and logically dynamic and discontinuous process. It is important to show how and where this process is configured, as well as to identify modes of production, maintenance and legitimization of technological knowledge, different uses and conceptions, and to demonstrate to what extent and why this knowledge can be understood as a social process.

Thirdly, the pragmatic relationship is the less abstract level of the relationship between technology and society, a level at which the conceptual elements worked on in the courses can be articulated and at which concrete cases can be analyzed to allow the apprehension of specific knowledge, but especially to allow students to discern ways of making knowledge operative.

Development of Critical Thinking

Through the courses and evaluations carried out (Jiménez Becerra and Rojas-Alvarez, 2016), another central element has been the configuration of practices in higher engineering education. Such practices give rise to the emergence of critical thinking and allow its consolidation as a habit within the university community. The courses help to refine the argumentative tools and skills associated with the encoding, decoding and interpretation of texts that make the construction of knowledge possible.

This perspective has been reinforced in the network with the consideration of the aspects that influence engineering design. These aspects highlight the importance of studying technological development and sociocultural change in Colombia through an active methodology associated with the design of technological systems in social, economic and cultural terms. These dimensions improve the ability to design systems, work interdisciplinary, identify and solve engineering problems, communicate effectively, understand the local and global context and measure the impact of the designed solutions, understand the ethical and professional responsibility of engineering and the engineer, learn to learn and know contemporary issues. The social, economic and cultural dimensions are highly relevant to critical thinking.

All of the above implies including in the courses the reflection on the plurality of visions involved in the construction of technological projects, the difficulty of adopting national policies polarized towards globalization, questioning the notion of technology as an applied science and the neutral and ahistorical perspective of the technological problem. The role of engineering design oriented by STS thinking also emerges as a scenario for thinking about the relationship between technology and society. Through this reflection, an active and dialogic space is created that allows students to build meaningful agreements about the world they want. The development of skills necessary for decision making in socio-technical design and implementation is expected, as well as for the analysis of its implications and impact on society, and the role of engineering in the construction of the world. Reflection on the impact and role of engineering in socio-technical construction is entrusted as a central axis of ethical reflection and learning in being, speaking, creating and sharing knowledge; as well as in the activities to transform themselves and responsibly transform their world (Lleras, 2010).

THE SOCIAL MANAGEMENT APPROACH TO TECHNOLOGY IN POSTGRADUATE EDUCATION

In recent years, the network has participated in the design of STS courses for interdisciplinary postgraduate training whose target population is mostly engineers (Jiménez Becerra and Rojas-Alvarez, 2016). These proposals consider that one way in which engineering can relate to public policies and the demands of the private and productive sector is through STS reflection.[2] For example, cases such as that of the federal institutes in Brazil have made it possible to create an educational proposal for engineering and from engineering that takes into consideration, on the one hand, the basic local needs of the country and, on the other hand, becomes a reference to complement the development of specific competencies and skills required in fields that have to do with infrastructure, design and consulting to clusters and technological processes (Ministério da Educação, 2009).

In a complementary manner, and at the Colombian level, several studies on the profile of engineers have revealed the need to broaden the training processes of professionals to enable the competent design and management of socio-technical systems in their areas (García et al., 2006), and to promote a more holistic and contextualized vision of technology that balances the global and local aspects of the productive environment and effectively incorporates interdisciplinary teams in engineering projects (Osorio Marulanda, 2008).

Therefore, the value of offering a postgraduate program related to engineering, technology and society studies lies in the interaction achieved between careers traditionally considered to have a technical focus and careers with a humanistic focus. Students acquire interdisciplinary knowledge that allows them to diversify their strengths and broaden their range of action. The teaching of technical skills is not left aside, but rather these are enriched to achieve a more complete academic training that satisfies a labor market that is increasingly involved in decisions that concern both technology and society.

The premise is to awaken in students an interest in design, technology management and its impact on society. It is about teaching students how to make decisions that achieve a balance in the use of technology and social and environmental demands (Thomas and Santos, 2016). For these reasons, the subjects that are designed are varied in their contents, promoting dialogue between engineering and social problems; for example, in terms of government policies on science and technology, cases of successful and failed technological development, as well as the development of infrastructure with prior consultation processes with potentially affected communities.

Through socio-technical analysis, and recognizing the social, cultural, economic and historical contexts present in the various technological players, students are expected to be able to identify, problematize and evaluate transversally and interdisciplinarity the impact of a technological process in a reflective manner and situated to the national reality. The consolidation of this interaction has demonstrated the relevance of the STS theme with the social and technological needs of the country where the graduate program is developed, which allows it to respond to the direct demands of productive sector entities (public or private), since it manages to involve social actors for whom reflection on technology from an STS perspective is relevant in their work environment (technology decision-makers, consultants, professionals associated with the development of clusters, large technological systems, etc.). In this context, a direct relationship between the academy and the productive sectors is established.

Likewise, the consolidation of this interaction allows the STS postgraduate offer to be relevant for some non-governmental organizations in the area of technologies for development, appropriation and transfer of technologies to support social development processes. On many occasions, due to their international contributions, these organizations seek training offers where the relationship between technology and society in development contexts is worked on, from a specific transdisciplinary perspective, usually focused on the applicability of the knowledge acquired and the “appropriation” of some platform or program for social transformation.

A Constructivist Vision in Engineering

In the case of engineering, the graduate program considers that the development of a constructive vision of science and technology promoted by STS studies is of utmost importance, insofar as it is a profession that is increasingly associated with decision-making, management and implementation of technology; activities that in the 21st century are increasingly related to issues of design in context, ethical reflection and interdisciplinary dialogue (Camargo Uribe and García Rozo, 2009; Jiménez Becerra and Bustamante Salamanca, 2006).

For a full understanding of this professional practice, it is necessary to consider the training that engineers receive. For this reason, STS research over the last two decades has emphasized the importance of understanding the relationship between engineering practices and social processes. As our society becomes more technological, the engineer becomes a central social agent, because his or her professional practice organizes, designs, creates, manages and implements projects that are changing our society (Schlierf, 2010). For example, in companies associated with infrastructure issues, engineers play a preponderant role in decision making and it is necessary for them to incorporate a comprehensive vision. STS education creates awareness of the balance that such decision-making must have between technology and social responsibility (Downey, 2008). Engineering education cannot be decontextualized, since their future work will increasingly have social aspects from which it will be difficult to separate their decisions.

STS, Engineering and Social Participation

One of the most relevant consequences of the approach described above is the importance of generating social spaces to promote public participation in the decisions that guide the development of technology, in order to democratize and bring society closer to the responsibilities involved in the growing use and implementation of technology, which cannot be done without understanding technological practices such as engineering.

Reflecting on the social role assigned to technology is fundamental, because to the extent that technology is considered from a modern perspective, and no critical position is taken towards it, it prevents the existence of a social conscience around artifacts and their consequences. In this sense, STS studies call on society to consider in a more concrete way the ends toward which technologies are directed and seek a better understanding of them in terms of their consequences for contemporary society. It is also considered important to assume and socially generalize an adjusted vision of technology based on the demystification of the basic principles that support the inherited vision of technological development (Organization of Ibero-American States, 2001). These principles are:

- The more science and technology there is, the greater the public and social benefit. public and social.
- Scientific information is objective information that provides truth through specific rules and laws.
- Knowledge generated at the frontiers of science is autonomous with respect to its moral and practical consequences in society.
- The myth of authority: scientific research is considered to provide an objective basis for resolving the disputes generated by developments in science and technology.
- The myth of the endless frontier: new scientific and technological knowledge is considered to be autonomous with respect to its practical consequences in nature and society.

In contrast to such principles, it is considered important to assume critical, interpretative and evaluative approaches that show that any technological production, like other cultural achievements, configures cultural systems through networks of meaning. This happens because the fundamental qualities of a cultural system in which technology intervenes are mediated by artifacts, techniques and material constructions; and together they establish a symbolic environment of conceptualizations, interpretations and legitimations that make such system viable (Medina, 2001). For this reason, technology seen from the STS approach, far from being neutral, reflects the plans, purposes and values of our society, so that the criteria contributed by scientists and engineers must be put into dialogue through community participation in all technological decisions.

STS, Engineering and the Evaluation of Technologies

From the STS perspective, the great technological and scientific achievements of the twentieth and twenty-first centuries have demonstrated their great social value, but they have also revealed their capacity to cause serious harm to human beings and enormous environmental disasters. The criteria of efficacy and economic efficiency cannot be the only patterns that guide technological development. The STS perspective shows that, in the assessment of technological development proposals, it is important that other criteria also be taken into consideration and demands that decisions on technological developments be open to public debate to allow the participation of all those involved and affected (Gutiérrez et al., 2021).

Technology assessment is therefore fundamental to the STS approach. For example, before defining the route of a road (or deciding that a certain option is better than rail as a solution to transportation problems), installing a hydroelectric plant for energy production, approving experimentation with new medicines, or planning the future of an urban space for the growth of a city, the foreseeable effects of each of the options on the environment and people's lives must be evaluated. For each of these technological development decisions, there are various alternatives, each of which may have different costs and consequences.

In many cases, classical technology assessment has been reduced to analyzing the equation between the costs and effects of each option in order to choose the most appropriate one. In this sense, the evaluation of the consequences of a technology tends to be identified with the evaluation of the impacts and their eventual acceptance in terms of the expected benefits of that technology. However, it is not examined whether the benefits of a certain technology outweigh its negative effects, nor is it looked at whether only technical criteria account for these problems (Lleras Manrique et al., 2016).

STS postgraduate programs propose to generate constructive evaluation models of technologies that seek to encourage the participation of the various social actors. These models seek to involve social actors not only in the assessment of the implementation of a given technology, but also in its design process. They are models that seek to anticipate the effects of a given technology and incorporate not only the criteria of experts (Valderrama Pineda and Jørgensen, 2018).

It is a commitment to public participation at all levels of technological development and seeks democratization and social participation as its core. To make participation possible, it is necessary to seek mechanisms that allow social actors to be informed and interested in issues related to the consequences and effects of a given technological development. The importance then of a literacy in STS issues that allows us to understand in a contextualized and daily way the positive and negative effects of technology is a condition to make possible public participation that democratizes decisions on technological developments (Jiménez Becerra et al., 2020).

In the case of engineering, the inclusion of the STS vision allows, both at the level of training and professional practice, to understand the importance of generating interdisciplinary technology assessment processes, as well as the recognition of the importance of social participation at the design level in the technological systems themselves and their management; for example, the analysis of this perspective of technological systems associated with water, energy, mobility, etc. It can help in the orientation of its technological trajectory in order to make it more democratic, inclusive, socially responsible and aware of its impact on the environment.

CONCLUSIONS

This teaching proposal for engineering education and STS coexists harmoniously with teaching-learning activities of conceptual content and design in context, as well as the development of competencies that provide students with both university and professional-labor skills, in accordance with the objectives already stated, that is, a deeper reflection on technological artifacts, their consequences, history, impact, limitations and possible functions.

The fact that these courses improve argumentative tools and analytical skills linked to a broader perspective for the design and management of technology allows the enhancement of knowledge situated in the practice of engineering with a conscious social influence. Awareness of this aspect contributes to deepen the analysis of the technological task in an autonomous and democratic way. In this way, it contributes to the development of the necessary competences for making socio-technical design and implementation decisions, the analysis of their implications and impact on society, and the role of engineering in building the world.

STS studies in engineering education in the Network of Engineering, Technology and Society have created flexible and autonomous approaches useful for student learning by visualizing different points of view of a technological problem and formulating contextual reflections on the relationship between technology and society. Further systematization of this experience will be necessary from the perspective of the graduate student in terms of the pedagogical contribution, the vision of technology, the theoretical basis of the courses and the development of critical thinking.

ENDNOTES

1. In the configuration of the controversy and in the identification of the actors, an attempt is made to guarantee an adequate balance of positions and arguments in order to encourage and understand the importance of public participation of citizens in science and technology (López Cerezo and Verdadero, 2003).
2. In particular, international experiences such as those of the Grenoble Institute of Technology, the Colorado School of Mines and the Technical University of Denmark, the Universidade Federal de Santa Catarina (Brazil), the Universidade Estadual de Campinas (Brazil) and the Instituto de Estudios Sociales de la Ciencia y la Tecnología of the Universidad Nacional de Quilmes (Argentina).

ACKNOWLEDGEMENTS

Paper first published in Spanish at Revista Iberoamericana De Ciencia, Tecnología Y Sociedad – CTS. You may access here: http://ojs.revistacts.net/index.php/CTS/article/view/329

Translated & edited by American Publishing Services (https://americanpublishingservices.com/).

REFERENCES

Akrich, M., Callon, M., & Latour, B. (2006). *Sociologie de la traduction: Textes fondateurs*. París: Presses des MINES.

Albornoz Barriga, M.B., Jiménez Becerra, J.A., & Rojas Alvarez, J. (2017). *Ingeniería, innovación y tecnología social*. Universidad Nacional de Colombia, FLACSO Ecuador. Retrieved from https://www.uneditorial.com/ingenieria-44-innovacion-y-tecnologia- social-ingenieria-de-sistemas.html

ARGO. (2003). *La controversia de las antenas de telefonía móvil. Simulación educativa de un caso CTS sobre radiaciones y vida cotidiana*. Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura (OEI).

Arribas Ramírez, R., & Fernández García, L.E. (2001). *¿Qué hacemos con la basura? La gestión de los residuos urbanos*. Simulación educativa de un caso CTS sobre el medio ambiente. Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura (OEI).

Baillie, C. (2022). *Engineers within a Local and Global Society*. Springer International Publishing.

Bijker, W.E., Hughes, T.P., & Pinch, T. (2012). *The Social Construction of Technological Systems, anniversary edition: New Directions in the Sociology and History of Technology*. MIT Press.

Brown, J.K., Downey, G.L., & Diogo, M.P. (2009). The Normativities of Engineers: Engineering Education and History of Technology. *Technology and Culture*, *50*(4), 737–752.

Camargo Uribe, J.A., & García Rozo, A. (2009). Pensamiento crítico y aprendizaje activo en ingeniería. *Revista Educación en Ingeniería*, *4*(7), 98–106.

Claussen, S.A., Tsai, J.Y., Boll, A.M., Blacklock, J., & Johnson, K. (2019). Pain and Gain: Barriers and Opportunities for Integrating Sociotechnical Thinking into Diverse Engineering Courses. *2019 ASEE Annual Conference & Exposition*. Retrieved from https://peer.asee.org/pain-and-gain-barriers-and-opportunities-for-integrating- sociotechnical-thinking-into-diverse-engineering-courses

Downey, G.L. (2008). The Engineering Cultures Syllabus as Formation Narrative: Critical Participation in Engineering Education through Problem Definition. *St. Thomas Law Journal*, *5*(2), 101–113.

Fressoli, M., Garrido, S., Picabea, F., Lalouf, A., & Fenoglio, V. (2013). Cuando las transferencias tecnológicas fracasan. Aprendizajes y limitaciones en la construcción de Tecnologías para la Inclusión Social. *Universitas Humanística*, *76*, 73–95.

García, A., Jiménez, J., & Pérez, C. (2006). El perfil del ingeniero electrónico: Competencias como una red de relaciones de actores oferta – Demanda educativa. *Revista Educación en Ingeniería*, *1*(2), 19–25.

Gutiérrez Pérez, Á.A., Molina-Soler, A., Lleras Manrique, E., & Gaitán-Albarracín, N. (2018). Memorias Primer Encuentro Colombiano de Ingeniería y Desarrollo Social: Ingeniería, tecnología y tejido social. *Red Colombiana de Ingeniería y Desarrollo Social*. Retrieved from https://www.researchgate.net/publication/329362000_Memorias_ Primer_Coloquio_Latinoamericano_de_Ingenieria_para_el_Desarrollo_Social_ Primer_Encuentro_Colombiano_de_Ingenieria_y_Desarrollo_Social_Ingenieria_ Tecnologia_y_Tejido_Social/download

Gutiérrez, Á., Lleras, E., & Díaz, J. (2021). Communities of learning as support for one knowledge and innovation management system: A case study. *Systems Research and Behavioral Science*, *38*(4), 527–536. https://doi.org/10.1002/sres.2720

Hughes, T.P. (2005). Technology as Systems, Controls, and Information. *Human-Built World: How to Think About Technology and Culture*, pp. 77–110. University of Chicago Press.

Hynes, M., & Swenson, J. (2013). The Humanistic Side of Engineering: Considering Social Science and Humanities Dimensions of Engineering in Education and Research. *Journal of Pre-College Engineering Education Research*, *3*(2), 31–42.

Jiménez Becerra, J.A., & Bustamante Salamanca, M. (2006). La controversia en la representación del uso de las NTIC en educación: El caso “Red-P” en Bogotá, Colombia. *VI Jornadas Latinoamericanas de Estudios Sociales de la Ciencia y la Tecnología*. Bogotá: ESOCITE.

Jiménez Becerra, J.A., & Rojas-Alvarez, J. (2015). La estrategia del texto argumentativo para una reflexión sobre las relaciones entre Tecnología y Sociedad. In E. Escallón Lagarcha, & A. Forero Gómez (Eds.), *Aprender a escribir en la universidad* (pp. 27–34). Ediciones Uniandes.

Jiménez Becerra, J.A., & Rojas-Álvarez, J. (2016). Aportes a la educación en ingeniería desde una reflexión sobre la tecnología y su contexto: Experiencia del área Tecnología y Sociedad en la U. de los Andes (Colombia). *Anais dos Encontros Nacionais de Engenharia e Desenvolvimento Social*, *13*(1). Retrieved from https://anais.eneds.org. br/index.php/eneds/article/view/412

Jiménez Becerra, J.A., & Rojas-Álvarez, J. (2016). Estrategias de aprendizaje virtual como apoyo al diseño de soluciones tecnológicas en contexto: El caso del curso Tecnología y Sociedad en la U. de los Andes (Colombia). In A.H. Galvis Panqueva, O. Mariño Drews, & L.A. Osorio Gómez (Eds.), *Innovate 330: Investigando la innovación con TIC en Educación* (pp. 408–413). Universidad de los Andes. Retrieved from https:// conectate.uniandes.edu.co/contenido/innovate_330/doc/Innovate-330.pdf

Jiménez Becerra, J.A., & Rojas-Alvarez, J. (2017). Contributions and reflections of the STS studies in the education of engineers in the Colombian case. *7th Research in Engineering Education Symposium*, *1*, 79–86. Retrieved from https://www. proceedings.com/36539.html

Jiménez Becerra, J.A., Bustamante Salamanca, M., & Gutiérrez Pérez, A.A. (2020). Challenging Asymmetries of Power and Knowledge Through Learning Communities and Participatory Design in the Creation of Smart Grids in Wayúu Communities. In C. Martens, C. Venegas, & E.S. Tapuy (Eds.), *Digital Activism, Community Media, and Sustainable Communication in Latin America* (pp. 287–310). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-45394-7

Jiménez Becerra, J.A., Guerrero Hernández, J.C., & García Rozo, A. (2003). *Tecnología y sociedad: El salón de clase como lugar de construcción de la sociedad*. La dimensión social de las facultades de ingeniería. Asociación Colombiana de Facultades de Ingeniería (ACOFI).

Jiménez Becerra, J.A., Rojas-Alvarez, J., & Bustamante Salamanca, M. (2022). Contextualization courses for engineering students based on sociotechnical thinking. *HEAd'22 Proceedings*, pp. 505–512. https://doi.org/10.4995/ head22.2022.14544

Leydens, J.A., & Lucena, J.C. (2017). *Engineering Justice: Transforming Engineering Education and Practice*. John Wiley & Sons.

Lleras Manrique, E., Jiménez Becerra, J.A., Bustamante Salamanca, M., Gutiérrez Pérez, Á.A., & Rojas-Álvarez, J. (2016). Vocaciones, política y aprendizaje: Desarrollo económico y tecnológico en el Tintal de Bogotá. *Anais dos Encontros Nacionais de Engenharia e Desenvolvimento Social*, *13*(1). Retrieved from https://anais.eneds.org. br/index.php/eneds/article/view/397

Lleras, E. (2010). From educating to «pedagogying». *Polis* (Santiago), *9*(25), 235–242. https://doi.org/10.4067/S0718-65682010000100013

López Cerezo, J.A., & Verdadero, C. (2003). Introduction: Science, technology and society studies - From the European and American north to the Latin American south. *Technology in Society*, *25*(2), 153–170. https://doi.org/10.1016/S0160- 791X(03)00027-7

Martín Gordillo, M. (2017). *El enfoque CTS en la enseñanza de la ciencia y la tecnología*. Consejo Nacional de Ciencia y Tecnología (CONACYT). Retrieved from http://formacionib.org/noticias/?El-enfoque-CTS-en-la-ensenanza-de-la-ciencia-y-la-tecnologia-Por-Mariano-Martin

Medina, M. (2001). Ciencia y tecnología como sistemas culturales. In J.A. López Cerezo, & J.M. Sánchez Ron (Eds.), *Ciencia, tecnología, sociedad y cultura en el cambio de siglo* (pp. 69–87). Biblioteca Nueva.

Ministério da Educação. (2009). *Princípios Norteadores das Engenharias nos Institutos Federais*. Ministério da Educação. Retrieved from http://portal.mec.gov.br/index.php?Itemid=&gid=504&option=com_docman&task=doc_download

Organización de Estados Iberoamericanos. (2001). *Ciencia, Tecnología y Sociedad: Una aproximación conceptual*. Organización de Estados Iberoamericanos. Retrieved from http://campus-oei.org/ctsi/ctsaprox.htm

Osorio Marulanda, C.A. (2008). La formación de ingenieros para la participación pública en Ciencia y Tecnología. *ALEXANDRIA Revista de Educação em Ciência e Tecnologia*, *1*(1), 91–108.

Pacey, A. (2014). Technology: Practice and Culture. In R.L. Sandler (Ed.), *Ethics and Emerging Technologies* (pp. 27–36). Palgrave Macmillan. https://doi. org/10.1057/9781137349088_2

Riley, D.M. (2008). *Engineering and Social Justice*. Morgan & Claypool Publishers.

Schlierf, K. (2010). La enseñanza Ciencia, Tecnología y Sociedad (CTS) en el entorno universitario politécnico. La metodología de la descripción de controversias en la Escuela de Minas de París. *Revista Iberoamericana de Ciencia, Tecnología y Sociedad — CTS, 5*(15), 73–93. Retrieved from http://www.revistacts.net/contenido/numero-15/la- ensenanza-ciencia-tecnologia-y-sociedad-cts-en-el-entorno-universitario-politecnico-la-metodologia-de-la-descripcion-de-controversias-en-la-escuela-de-minas-de-paris/

Thomas, H., & Santos, G.M. (2016). Introducción. Tecnologías para incluir: Marco analítico-conceptual. In H. Thomas, & G.M. Santos (Eds.), *Tecnologías para incluir. Ocho Análisis Socio-Técnicos Orientados al Diseño Estratégico de Artefactos y Normativas* (pp. 13–48). Lenguaje Claro Editora.

Valderrama Pineda, A., & Jørgensen, U. (2018). The challenges of teaching sustainable system design. *DS 92: Proceedings of the DESIGN 2018 15th International Design Conference*, pp. 2485–2494. https://doi.org/10.21278/idc.2018.0528

Valderrama Pineda, A., Burbano Valdés, A.E., Escobar Gutiérrez, J.A., & García Rozo, A. (2007). *STS Problems in Colombia*. Memories of the Annual Meeting of the Society for the Social Studies of Science.

Vinck, D. (2012). Pensar la técnica. *Universitas Philosophica*, *29*(58), 17–37.