International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 1 (2019) pp. 212-219

Epistemological Reflection of Science and Technology Leading to the Integration of Science, Technology and Engineering

Jimmy William Ramírez Cano[1], William Manuel Mora Penagos[2]

[1] Universidad Pedagógica Nacional. Interinstitutional Doctorate in Education (DIE-UPN). Calle 72 # 11-81. Zip code 110221. Bogotá, Bogotá D.C. – Colombia.

[2] Universidad Distrital Francisco José de Caldas. Interinstitutional Doctorate in Education (DIE-UD). Calle 13 No. 31 - 75, Edificio de Investigadores, Segundo Piso, Zip code 111611. Bogotá, Bogotá D.C. – Colombia.

Abstract

The article presents a conceptual reflection of some epistemological currents of science and technology. In a brief way, it deals with the thought of eight philosophers of the sciences (Comte, Popper, Kuhn, Lakatos, Feyerabend, Lacey, Bachelard and Hacking), five approaches from the epistemology of technology (instrumentalism, technological determinism, the school of social constructivism of technology (SCOT), Hughes' technological systems and the model of technological change) and the Echeverría's techno-science. It is intended that this reflection can be used as an epistemological conceptual basis in research related to science, technology, and engineering, as well as in the design of teaching in these areas, that is, in the curriculum. In particular, the articulation of science and technology is sought. Finally, as an exercise, a methodological alternative is proposed in which the design of instruments is used as a bridge between science education and technology and engineering education. Methodologically and conceptually it is based on a hermeneutic philosophical conception that used content analysis as data analysis. This paper belongs to an academic discussion that takes part of the doctoral thesis of the first author of this document, under the direction of the second author.

Keywords: Epistemology, Science, Technology, Engineering, Education.

INTRODUCTION

Our societies are permeated by the ideas and experiences that have brought the artifacts product of Science, Technology, and Engineering (STE). It is very likely that their influence will continue to increase in the coming years. Scientific and technological knowledge, skills and artifacts "invade" all areas of modern society. The workplace and the public and private sphere, as well as free time, increasingly depend on new and more established technologies. Consequently, knowledge and skills in STE are crucial for most actions and decisions (Sjøberg, 2002).

However, it is not just the STE products that we need. In our societies, there are other areas in which STE knowledge is required. Sjøberg (2002) suggests industry, universities and research institutions, schools, the labor market and especially, citizens to participate actively and democratically.

This knowledge became the axis of some proposals that seek the integration of the STE, one of them, the classroom. The aim is to strengthen this knowledge and skills needed in various fields. These proposals are not new, however, *there are not many of them* (Gilbert, Boulter, & Elmer, 2000; Gilbert & Stocklmayer, 2001). Within these proposals is the use of the artifact. It can be stated that artifacts, used as instruments, have been important in the development of sciences (Gilbert, 1992a) and have had mutual support that can be translated from the use of the instrument and the experiment in the development of scientific and technological knowledge. In this regard, Davies & Gilbert (2003) suggest that the STE have a high degree of epistemological congruence, however, few studies show it. Consequently, this strength does not translate into integrative proposals of diverse areas. For example, in the field of education, *the epistemological integration of STE has not yet been translated into the curriculum*.

Taking into consideration the statement of Davies & Gilbert (2003) we will seek to present some aspects of the epistemology of science and technology that allow us to understand the positions of the most relevant epistemological proposals of these areas, for the consideration of the authors, during the nineteenth and twentieth centuries. It is expected that the presentation of these ideas will be the conceptual epistemological basis in research related to science, technology, and engineering, as well as in the design of teaching in these areas, that is, in the curriculum. In particular, there is the need for the teacher to know the nature of scientific and technological knowledge, how it is generated, the implicit relations, the manifestations of this knowledge, among others, aspects that will allow reverting this knowledge in the design of its pedagogical action (Moreno & Waldegg, 1998).

The way in which information is approached *is not intended to interpret ideas by questioning them about the truth or about their origin, investigating reasons or looking for causes*. In other words, information is presented in the form of "dogmata" in which *the thesis is accepted and, therefore, the method* (Goldschmidt, 1963). In this order of ideas, this work does not pretend to make a history of the sciences, only to take a short space of time, an idea and present it succinctly.

The epistemology of the sciences will then be presented. It shows what is meant by epistemology and then presents the ideas of Comte, Popper, Kuhn, Lakatos, Feyerabend, Lacey, Bachelard and Hacking in the scientific epistemology. Next, the epistemology of technology is presented with the Feenberg's ideas, technological determinism, the school of social constructivism of technology (SCOT), Hughes' technological systems and the model of technological change, in addition to Echeverría's techno-science. Finally, a methodological alternative is proposed in which the design of instruments is used as a bridge between science education and technology and engineering education.

THE EPISTEMOLOGY OF SCIENCE.

To begin with, epistemology has the task of establishing relationships between separate domains: philosophy, science, technology, and techno-science. This requires questioning them, to determine what their practices are. However*, in doing so, a language is usually used that is not the one with which it has been constructed*, as Poincaré does in science and hypothesis. Poincaré does not disseminate science, but rather epistemology.

Because of the differences that arise at this point, in trying to establish relationships between separate domains, epistemology becomes more of a symbol of divorce, i.e. a questioning rather than an agreement between domains. Figure 1 best illustrates this action. It shows how epistemology studies the domain of techno-science and this, in turn, studies the STE. Then, the STE studies nature from the data obtained when investigating it (Lebrun, 2006).

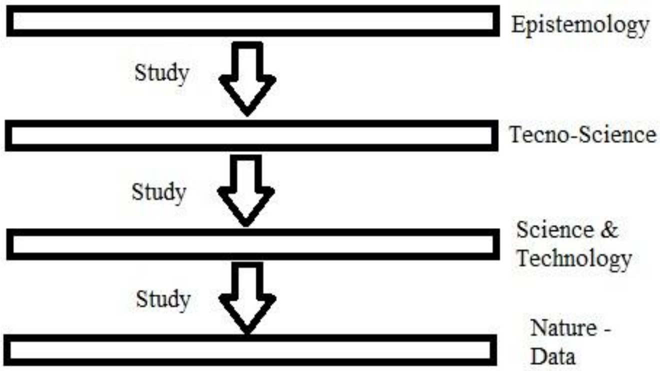

Figure 1. Relationships of epistemology with domains.

Having explained what is understood by epistemology, figure 2 presents a timeline in which the epistemological currents of the sciences and the most relevant facts are synthesized for the consideration of the authors. This will be used as a route to address the different ideas in the text. The first idea to be addressed is the positive philosophy proposed by Augusto Comte. In this philosophical movement, it is affirmed that authentic knowledge is scientific knowledge. This knowledge can only emerge through the use of a scientific method, that is, by applying a procedure that takes Hume's empiricism as its starting point (Hume, 1980). Here, *the method allows us to investigate nature based on experience and sensory perception to construct authentic knowledge*. For this reason, this current is considered experimental and dependent on observation, in addition, its purpose is to contribute to the growth of sciences from the mathematization of nature, experimentation with it, mediated by magic in development (Comte, 1983).

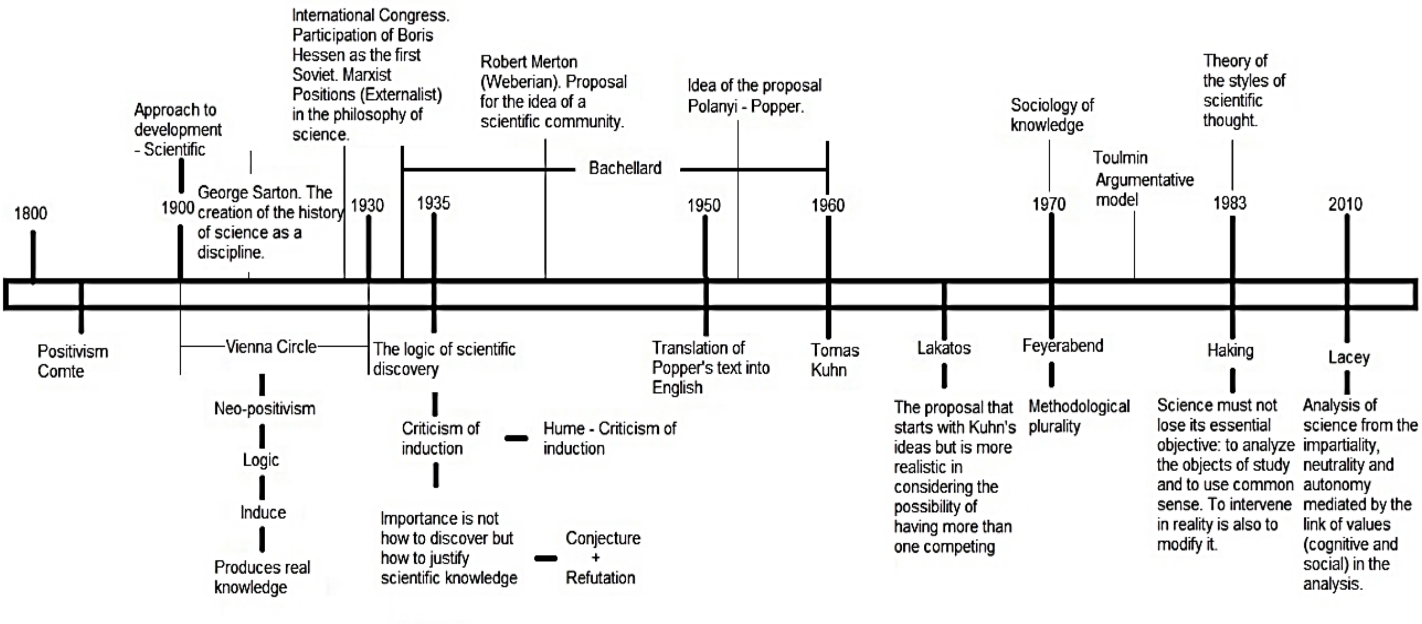

Figure 2. Synthesis of the epistemological currents of the sciences at the authors' discretion.

Under this current, the sciences were also divided. In addition, it is possible to glimpse a break with the scholastic. This is identified from the fact that the product of scientific knowledge comes from experimentation and observation, therefore, *what is not constructed in this way will be considered a metaphysical product without value for science*, ideas that can be related to those proposed by Descartes in the Discourse on the Method two centuries before (Descartes & Santiago, 1930). Consequently, positive science became a fact of relevant importance for building knowledge in the sciences.

From an educational point of view, it can be said that many strategies for teaching the natural sciences now adopt this method. However, the experimental activity is used to prove what the theory has already constructed. For this reason, *observation and the mathematization process are superficial* (Romero & Aguilar, 2013).

Returning, a fact that marked positive science was framed in the distinction between what could be considered science and what could not (metaphysics). This distinction was one of the lines of work of the Vienna circle, together with the elaboration of a common language for the sciences. This philosophical position was called logical empiricism, logical positivism or neo-positivism. *This conception states that true knowledge is conceived by empiricism, logic, and induction, and also has principles of verification and confirmation of this knowledge*. The work of this current was widely disseminated and influenced in the development of the history of the philosophy of science that George Sarton proposed as a discipline, thus contributing to the logic of scientific discovery.

At this point, the philosophy of science had a strong Western influence. However, it is only until the second international congress on the history of science, held in London in 1931, that Soviet philosophy enriches what was proposed at the time with the participation of Boris Hessen. The document presented "the socio-economic roots of Newton's Principle" shows the Marxist influence in this philosophical movement. The work was considered revolutionary for its time and allowed the development of studies of scientific revolutions and the sociology of sciences.

These contributions connect with the scientific community approach made by Robert Merton, a Weberian who stratifies the scientific community within a society permeated by economic, political and social elements. This stratification prompts a scientific structure that manifests itself in the work of Karl Popper, Thomas Kuhn, Imre Lakatos, Paul Feyerabend, among others.

To broaden this idea, Popper proposes a work that aims to delimit the field of science itself. He directs criticisms towards the verification process proposed by the Vienna circle, stating that science operates by falsehood and not by induction. Under this approach, *the basis of empirical control is to falsify a hypothesis, a process that leads to scientific truth* (Popper, 2004).

Figure 3 summarizes the way in which induction and deduction are manifested in the construction of knowledge. On the left is the positivist proposal. The figure of paradigm linked to the theory proposed by Kuhn is also located. On the right is the logical proposal that is dissenting from positivism and that starts from the theory to deduce and find conclusions. In this process the conjecture is also subscribed, a process proposed by Fleck and that was used by Kuhn in his proposal (Fleck, 2010). At the base is Popper's proposal. Note that the concept of falsifying covers the ways of constructing scientific knowledge. *An assertion is expected to be false when designing an experiment that in its results shows a part of the assertion is false. Consequently, the assertion will be refuted, otherwise, it will be true*. For this reason, Popper suggests that science is constructed from false claims (Popper, 2004).

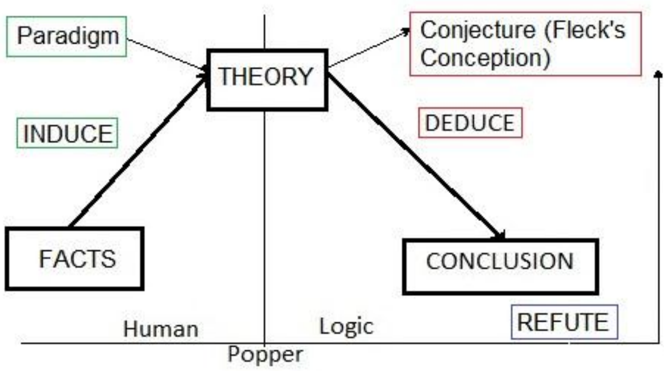

Figure 3. Relationship of knowledge construction by induction in relation to knowledge construction by deduction.

The structure of scientific revolutions shows the basis of Kuhn's thought. *This structure seeks to respond to the way in which we pass from normal science to a mature science, a process that is mediated by a scientific community*. For Kuhn, normal science harbors the investigation of one or more scientific realizations that a scientific community recognizes for a certain period of time. This science is largely based on "classical" or popular 19th-century books. To make sense to mature science, Kuhn proposes the paradigm. This is a sustainable theoretical framework that brings together past scientific achievements and brings together a group of supporters is, therefore, a social construct (Kuhn, 1996).

At this point, the two forms of build science knowledge have in common the generation of theories. However, in the process of transition from one theory to another, one of the theories succeeds in imposing itself on the competitors. This change attracts research in the new field and generates an imbalance between the supporters of the previous outstanding theory in relation to the new one. For this reason, *the schools of the previous theory begin to be left without supporters giving place to a scientific revolution, in other words, a finding of a paradigm that reaches worldwide acceptance*. It is relevant to point out that this process is continuous and does not come from the accumulation or enlargement of a paradigm. In other words, one paradigm replaces another and they are not compatible (Kuhn, 1996).

Within this process, problems are crucial in the progress of mature science. Experimental and theoretical problems are required, as well as incentives for scientists to solve these problems, enigmas (a category of problem that serves to test a scientist's ingenuity or ability to solve it), instrumental, conceptual, and mathematical. Likewise, to have priority of paradigms over rules and to have debugging operations (Kuhn, 1996).

As for scientific discoveries, Kuhn mentions that they are not isolated facts but long episodes. In other words, the scientist is surprised by the perception of an anomaly (manifestation of nature contrary to the current rules), he studies the anomaly and develops a theory of the paradigm that assimilates the anomaly. For this reason, the paradigm does not solve the set of problems that arise (Kuhn, 1996).

Despite the fact that, in some cases, the educational activity in the science classroom is mediated by positive looks, it can be affirmed that our education has a strong Kuhnian influence. *In the teaching processes, it is common to start from theory and then to carry out exercises that allow the demonstration of the theory that the textbooks present. A very common methodology in science, technology, and engineering education.*

Kuhn's proposal has been the basis for other positions. This is due to the broad analysis of the work and the detractors that arise from it. In particular, Lakatos collects some aspects of Kuhn for his work. He recognizes the importance of the history of science in the philosophy of science. In his scientific research program, he suggests that theories are interrelated. For this reason, the new theories start from old theories. *All of these, old and new, share a hardcore, a term that is related to the paradigm. This hardcore is protected by a protective circle containing the generated hypotheses.* These can be modified by new ones giving strength to the firm nucleus in a heuristic process that defines the behavior of hypotheses and theories (Lakatos & Musgrave, 1979).

For the modification of the theories and hypotheses requires a validation process that starts with Popper's ideas, however, Lakatos, in turn, becomes a detractor of these ideas. He shows that scientists did not use falsehood to dismiss theories. He shows that this process is used in the progress of science giving significant importance to confirmation in the construction of scientific knowledge (Lakatos & Musgrave, 1979).

It is also possible to identify Popper's influence on Feyerabend's ideas. However, the search for a rationalist scientific method is criticized in "Against Method". For Feyerabend, no theory would be consistent with all the relevant facts, therefore, *there is a diversity of hypotheses to cover the inconsistencies that arise in the process*. Consequently, induction is proposed to measure the success of a hypothesis, but in turn, counter-induction is encouraged. In other words, *the introduction of hypotheses that are inconsistent with theories is encouraged, as this information is also useful for contrasting or validating it.* From this point of view, in order to build knowledge, a methodological plurality is suggested in which science is seen as a type of knowledge (Gargiulo, 2015).

Lacey subscribes to the development of a methodological plurality. His proposal is based on an analysis of the scientific gaze and a critique of postmodernism. In the scientistic approach, science is seen as free of values that can be evaluated from three aspects: Impartiality (morality and knowledge), neutrality (evaluation of all possible phenomena) and autonomy. In this approach, the world is described by theories that work in an underlying order, that is, they do not take the context into account. At this point, Lacey connects critique to postmodernism. *The starting point is to accept the feasibility of impartiality*; however, it is argued that it is not possible to explain the events of technology and sciences without having the social context, therefore, there is a strong interwoven relationship of technology and science in which cognitive and social values must be present (Lacey, 2010).

If it is accepted that impartiality in science is feasible and that it seeks human welfare, it is proposed that neutrality is only possible if methodological-strategic pluralism is employed. For this, a phenomenon and at least two strategies (paradigms) must be available, since if only one is used, a biased view would be taken in the validation process. Once the strategies (agricultural, feminist, biotechnological, etc.) and the phenomenon are defined, the theory is validated and confronted, in this case, seen as the application in the real world. As a result of analysis and validation, cognitive values emerge (Lacey, 2010).

For the development of the process requires three moments: *In the first one, priorities are determined, and research is directed. In the second, the theories are validated and in the third, scientific knowledge is applied*. It is for this reason that Lacey considers that technology and engineering are the application of science (Lacey, 2010).

In this process, it is favored to dominate the theory and its lexicon. Furthermore, paradigms are allowed to learn from the phenomenon, for this reason, if a greater number of strategies are available, the phenomenon will be learned in greater depth. This is useful since current phenomena are increasingly complex and require different sources of knowledge that involve many strategies. On the third aspect, autonomy, Lacey affirms that this is not possible in science given the diversity of interests that are evident in the different investigations (Lacey, 2010).

Parallel to these glances is the thought of Gaston Bachelard. In "the formation of the scientific mind" he shows us that "science is absolutely opposed to an opinion", consequently, "the knowledge of the real is the light that always casts some shadow" the reality is not what could be believed but what should have been thought. *The scientific knowledge is exposed in terms of obstacles, in which the greatest consideration is the daily knowledge because these obstacles are not external but internal. As a result, it is known by destroying the badly acquired knowledge and it is overcome with a modified one overcoming what hinders that knowledge.* For this reason, scientific knowledge surpasses the methodological vision of science. In this process all knowledge is the answer to a question if there was not this one, it is not scientific knowledge (Bachelard, 1996).

The notion of the epistemological scientific obstacle can be studied in the historical development of scientific thought and in the practice of education. The epistemologist must establish concepts of each notion, these concepts must show how one concept produces another and how it is linked. Therefore, only reason can dynamize this practice. It is intended that reason

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 1 (2019) pp. 212-219
© Research India Publications. http://www.ripublication.com

dynamizes research and thereby improve the scientific experience. Consequently, *scientific culture must begin with an intellectual and affective catharsis to promote a permanent mobilization that promotes dynamic knowledge. This catharsis will be mediated by dialectics and experimentation.* The first strengthens experience (basic observation) and makes the obstacle in scientific culture evident. The second allows the rupture between observation and experimentation. These activities favor the art of manufacturing phenomena or “phenomenotechnology”, necessary in the evolution of science (Bachelard, 1996; Torretti, 2012).

Finally, in this tour of the epistemology of the sciences, Hacking *seeks to strengthen in science the analysis of objects of study, the use of common sense and to show that as reality intervenes it is possible to modify it.* For this reason, it is considered that his proposal is an instrumentalist. Additionally, its approach is supported by the scientific community (science), constituted by scientists who are in charge of making science. In this view science is considered a scientific activity, therefore, it will be a social activity. This thesis is widely developed in "Representing and Intervening" (Hacking, 2001). For the development of the scientific activity, Hacking proposes reasoning and a method that are associated to different styles of scientific thought, in such a way that, these styles favor to speak of the objects of study.

THE EPISTEMOLOGY OF TECHNOLOGY

From the point of view of the epistemology of technology, there are five epistemological currents linked to the construction of technological knowledge. The first is called technological instrumentalism. This current states that *technologies are tools that do not possess values, which endows them with neutrality and allows them to be available to achieve any purpose of the user*. Andrew Feenberg identifies 4 senses to this thesis (Martínez & Suarez, 2008):

- Technology is indifferent to the variety of purposes in which it could be used.
- Technology is indifferent to political aspects.
- This social and political neutrality is related to the rational character and the "truth" it has in terms of verifiability.
- The neutrality of technology is affirmed because it responds and functions with the same efficiency in any context.

In this regard, the idea that technology, like science, is free of values is associated with the fact that its development and evaluation depend on epistemic values typical of science and that, given this condition, it remains neutral in the face of social values, a current idea that is widely discussed in the philosophy of science and technology. Historically, from a Platonist point of view, science is associated with the representation of disinterested knowledge. This idea is modified at the beginning of the XVII century with the work of Francis Bacon who grants a relation to science with practice (Martínez & Suarez, 2008). *In this sense, modern science shows the importance of recognizing that scientific human knowledge has different ways of characterizing it and that in most of moments they are not compatible, but that at the same time they are legitimate* (Páramo, 2013). These ideas give origin to the different epistemological studies that currently link the character of values in the development of science and technology.

At this point, the history of science and technology shows diverse examples, particularly those linked to the field of genetics, in which values have permeated research, thus affecting their autonomy and regulation, autonomy that in some of these cases is given as a condition for obtaining benefits in investment and restriction that makes them depend on a material context (Martínez & Suarez, 2008) in which substances, processes, apparatus, instruments, and other more specific elements such as organisms, among others, are granted on the basis of those governmental and industrial values and interests.

Given the binding nature of science, technology, and engineering, Martínez & Suarez (2008) affirm that the relationship between technology and values is similar to the look that is made at the relationship of values with science. This aspect gives relevance to epistemological studies in technology, although the construction of knowledge, in this case, scientific and technological, is mediated by a social aspect (Páramo, 2013). In this space, *the epistemological perspective of the social constructionism that links the historical, social and collective processes, takes greater relevance in the construction of this social knowledge*.

In consideration, Martínez & Suarez (2008) affirm that philosophers such as Herbert Marcuse, David Noble, Michell Foucault and Karl Marx maintain that certain values that are arranged in technological design obey a logic or rationality that are permeated by capitalist relations, aspects of this critical tradition that give ambiguity and power to the characteristics of technology and *question the idea that tools do not possess values.*

The second current is called technological determinism. This current is understood from *the impact of technology on social life, in other words, it seeks to find the factors, and even causes, that can explain social change*. The deterministic thesis was proposed by Pierre-Simon Laplace in the late eighteenth century. This thesis affirms that knowing the physical state of a system at a given moment will allow us to know its past and future. Technological determinism then refers to the dependence of technological development regarding the scientific development. In this dependence, scientific development will make possible the development of some technologies and others will be diminished (Martínez & Suarez, 2008).

The third epistemological current is linked to the School of Social Constructivism of Technology (SCOT). This school shares the position of technological determinism in the sense that scientific and technological change is articulated by interests, values, and other "social factors". The purpose of this school is *to explain the stabilization of certain technological artifacts from a "micro" or more locally called social analysis, as opposed to deterministic theses that propose more traditional approaches to the "macro" social sciences*. In particular, the analyses focus on the different values and interests of social groups involved in the development or stagnation of technology or a particular artifact (Martínez & Suarez, 2008).

The fourth current is called "technological systems". This current is proposed by technology historian Thomas Hughes. He criticizes determinism and maintains that this thesis emphasizes the role that technology plays in society but emphasizes that this view is made in a single sense of social aspects. In the case of constructivism, the path of the cause in the sense of social and cultural aspects towards technology is highlighted, but the fact that technology does not contemplate the importance of purely technological aspects in this relationship is criticized. In Hughes's thesis, *technological systems are linked to diverse elements that are not susceptible to be understood as parts in a specific order but raises the term of "resources that make sense and relevance in the solution of problems", resources that are constituted as social construction and that play a preponderant role in the vision of system as such* (Martínez & Suarez, 2008).

Finally, in the epistemology of technology, science often ignores the relevance of the history of a particular phenomenon. This is an idea in which explanations that come from laws do not change or do not have history, an idea in which laws play an "index" role that aims to locate the explanation in a given time and space. The fifth current is named model of technological change dependent on the trajectory. It shows us that facts, designs or artifacts themselves resist modifications that could have repercussions on substantial improvements in production and that should be explained from the dependence of trajectories of many technologies. In other words, "*a succession of economic changes is dependent on trajectory if important influences on the outcome can come from temporarily remote events, including events dominated by random elements, rather than by systematic forces*" (David, 1985). This is the case of the "qwerty" keyboard. A design destined to solve the problems of the entanglement of the keys with the old typewriters. However, after fulfilling its function, this distribution is still used in the keyboards of current computers for reasons that have not yet been disclosed.

At this point, it is important to point out that in the epistemology of technology there are currents that associate science, but this is not the case in the epistemology of science. It can be said that the participation of technology in the epistemological currents of this area is quite tangential. In this regard, in relation to this aspect, a more binding epistemological view is approached called technoscience, which is developed by Echeverría (2003). This idea is explained from the techno-scientific revolution, which proposes the consolidation of a macro-science around the '30s and which is strengthened by military research. Presented in another way, the scientific revolutions that Kuhn analyzed allowed the transformation of the structure of scientific knowledge. However, *the techno-scientific revolution proposes a radical change in the structure of scientific activity*. It is for this reason that there are different facets to be analyzed, including the changes in theory derived from it.

As for revolutions, it can be said that the first industrial revolution took place in Great Britain. Its impact is evident in social, economic and political aspects and its center was Europe. It can be indicated that the engine of development was technology, while science had an indirect influence on this industrial development. In the second industrial revolution, there is a strong alliance between industry and the STE. It is consolidated especially in Great Britain, Germany and in smaller proportion, France. During this revolution, new professions such as scientist and engineer emerged. For this reason, during the 19th-century science, technology and engineering interacted closely, even though their professional fields were clearly differentiated. At this point, scientists show that their knowledge can be useful in industry and war (Echeverría, 2003).

As a result, the techno-scientific revolution emerges, however, *it is not carried out by a person or research center, nor by an epistemological change of methodology or at a theoretical level as happened in the scientific revolution of the 17th century*. This revolution was consolidated as a radical change in the research activity that took place in several research centers. It can be affirmed that this mega-science is consolidated with the projects of "the Radiation Laboratory of Berkeley, the Radiation Laboratory of the M.I.T., the ENIAC project of the Moore School of Pennsylvania and, above all, the Manhattan Project (Los Alamos), an authentic paradigm of macro-science, which led to the manufacture of the first atomic bombs" (Echeverría, 2003, p. 13).

So, the techno-scientific revolution is a new way of doing science. It began in the USA in the middle of the Second World War, however, it became solid in the Cold War. The events after the Second World War caused this revolution to spread to Europe, Japan, and Canada. Consequently, it can be said that, although modern science is a European creation, techno-science is created in the United States of North America. The consolidation takes place in three stages: between 1940 - 1965 where macro-science or big science emerges with a high impact on physics, chemistry, and mathematics. There is a stagnation in the period 1966 - 1976 with the failure of the USA in the Vietnam War and the social revolutions that gave rise. After 1976, techno-science arose, strictly speaking, driven by companies and focused on the development of new technological products, projects that link diverse researchers, scientists, and technologists, engineers, administrators, economists, among other professionals, and that are the basis that differentiates this epistemological current (Echeverría, 2003). Despite the rise of techno-science, it can be said that science has not disappeared. Scientific societies and academic science itself continue to exist. Nevertheless, macro-science and techno-science have a great strength that has changed the STE. In addition, it has allowed a great economic, social and informational change that has its beginnings in the last decades of the twentieth century but that in the twenty-first century has a greater boom (Echeverría, 2003).

From the point of view of current education, we have many historical examples that allow us to make a more in-depth analysis of the relationships between science, technology, society and the environment. This allows us to approach more critical, binding and formative positions around research strategies such as socio-scientific questions, socio-technological questions, or oriented research. These proposals tend to become related factors from the STS that boost the positioning of third world countries in education in STE, this if we take into account that "*theoretical advances in the humanities have clear practical repercussions, which in turn feedback from these experiences, is clearer in countries with highly developed democracies such as the Nordics, the European Union, and the United States*" (Martínez & Suarez, 2008).Another binding alternative is linked to the development of artefacts that can be used as scientific instruments in the classroom. A proposal that starts from the importance that the use of instruments has had in the development of sciences (Gilbert, 1992a). *The design, construction and use of these artefacts will benefit the development of technological knowledge, the objective of education in technology (edutech) and engineering* (Ramírez & Mora, 2016; Williams & others, 2000).

To widen this idea, the design stage will require the use and appropriation of scientific knowledge, which will allow relate the phenomenon, artifact technology, knowledge, activities and social aspects (Ramírez & Mora, 2016; Jones, Bunting, & de Vries, 2013; Williams, 2013). The construction stage will require the use of manual skills, in other words, manufacturing. An activity linked to technique and which is an essential part of the STE, given the fact that education in technology and engineering is learned by doing (Gilbert, 1992b). Finally, at the use stage, manual skill is enhanced, and scientific thinking is fostered. At this point is where the questions of the behavior of the phenomenon appear (Pešaković, Flogie, & Aberšek, 2014). *With the use of the instrument will arise problems, it will also be possible to investigate and learn with it* (Jones et al., 2013), *in addition, the student will be attracted by the desire to explore a new territory, find order and test the established knowledge, objective of the scientist in Kuhn´s words*.

About this, Davies & Gilbert (2003) present five arguments that show why it is relevant to relate Science and Technology in the classroom and why to link the experience of science education (eduscience) with technology and engineering education:

1. All of them require the student to reflect on his or her practice. This is difficult in eduscience because generally experiments are carried out only once and there is few for reflection in the macro domain (concrete evidence). Edutech and engineering education provide this concrete evidence. Students must test their products. A skill that requires science education.
2. A consistent approach to the promotion of metacognition through STE could be developed due to the high degree of epistemological congruence between them.
3. Eduscience, edutech and engineering education require students to develop the ability to visualize what cannot be seen or has not yet been seen.
4. The explanatory concepts of eduscience, such as force, energy, etc., are often used to provide solutions to design approaches in edutech and engineering education.
5. The use of technological contexts can be motivating in science teaching because they provide utilitarian reasons in which abstract concepts - often difficult - of science should be dominated by students.

CONCLUSIONS

As a conclusion, it can be stated that solving problems and that these are materialized in instruments, helps the student to interpret mathematical and scientific principles and apply the STE to solve natural and artificial problems. In this process, it is possible to evaluate designs and recognize the variety of knowledge that is required. An activity that allows the integration of mathematics, science, techniques, and technologies, but above all a development mediated from a social context.

The social aspect is an axis of analysis present in the epistemological currents of science and technology that move away from instrumentalism, or that show that the STE is not devoid of values, therefore, its neutrality, impartiality, and autonomy remain in doubt. These currents show knowledge in STE as a social construction, directly influenced by the context and dependent on the situations and relationships that emerge from it.

It has been indicated that educational activity is strongly influenced by positivism and Kuhn's approach, consequently, the social aspect in the construction of scientific and technological knowledge has been marginalized in the classroom. This situation is contradictory to what is proposed by most of epistemological currents exposed in this article. For this reason, the teacher in the design of his teaching can make use of these relationships to bring the student closer to the way in which knowledge is constructed in STE.

Finally, another alternative for linking these dimensions in the classroom can be found in the design of STS activities. Socio-scientific questions, socio-technological issues, oriented research, among other proposals, are ideal for the teaching of the STE. Their use will help the student to understand the relationships inherent in these dimensions, as well as to identify elements that help him or her to construct an image of the structure of the STE.

REFERENCES

[1] Bachelard, G. (1996). "A formação do espírito científico". *Rio de janeiro: Contraponto*, 7.

[2] Comte, A. (1983). "Curso de Filosofia Positiva″. Editora Abril, São Paulo,.

[3] David, P. (1985). "Clio and the economics of qwerty". *The American Economic Review; papers and proceedings of the ninety - seventh Annual meeting of the American Economic Asociation.*, *75*(2), 332–337.

[4] Davies, T., & Gilbert, J. (2003). "Modelling: Promoting creativity while forging links between science education and design and technology education". *Canadian Journal of Science, Mathematics and Technology Education*, *3*(1), 67–82. https://doi.org/10.1080/14926150309556552

[5] Descartes, R., & Santiago, H. (1930). "Meditações metafísicas". Imprensa da Universidade.

[6] Echeverría, J. (2003). "La Revolución Tecnocientífica". Fondo de cultura económica de España.

[7] Fleck, L. (2010). "Gênese e desenvolvimento de um fato científico: introdução à doutrina do estilo de pensamento e do coletivo de pensamento". Fabrefactum Editora.

[8] Gargiulo, T. (2015). "Paul Karl Feyerabend. En Defensa de la Continuidad de su Pensamiento". *Trans/Form/Ação*, *38*(2), 129–169.

[9] Gilbert, J. K. (1992a). "The interface between science education and technology education". *International Journal of Science Education*, *14*(5), 563–578.

[10] Gilbert, J. K. (1992b). "The interface between science education and technology education". *International Journal of Science Education*. https://doi.org/10.1080/0950069920140507

[11] Gilbert, J. K., Boulter, C. J., & Elmer, R. (2000). "Positioning Models in Science Education and in Design and Technology Education". En J. K. Gilbert & C. J. Boulter (Eds.), *Developing Models in Science Education* (pp. 3–17). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-010-0876-1_1

[12] Gilbert, J. K., & Stocklmayer, S. (2001). "The Design of Interactive Exhibits to Promote the Making of Meaning". *Museum Management and Curatorship*, *19*(1), 41–50. https://doi.org/10.1080/09647770100401901

[13] Goldschmidt, V. (1963). "Tempo histórico e tempo lógico na interpretação dos sistemas filosóficos". *A religião de Platão*, *2*, 139.

[14] Hacking, I. (2001). "Representar e intervenir" (Traducción:). Instituto de Investigaciones Filosóficas / Paidós.

[15] Hume, D. (1980). "Investigação sobre o Entendimento Humano" (Trad. Leon, Vol. 2). Abril Cultural, São Paulo.

[16] Jones, A., Buntting, C., & de Vries, M. J. (2013). "The developing field of technology education: a review to look forward". *International Journal of Technology and Design Education*, *23*(2), 191–212. https://doi.org/10.1007/s10798-011-9174-4

[17] Kuhn, T. (1996). "La tensión esencial: estudios selectos sobre la tradición y el cambio en el ámbito de la ciencia" (pp. 56–89). Fondo de cultura económica.

[18] Lacey, H. (2010). "Valores e atividade científica 2" (Vol. 2). Associação Filosófica Scientiae Studia e Editora 34.

[19] Lakatos, I., & Musgrave, A. (1979). "A crítica e o desenvolvimento do conhecimento": quarto volume das atas do Colóquio Internacional sobre Filosofia da Ciência, realizado em Londres em 1965. *Tradução de Octavio Mendes Cajado. São Paulo: Cultrix*.

[20] Lebrun, G. (2006). "A filosofia e sua história". Editora Cosac Naify.

[21] Martínez, S., & Suarez, E. (2008). "Ciencia y Tecnología en sociedad: El cambio tecnológico con miras a una sociedad democrática". (U. N. A. de México, Ed.) (Primera). Limusa Editores - Grupo Noriega editores.

[22] Moreno, L., & Waldegg, G. (1998). "La epistemología constructivista y la didáctica de las ciencias: ¿Coincidencia o complementariedad?" *Revista investigación didáctica, enseñanza de las ciencias*, *16*(3), 421–429.

[23] Páramo, P. (2013). "La investigación en ciencias sociales: Discusiones epistemológicas". (Primera, pp. 183–195). Universidad Piloto de Colombia.

[24] Pešaković, D., Flogie, A., & Aberšek, B. (2014). "Development and evaluation of a competence-based teaching process for science and technology education". *Journal of Baltic Science Education*, *13*(5), 740–755.

[25] Popper, K. R. (2004). "A lógica da pesquisa científica" (Vol. 1). Editora Cultrix.

[26] Ramírez Cano, J. W., Mora Penagos, W. M. (2016). "El diseño de instrumentos (de laboratorio) como articulador de la educación en ciencias y la educación en tecnología". *Tecné, Episteme y Didaxis: TED*, *Extraordin*.

[27] Romero, Á., & Aguilar, Y. (2013). "La experimentación y el desarrollo del pensamiento físico; un análisis histórico y epistemológico con fines didácticos". Universidad de Antioquia.

[28] Sjøberg, S. (2002). "Science and technology education: Current challenges and possible solutions". *Innovations in science and technology education*, *8*, 1–13.

[29] Torretti, R. (2012). "Fenomenotecnia y conceptualización en la epistemología de Gaston Bachelard". *Theoria; Revista de teoría, historia y fundamentos de la ciencia.*, *27*(1), 97–114.

[30] Williams, P. J. (2013). "Technology education for teachers". Springer Science & Business Media.

[31] Williams, P., & others. (2000). "Case Studies of Multidisciplinary Approaches to Integrating Mathematics, Science, & Technology Education". *Journal of Technology Education (spring 2000)*, *11*(2), 48–60.