Curriculum development for technology education: a perspective from Colombia

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Curriculum development for technology education: a perspective from Colombia

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Abstract
A new law of education, passed in 1994 (Law 115/95), established technology and informatics as one of the nine compulsory curricular subjects for basic and secondary education in Colombia. Proposals for the new area were urgently needed, but curricular development in Technology Education (TE) has proven not to be an easy task. The present paper describes the foundations of a curricular structure developed jointly by the Master's Programme in Pedagogy of Technology (National Pedagogical University), and DifuCiencia, a NGO working in Science and Technology (S&T) literacy programs. This is the first outcome of a joint Research and Development (R&D) project sponsored by Bogotá's Secretary of Education, which has included on-the-job training for almost 600 public school teachers in Colombia's capital.

The starting point is an epistemological delimitation of technology. Technological knowledge is conceived as having two main foundations: Mechanical logic and strategic thinking. Mechanical logic is that knowledge accumulated through the historical development of technology, from stone-age instruments to contemporary digital machines. Another important part of technological knowledge is practical problem-solving; however, not all strategic thinking is related to mechanical logic or to technology.

A curricular structure for TE can, then, be defined based on three main axes: a) Stages of historical development of technology; b) Learner's stages of cognitive development; and, c) The concept of 'learning environments' didactic principle. Further learning activities and the precision of an initial proposal of competencies and their related attainment targets are matters of research involving public school teachers in Bogotá.

A necessary delimitation
A new law of education, passed in 1994 (Law No 115/94), established technology and informatics as one of the nine compulsory curricular areas for basic and secondary education in Colombia. Thus the need for developing curricular proposals for this new subject became evident. However, this endeavour proved to be all but easy. On the one hand, basic and secondary education teachers lack experience with the pedagogy of technology. On the other, given the high complexity of contemporary technology, an epistemological delimitation of technology, a necessary task for technology education (TE), becomes a complicated matter.

It seems a good criterion for developing this delimitation to understand technology as that set of activities leading to the production of the artificial environments which a large part of mankind inhabit. However, these environments, in becoming so highly sophisticated pose a dilemma: as they become more transparent to the user, they demand higher-level intellectual capacities both for technological literacy and for innovation.

Such a dilemma implies complex educational challenges, among which the two most important, perhaps, are the following. Firstly, contents that not so long ago were the matter of higher education for engineers must become part of basic and secondary education for all, so that engineering education can meet the increasingly higher levels of abstract thought demanded by today's complex technological systems.

Secondly, since project and design are basic activities of contemporary technology, it seems
rather natural to conclude that all students must do is to master the design method and/or the project method. Unfortunately, things are not so simple. Education for ‘creativity’ or developing capacity for innovation cannot be reduced to the mere learning of a ‘methodology’ or, what seems tantamount to a procedure.\footnote{In our work, we are increasingly confronted with the fact that educating a creative individual requires also domain-based knowledge. This seems related to what Novak has termed ‘supraordinated knowledge’, which he considers closely linked to creative behaviour.\footnote{In our terminology, we feel that there exists ‘cognitive conditions’ for creativity. The inescapable conclusion is that TE requires a domain-based, that is, a technological knowledge.\footnote{This is why an epistemological delimitation of technology is necessary for planning TE.}}}

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The present paper describes the theoretical propositions behind a curricular structure developed jointly by the Master’s Programme in Pedagogy of Technology of the National Pedagogical University of Colombia, and DifuCiencia, a NGO working in S&T literacy programs. This is the preliminary result of a joint R&D project between these two entities, partially sponsored by Bogotá’s Secretary of Education and which has also included on-the-job training of almost 600 public school teachers in the Colombian capital.

Previous definitions: technology and technological knowledge
The design of a curricular structure for TE demands, as discussed earlier in this paper, an epistemological outline, firstly, of that confine of human experience in which that set of activities we call technology has developed and, secondly, of the nature of the knowledge that has been built in that context.

The social confine of technology
The actions of work, as the production of the material conditions for human living, conforms the extent of social experience in which technics and technology have evolved. We find in this context man’s activities in transforming nature, activities that have finally concluded in the artificial environments in which large percentages of mankind live. It is evident that those actions have also changed man’s needs through history, from the caves to contemporary society.

In this outline of technology we shall refer only to the production of material goods, i.e., to action as work. It is not necessary to take into account how men relate to each other in this process.\footnote{Understanding technology in all its complexity means considering it as an active process. In other words, in order to examine the nature of technology it is necessary to start with the productive cycle that generates material goods.\footnote{Even though the conditions of that cycle have changed through history, it is possible to identify four major invariants, present in every productive cycle. These are: Purpose, objective, goal; Means, conformed by the raw materials to be transformed, tools machines and other equipment used in the transformation, and a power supply; Processes, methods and ways of organising labour division in order to achieve the purpose; and, Product, good or commodity.\footnote{The development of these four factors in order to make them more productive, a constant pursuit in almost every human culture, is the essence of technics and technology.\footnote{The presence of technology in these four invariants could be considered as follows: • In the purpose: as design and planning strategies. • In the means: as research and development of new materials, instruments, tools or machines. • In the processes: as developments in the methods and ways of organising the labour division for production. • In the product: as improvements in the quality of the final good. Here, the cycle, that feeds permanently back in its development, closes itself in a materialised purpose.\footnote{Technology, in a final stance, represents a mimicry of the operational functioning of human beings and of nature’s processes. In this respect, Habermas notes:}}}]

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The inescapable conclusion is that TE requires a domain-based, that is, a technological knowledge.\footnote{This is why an epistemological delimitation of technology is necessary for planning TE.}
“The evolution of technics/technology may be adjusted to the following interpretative model: (...) first, the functions of the locomotive apparatus (hands and legs) are substituted; later, the energy supply (by the human body); later on, the functions of the senses (eyes, ears, skin) and, finally, the functions of the control centre (brain)”.

As stated before, starting to understand technology requires examining the productive cycle of material goods. Something different is the impact of the use of high-tech goods such as happens in today’s transportation and communication systems, a phenomenon that is frequently mistaken as technology.

The productive cycle has gone through different levels in different historical circumstances. Understanding contemporary technology requires comprehension of the conditions of the most developed cycle and its influence in less developed societies.

The most developed cycle, which can be found in the USA, Western Europe and Japan, has emphasised the development of certain aspects such as:

- Preferential orientation of design to innovation in consumer goods, rather than in the means of production. Innovation in consumer goods consist mainly in formal modifications.
- Importance granted to innovations in the processes and ways of organising production, an aspect of technology known as ‘problem-solving’.
- Intensive use of information at the expense of a relative reduction in the use of energy and raw materials.
- Software development for flexible manufacturing systems and innovations in organisation and methods.

This emphasises of the highly developed cycle, along with the raising of illusive necessities, typical of the consumer’s society, has generated a perception that technology is intangible and has fostered the idea that it is based only in creativity and strategic capacities, not demanding any knowledge domain. The influence of these misconceptions, that have intended to reduce all technological knowledge to its formal and symbolic aspects in TE is another important reason for this epistemological delimitation.

The nature of technological knowledge

The actions intended to achieve a goal or purpose, that is, of work may be understood in two ways: either as instrumental action, or as strategic action. Both, instrumental and strategic actions, are operational in the sense that they are actions oriented to choose among alternatives, which implies prediction, calculation, regulation, control and the search for efficiency in a productive process or in the use of a product of technology.

Those actions of men in transforming nature and producing goods are oriented by peculiar ways of thinking, that have been characterised as instrumental and strategic reasons or logics. Instrumental reason materialised in the development of machines throughout history has become mechanical logic. This mechanical logic, of course, implies strategic thinking also, but there are instances of strategic thinking not limited to mechanical logic, such as certain organisational processes and the mimicry of nature’s processes in biotechnology.

Accordingly, mechanical logic and strategic thinking would be the components/foundations of the operational principle, proposed by Polanyi as the central category of technological knowledge.

Mechanical logic has evolved, along the course of human history, resulting in an increasing accumulation of technological knowledge and the development of mechanical operators systematised in a theory of machines. More recently, since Norbert Wiener’s theoretical models, logic operators have become part of this knowledge. The development of mechanical logic is universal in the sense that it takes on a character of necessity in different human cultures.

As to the different expressions of strategic thinking, these have been more conditioned by historical and cultural variants. It is possible to forecast that there would be many developments in strategic logic, not necessarily related to mechanical logic.
Finally, this effort to delimitate technological knowledge, a necessary, prior conceptualising to developing a curricular structure for TE, does not mean ignoring other related knowledge, particularly that from natural sciences. It is considered appropriate that, in higher educational grades/levels, concepts from social sciences, in general more abstract than those of natural sciences, should be taken as a basis to reflect on the social and ethical impact of technology and its applications.

Structural elements of the curricular proposal

Historic development of technology
Several authors (eg Piaget, Habermas) have noted a parallel between the large stages of mankind’s history and those of the cognitive development of the individual. This parallel suggest that one of the axis for a curricular structure would be given by the stages of historic development of technology, from the initial stone-age instruments to current-day robots.

Thus, historical development of mechanical logic - from its beginnings in the shape of an instrument reflecting the purpose behind it, to the logic operators of today’s digital machines - furnishes a guide to design a sequence of technological knowledge contents along the different levels of basic and secondary education.

Students’ stages of cognitive development
An evident and important element for defining a curricular structure should be how it fits the levels or degrees of cognitive development of the learners involved. In this case, Piaget’s theory allows preliminary definitions of curriculum stages and attainment targets.

The possibilities for competent performance or for being part of decision-making that somebody may have, are closely related to his/her comprehension of contemporary artificial environments. This understanding requires, as we have seen, the development of capacities for abstract thinking.

Accordingly, the curricular structure is based on the necessities of intellectual development if the students are to understand contemporary technology. Other needs, such as those of the local environment, the pressing income needs of socio-economically deprived sectors, should only be considered in the particular level of curricular implementation, that is, at the didactic level.

The concept of ‘learning environment’ as ‘didactic principle’
In addition to key concepts (such as ‘system’, ‘design’, ‘structure’, ‘function’, etc.), technological knowledge also includes a strong factor which differentiates it from other types of knowledge, particularly from scientific knowledge. Exercising these two aspects, conceptual and practical, implies to foster in the students the development of the capacity for strategic thinking along with the understanding of the foundations of mechanical logic. This could be possible by means of strengthening students’ ability for practical problem-solving in a series of classroom activities duly organised as ‘learning environment’.

Items of the proposal
Curricular structure includes:
1. School levels and the corresponding average ages, grouped according to the stages of cognitive development as proposed by Piaget.
2. Technological knowledge contents. That is, the contents of mechanical logic as constructed through action and operativity, arranged sequentially according to the large historic stages of technology development. Four major stages are considered: A:- The Instrument; B:- The Instrument + Mechanical operators; C:- The Instrument + Mechanical operators + Power supply; D:- The Instrument + Mechanical operator + Power supply + Regulation and Control.
3. Suggested classroom activities, as a guide for further designing ‘learning environments’. A certain number of these activities have been developed by DifuCiencia’s staff and students of the Master’s programme. They are being validated in schools by teachers participating in an on-the job training program financed by Bogotá’s Secretary of Education.
4 Competencies. Includes definition of the capacities related to apprehension of mechanical logic and the development of strategic thinking, in relation to the stages of cognitive development.

Two precisions are necessary at this point. First, ‘competency’ is a domain-based capacity associated with the possibility of applying knowledge in different contexts. Second, the competencies presented in the curricular structure correspond to the proposal discussed in the work about ‘learning environments’ with some variations dictated by practice.19

It was necessary to itemise two of the original competencies in items both readily measurable and that gave indication as to the educational ways of promoting it as a competency. Thus, the capacity for structuring and formulating problems ended up divided into two: i.- Capacity for representing objects, artifacts and situations using different languages, particularly those associated with technology, such as descriptive geometry and mathematics. ii.- Capacity for establishing differentiations, classifications, analogies and variables related to mechanical logic. The capacity for developing and presenting proposals of solutions was also divided into two: i.- Capacity for discriminating among several alternatives, and, ii.- Capacity for explaining the reasons for decision-making.

Finally, the tendency to self-control one’s own formative process was suppressed because it is not really a ‘competency’, rather a degree of maturity as a result, expectedly, of the other four.

5 Attainment targets. A definition of the levels of acceptability of several indicators related to the competencies. The idea is that a learning objective is an attainment target at the youngest age in which such learning is possible but means a cognitive challenge for the learner. The initial proposal is inspired by Piaget’s theory, but a final precision of every indicator depends on experimental work, already underway, directed by DifuCiencia with the participation of groups of teachers in Bogotá’s public education system.

6 Some related knowledge, particularly of the natural sciences, corresponding to the contents of technological knowledge.

Notes

2 In Novak’s terms, ‘supraordinate knowledge’ involves meaningful learning of highly abstract concepts. This would allow a creative individual to establish relationships among lower-level concepts that others are not able to ‘see’ by themselves. Cfr. Novak, J. (1997), A theory of education, Cornell University Press. We used the Spanish translation by Alianza Editores, Madrid, 1982.

3 At a more basic level, not only creativity but intelligence itself, when considered a faculty that can be developed rather than a birth-gift, requires also a domain-based knowledge. See, for example, the discussion about Piaget’s conception of intelligence in Legende-Bergeron, Marie-Francoise (1994) ‘Une conception dynamique de l’intelligence’ (A dynamic conception of intelligence) Vie Pedagogique, MAY-JUNE, Québec.

4 This limitation is necessary in order to leave social relations out of the realm of technology. Taking these social relations into account is entering into the realms of history, political economics and/or sociology.

5 This stance is quite different from that which attempts to comprehend technology
by means of ‘object analysis’, i.e., considering isolated goods. This object analysis may be valid as a method for reconstructing the design process of that particular commodity. But technology is not only design.

6 Technics, strictu sensu, refers to the instruments and processes involved in shaping materials, whereas technology implies both the reflection (logos) about those instruments and processes, as well as the coordination of several technics in order to achieve a production goal.


11 “... Japan increased her industrial production by two and a half times, almost without increasing her consumption of raw materials and energy. (...) The newest ‘energy’ of all, information, has contents neither of matter nor energy. It is completely knowledge-intensive’. Drucker, P. (1990) LasNuevasRealidades (The new realities), Editorial Norma, Bogotá, 117.

12 “The use of knowledge, in full activity since the 70s, consisted in applying system analysis to the production process itself. Here, the hardware is not essential (...)”. Drucker, P. (op.cit., p 181)

13 “{The new knowledge statute} has been widely elaborated by experts and is already directing certain decision-making in public administration and in the private corporations most involved, like those of telecommunications. It is already part of the order of perceived realities”. Lyotard, J.F. (1994), La condición post-moderna (The post-modern condition, 1984) Ediciones Cátedra, Madrid, 21.

14 Habermas, J. (op.cit., p. 68)

15 Habermas, J. (op.cit., p. 106)


17 “This law enunciates an intra-technical event, a development not sought by men, but something that has imposed itself on men along all history of human culture. In addition, according to this law, there cannot be any technical development beyond complete automation, since it would not be possible to specify any other realm of functional human activity that could be substituted”. Gehlen, A. (1965) Antropoligische ansicht der technik, quoted in Habermas, J. (op.cit., p. 62)

18 A wider discussion on the idea of transforming the classroom into a ‘learning environment’ can be found in Andrade-Londoño, E. (1996) ‘Ambientes de aprendizaje para la educación en tecnología’ (Learning environments for TE). Educación en tecnología, 1, 1, Bogotá, 1-15. An English version was
presented at JISTEC’96. See Book of Abstracts, Jerusalem, Jan 8-11/96.

19 Cfr. Andrade-Londoño, E. (op.cit.) The original proposal in this paper consisted of 5 competencies derived from the idea that TE should form: a.- Technologically literate citizens; b.- Technology innovators. These competencies are: 1.- Ability to use information sources; 2.- Capacity for structuring and formulating problems; 3.- Capacity for developing and presenting proposals of solutions; 4.- Some technical skills; 5.- Tendency to self-control one’s own formative process.

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• Piaget, Jean y otros (1996) Las formas elementales de la dialéctica (Elementary forms of dialectics), Gedisa editorial, Barcelona.


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<th>SUGGESTED ACTIVITIES</th>
<th>COMPETENCIES</th>
<th>ATTAINMENT TARGETS</th>
<th>RELATED KNOWLEDGE</th>
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<tr>
<td>0-10 (4-7 years)</td>
<td>Shaping materials</td>
<td>Handling materials (dow, ceramics,..) for making familiar objects.</td>
<td>Fine motility. Eye-hand coordination.</td>
<td>Relates the shape of an object with its function.</td>
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<td>20-30 (7 - 9 years)</td>
<td>Shaping materials with an intended purpose</td>
<td>Classifying materials; game of cards; sequence of various production processes; Exploring household appliances &amp; moving toys.</td>
<td>Establishing differentiations, classifications, analogies &amp; variables referred to artificial environments.</td>
<td>Differentiates purpose-material-tool-process.</td>
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<td>Skills</td>
<td>Uses tools with an intended purpose.</td>
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<td>Skills</td>
<td>Represents 3-d objects in 2-d drawings.</td>
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<td>Explaining decision-making</td>
<td>Solves problems using mechanisms.</td>
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<td>Free-hand sketching.</td>
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<td>Representing objects, artifacts, situations.</td>
<td>Represents operational relations using formal operators.</td>
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<td>Establishing differentiations, classifications, analogies &amp; variables referred to artificial environments.</td>
<td>Differentiates natural environments.</td>
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<td>Discriminating among alternatives</td>
<td>Solves mechanical logic problems using simulators and formal operators.</td>
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<td></td>
<td></td>
<td></td>
<td>Explaining decision-making</td>
<td>Uses some machine-tools safely &amp; purposefully.</td>
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Proposed curriculum structure for Technology Education in Colombian schools (continues on next page)
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