

Technical objects in French middle school: three-steps project

MARIA-ANTONIETTA IMPEDOVO, COLETTE ANDREUCCI

*Aix Marseille Université
ENS Lyon, ADEF EA 4671
13248, Marseille
France
aimpedovo@gmail.com
colette.andreucci@univ-amu.fr*

ABSTRACT

In this article we present a research carried out in order to understand how students (from 12 to 14 years old) relate to technical objects that are part of everyday life and mediated reality. The three-steps of the research with a mixed method are discussed: the exploratory research (57 students) in French classes; interview to 4 children; the extended research (124 students) with the final version of the questionnaire, composed of three parts: 1) the detection of technical characteristics of objects; 2) the ability to create relationships between objects; and 3) the direct use of technical objects and personal interest in sciences and technology. The results show the complexity of the relationship with technical objects and the need for an educational mediated intervention of design and technology education.

KEYWORDS

Artefact, technical object, categorization, learning, technological education

RÉSUMÉ

Dans cet article, nous présentons une recherche effectuée afin de comprendre comment les élèves (de 12 à 14 ans) appréhendent les objets techniques qui font partie de la vie quotidienne et de la réalité médiatisée. Nous présentons les trois étapes de la recherche: l'enquête exploratoire avec la première ébauche d'un questionnaire papier (57 élèves) dans les classes françaises; l'entretien approfondi de 4 élèves de collège; la recherche élargie (124 élèves) avec la version finale du questionnaire en ligne, composé de trois parties : 1) la détection des caractéristiques techniques des objets; 2) la capacité de créer des relations entre les objets; et 3) l'utilisation directe des objets techniques et l'intérêt personnel eu égard au domaine scientifique et technologique. Les résultats montrent la complexité du rapport des élèves aux objets techniques et l'intérêt d'un enseignement intégré des sciences et des technologies.

MOTS-CLÉS

Artefact, objet technique, catégorisation, apprentissage, enseignement technologique

THEORETICAL FRAMEWORK

Many French researchers have been interested in the definition, in comprehension, extension or practical use, of the concept of technical object (Simondon, 1958; Akrich, 1987, 1993; Cazenobe, 1987; Haudricourt, 1988; Perrin, 1991; Andreucci & Ginestié, 2002). Taking into account a broadly meaning, an object (for example a grafted tree, an artificial heart...) can be characterised as “technical” from the moment when its material existence is the consequence of a processing technique used or a traditional for an effective action (Mauss, 1936; Sigault, 1990; Séris, 1994). In the same perspective, Rabardel defines technical objects as “*anything that has undergone a transformation of human origin (...), which is ready to be used, developed in order to be part of finalised activities*” (1995, p. 59). So, for a large majority of authors (such as Ginestié, 2011; De Vries, 2012...), the material and technical nature of the object integrates a human intention of manufacture: it explicitly carries the practical goal for which it was designed. In other words, the technical object becomes a necessary mediator in the relationship with reality. But, understanding what the most important characteristics of technical objects are for students themselves becomes necessary for a better understanding of their conscious relationship with the world around them. Indeed, as suggested by Ineke, Sonneveld and De Vries (2012), understanding the nature of technical artefacts is a relevant part of technological literacy. Technology education in France is compulsory for all the pupils from 3 to 15 years of age. The specificity and the socio-cognitive role of technical artefacts have long suffered from a lack of attention and reflection in philosophical, psychological and educational approaches. However, some studies have shown (Andreucci, 1990, 2003; Andreucci & Roux, 1992; Impedovo, Andreucci & Ginestié, 2015) that their social use promotes the early acquisition of socio-pragmatic properties of artifacts (as variability and relativity of bulkiness, filling rate of the containers...) which disturb the subsequent learning of scientific principles (physical and geometric conservation of physical volume). Another later study (Andreucci & Ginestié, 2002) allowed us, among other things, to demonstrate that the concept of technical object becomes increasingly restrictive, leading to exclude less “modern”, ordinary and passive artifacts (like clothes, food, household utensils, buildings...). However, the students’ representation conferred to the concept itself of "object" will be more closely examined through this present study. Considering this perspective, the purpose of this article is to understand the relationship experienced by students in the middle of technological literacy education at school. In our opinion this type of research has the potential to contribute to the debate around Technological curriculum and design of objects and their impact on social and work environments.

METHODOLOGICAL FRAMEWORK

Aim of the project

From an early age children are required to interact with a multitude of technical objects to operate and transform the reality that represent a decisive factor in the Piagetian developmental theory of cognition (Inhelder & Piaget, 1958). In this way, Perrin (1991, p. 381) points out « *plus que pour une autre science, il semble donc approprié de partir d'une épistémologie constructiviste du type de celle proposée par Piaget pour fonder une science des techniques¹* ».

¹Traduction: “More than any other science, it seems appropriate to start from a constructivist epistemology like the same proposed by Piaget to found a science of techniques”.

How children organize and bring order in this gigantic "odds and ends" that constitutes the technological environment? The purpose of this exploratory study was to trace the relationship of students (aged 12-14 years old) with technical objects that are part of everyday life, such as in school, with family or with peers and mediated reality from textbooks, from schooling or media. In this way we wanted to explore three aspects related to:

- 1) General understanding of technical characteristics of objects;
- 2) Ability to make relationships between objects;
- 3) Personal and direct use of technical objects.

Research design

The research is organized in three steps:

- 1) The exploratory research with a first draft of a questionnaire administered to 57 students in between 12-14 years of age drawn from two different French classes in two different schools;
- 2) The children interview, and the purpose is to highlight new questions before the development of a large scale survey ;
- 3) The extended research with the final version of the questionnaire in digital format (Sphinx).

Methodology

Regarding the methodology, we use a mixed method.

- 1) First step: *the explorative survey*. We first propose a draft of a questionnaire based on the literature review on artefacts categorisation (Cannard et al., 2006). Usually the categorisation of objects is carried out in small workshops with a limited number of objects and subjects or directly face-to-face between the subject and the researcher. We design to use a questionnaire. The questions have been developed in a process of tuning between research interests, the literature on artefacts and adaptation to the generic didactic objectives of the curriculum of the French Technological Education in middle school. To improve the understanding of the students, it was decided to use closed questions and images. The questionnaires were administered manually to students in classes in a paper version, directly by the teacher after school activities. Considering the length of the questionnaire, it was administered in two sessions of about 20 minutes each. After the data collection, we have proceeded to the analysis of the data, with a qualitative analysis of the responses due to the limited number of participants. This first study is exploratory in purpose.
- 2) Second step: *the interviews*. The second step consists of four interviews (2M and 2F of 11 and 12 years old) made in a college. They belong at the same class. The four students decided to participate freely in the interview, at the invitation of the teacher of biology to the whole class. The four students are choice to have variability in the date of gender (M and F) and of scholastic level (good, average and low). They were interviewed by two of the researchers involved in the project in a separate room (the biology lab) while the class continued the lesson in the classroom. The interview took place in about 30 minutes. The children, seeing the Part II (see after) of the questionnaire in the paper version, were invited by the researcher to reflect aloud on reasoning, in a form of thinking aloud (Kuusela & Paul, 2000), that allows to reconstruct the reasoning implemented. The researcher helped the students to make explicit the reflections and the observations.

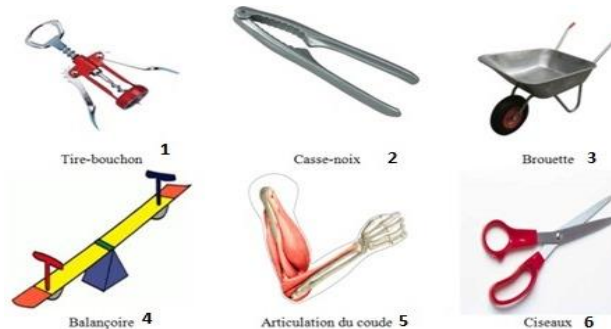
- 3) Third step: *the extended survey*. The final version of the questionnaire is set for the extensive research. For the extensive research, the questionnaire was developed in two versions, one for the younger children (11-12 ages) and the second, a full version for the older students (13-15 ages). It is in electronic format and completed online with the software Sphinx (http://sphinx.espe.univ-amu.fr/ade/EnqueteObT_2015-16/questionnaire.htm). The online version allows us to deal with an extensive number of participants and facilitates an initial automatic data analysis. Also, the use of images and the use of only closed questions will save time and facilitate its online completion by students. Specifically, this third step aimed to shed light on how children apprehend some aspects of their current environment according to the age, gender, socio-cultural environment to which they belong, and the type of area (urban or rural) where they reside. Respect to the explorative survey we reduced the number of items so that time of submission is around 30 minutes. The sample referred consist of classes of about 10 classes from mixed (urban, rural, semi-urban, priority education networks) primary schools and college. We also want to ensure the diversity of educational organizations including institutions involved in innovative activities in scientific and pedagogical education (hands-on, EIST, etc.). The diversity of the institutions involved and their homogeneity within a school network is designed to monitor the effect of variables that are the personal characteristics of students (gender, age, cultural background, curriculum, and school performance, interest science, etc.) and those of educational devices around them.

The structure of the questionnaire

The final version of the questionnaire is organized in three sections and 18 questions.

- Part I) detection of technical characteristics of objects (5 questions); In this first section we asked the participants to identify and assign technical characteristics (Not an object or Object; Living, Not living or Virtual) to a list of items at various levels of familiarity that included technical objects but also animated and natural entities.
- Part II) ability to create relationships between objects (10 questions). In this second part, we examine the classification of different items and examine the possible relationships between them, considering that knowledge is organized. In each task six images were presented, which included a representative picture and a tag with its name (an example in Figure 1 for the lever principle: 1. Corkscrew, 2. Nutcracker, 3. Wheelbarrow, 4. Swing, 5. Elbow articulation, 6. Scissors).

FIGURE 1



The lever principle

- Part III) direct use of technical objects and personal interest in the technical and scientific (3 questions). In this section, we have developed three questions related to different aspects:
 - 1) time that students spend using some technological object related to the school and house contexts for formal and informal learning;
 - 2) importance of learning a technology subject;
 - 3) generic students' interest in scientific and technological subjects.

RESULTS

Brief overview of results from the First step: the explorative survey

The results show that for the majority of students there is a consensus of over 50% on the collocation of the items for the category Not an object or Object. In Table 1 we present the items ranked in order of High to Low % for each category.

TABLE 1
Items classed as Not an object or Object

Item	Not an object	%	Item	An object	%
1	Salad	90	1	Bike	90
2	Volcano	88	2	Scarf	86
3	Tulip	84	3	Sheet of paper	74
4	Boiled egg	76	4	Train	54
5	Nuclear power plant	70			
6	Milk Cow	70			
7	Jam	66			
8	Plane tree leaf	66			
9	Home	58			
10	Submarine	58			
11	Bird's nest	50			
12	Uranium	49			

From results (Table 1) we see a gradation in the attribution of category object and not an object: 1) for some items, the students are almost unanimous in their collocation, for example Salad and Bike reach 90% of agreement in their collocation; 2) for some items the consensus is intermediate, for example the train is placed as an object for 54%, for 34% as not an object and for 12% they don't know; 3) finally for other items there is more dispersion in the consensus. For example, Uranium finds a less clear collocation indicated by 49% as not an object; 15% an Object, and for the last 36% they do not know.

In Table 2 we present the items ranked in order of High to Low % for the Living, Not living or Virtual category.

TABLE 2
Items classed as Living, Not living or Virtual

Item	Not living	%	Item	Living	%	Item	Virtual	%
1	Wig	98	1	Flu virus	90	1	Avatar	96
2	Snowman	94	2	Coral	90	2	Cartoon	92
3	Frozen fish	84	3	Bacterium	84			
4	Talking doll	74	4	Hair	62			
5	Robot	64						
6	Nails	48						
7	Smileys	46						

We find that most students know that virus, coral, bacteria are part of the living world. However, we note that membership of the living organic attributes such as Hair or Nails are much less evident. The first is considered by 62% to be living and by 30% non-living; vice versa the Nail is considered by 48% to be living and by 36% a non-living thing. Instead Avatar for 96% of all students is considering as Virtual. In general from Table 1 and 2 we can see that the classification becomes more uncertain for objects less tied to the prototype of their category or more distant from common experience. Also, if we consider technical object as anything that has undergone a transformation of human origin (Rabardel, 1995), these first results show that students have a narrow view of the concept of object.

From the second part of the questionnaire, we see that students show certain flexibility in the categorisation of data, considering that they do not use the same systematic indices to perform their grouping. In general, a functional and contextual categorisation is more activated by the students.

From the third part of the questionnaire, it appears that the use of the smartphone is the most common (more than two hours per day for 36% of students and at least one hour for 27% of them) followed by the use of the internet (2 hours by day for 23% of subjects and between 30 minutes and one hour for 50% of them). From the second question, the awareness of the importance of science literacy as an opportunity for the discovery of reality (65%) was the majority choice. The link between the study of technological objects and future professional choices remains relatively low (26% of answers). From this, it appears that student do not realise the importance of technical and scientific training for their professional future. Finally, we asked the students to indicate their interest in scientific and technological disciplines. The analysis shows that the most interesting for them was thus ranked: 1) greatest interest was in technology; 2) average interest was for physics and chemistry; biology, geology and astronomy; 3) lowest interest, computer science. A detailed description of this research can be found in Impedovo et al. (2015).

Results from the Second step: the interview

The four interviews are listening from the researchers. Significant episodes were identified, with interesting moments in line with our goals. Once selected episodes related to the same item of grouping activity, we proceeded to the transcript of verbal interventions. Then, the researchers carried out a thematic analysis in order to identify different styles of reasoning.

The four interviews show different three styles of answers to the questions proposed: Grouping all the items in the Figure; Grouping some items in the Figure; Grouping as a dyad in

the Figure. Here we present an example for each student in relation to the same grouping activity (Figure 1):

- *Grouping all the items in the Figure:*

In a first time, this student (best pupil in the class as indicated by the teacher after the interview) refers to an unusual criteria related to the daily use of the objects rather than their ontological nature (biological or technical) that usually lead to exclude the human elbow. But in a second time after a closer exploration he finds that all objects are articulated. But when we ask more explanation of that we note that he does not know the mean of the terms 'lever principle'. Later, he had identified some categories (natural, manufactured, energy, non-energy-related). He uses some categories also in the resolution of the successive proposals of grouping. So, we see that he is capable to find others possible links between the proposed items, articulating the different sub-categories of possible grouping, and demonstrating the cognitive flexibility of his thinking.

Excerpt:

R: Do you think we can put them all the items together?

S: They all have a joint, because they move, but we are obliged to take out the wheelbarrow. Others are used in everyday life. So we can group five items together, all but not the wheelbarrow. Ah, here is the wheel, so even it has an articulation, the wheelbarrow ...

R: Are all of them related to the principle of leverage?

S: I do not know.

- *Grouping all or some items but of the same type (technical objects vs biological)*

The second and third (F, M) students (averages pupils), as many students propose one or more groupings between three, four or five items but always without the human elbow. When we draw their attention on the existence of two parts in all items they continue they continue to say that all cannot be grouped.

- *Grouping as a dyad in the Figure:*

The fourth student (F, low pupil) tends to group the items into groups of two and only subsequently sought search for a point of contact between all the items. The grouping for two seems the most plausible for all proposed clusters. He says, only after being prompted, he did not know the term "leverage" principle. Finally, also the fourth student proposes combinations of two, so showing the cognitive rigidity of his thinking, and says he does not know the term "resistance".

Excerpt:

R: Can you choose the criteria from the list below? Do they all use the principle of leverage?

S: no, not all

R: and which not?

S: the swing...

Also in successive groups, certain items are considered unrelated to others, more when they are not linked by a semantic and visual closeness (such as power plants and foods).

Few results from the third step: the extensive survey

Data collection is still in process. The results presented therefore only concern 124 students (60 girls and 45 boys), corresponding to 11 years old (16.8%); 12-13 years old (32.7%) and 14-15 years old (50.5%). 36.8% are in 6e; 21.7% in 5e, 4e and 3e and 41.5% en 2e. The 32.1% followed an «Integrated education of science and technology» and not the 68.9%. Below there are just some of the results found related to the item object or not and biological, mineral, or artificial.

a) The meaning of concept of objet for students

Adults give a very broad extension to the concept of objet which might include ideas, natural things, technical artifacts, But what about children? Obviously, our first results (Table 3) show that the materiality of things is not a sufficient criterion to define an object. To a vast majority of the pupils, a volcano, a star, a spider's web, an egg, a birds' nest, a tree leaf is not objects. In accordance with the distinction described by Dagognet (1989), it seems that children differentiate "things" (natural entities) and "objects". But, it is noted that the artificiality criterion (human production) is also a not sufficient criterion to define what is or not an object. Human productions like tunnel, artificial lake, loaf of bread, cornflakes, factory, nuclear power plant, cathedral, bridge... too are not considered objects.

TABLE 3
Items classed as "Object" or "Not Object"

Item		Not an objet	12	Bridge	74.0%		Item	Objet
1	Volcano	94.1%	13	Jam	73.5%	1	Doll house	98.0%
2	Star	91.0%	14	Software	73.3%	2	Model of airplane	97.1%
3	Spider web	89.1%	15	Bird nest	73.7%	3	Box of chalk	95.2%
4	Egg	84.3%	16	Igloo	72.3%	4	Tube mayonaise	76.0%
5	Tunnel	82.2%	17	Building	72.0%	5	Tin of sardines	67.3%
6	Artificial lake	83.0%	18	Leaf of plane tree	71.6%	6	Honey pot	69.7%
7	French baguette	80.6%	19	Electric scheme	66.3%	7	Sheet of paper	85.1%
8	Corn flakes	78.4%	20	Train	64.0%	8	Artificial heart	61.9%
9	Factory	80.0%	21	Soup in box	62.6%	9	Photography	59.8%
10	Nuclear plant	76.7%	22	Box of aspirin	61.2%			
11	Cathedral	75.0%	23	Submarine	60.0%			

Therefore, these data give nuance to our first study (Andreucci & Ginestié, 2012). If often buildings of food products are not categorized as "technical objects" it is also and first because they are bad representations of the concept of object itself. Indeed we see that's when it is explicit that food are human products because they are packaged (mayonnaise tube, canned of sardine, pot of honey) they are then considered as objects. In the same way, we observe that a leaf is not

an object when it is leaf of tree but when it is a piece of paper it is an object because student know that paper is a made material. In the same way we can see that real buildings are not objects but if they are a functionality of toys (doll house), in this case they are considered as objects because they are concrete and pragmatic tools of playful activities. The same difference appears between train and model of airplane according to the statue of transport vehicle or toy manipulated. The effect of cumulated factors, like dimensions, social function and related action plans.

If the concept of technical object is very complex and difficult to define (Akrich, 1987; Cazenobe, 1987) because of its several dimensions (design, making, function, using...) can see that the concept of object is also difficult to contain. For the students it is related to a combination of criteria (materiality, artificiality, functionality, substantiality, packaging, dimensions,). So, the students' thinking appears even more complex and discriminant than one might anticipate.

b) The allocation of artificial character of objects

With this item we try to see what students are able distinction to make a distinction between what for adults may be generally grouped together under the terms of "beings" (the living) under the term "things" (entities natural inanimate) and under the terms of "objects" (human productions, artificial entities), in line to the Dagonnet consideration (1989): "Let us distinguish these two categories, that of things and that of objects. The stone, for example, belongs to the first -The one of thingness, -while, if cut, polished or simply "marked" and engraved, it becomes a 'clipboard' eventually, but then reports to the products of world or objects²" (p. 19-20). Nevertheless, given the ambiguity that these three terms may contain and to make the task much explicit for students, we proposed to categorize a list of entities indicating whether it is according to them something "biological" or "artificial" or "mineral". After much hesitation, this terminology was preferred to that of using other words including the word "technique" used in a previous study.

Results (Table 4) show that the idea of artificiality appears strongly related to technological innovation: for example, the item "Robot" (figure par excellence of modernity and the incorporation of human intelligence in objects) has the highest percentage of Artificial (88.1%). The heart, even when it is qualified as "artificial" is still considered part of the biological world for nearly 9% of pupils. This applies even aspirin which just over 11% of students assigns a biological nature and 7% a mineral one. This result would itself tend to show that the function of the object (act on living because of its therapeutic action) or even its physical and chemical composition can contribute to not see it as an artificial product, even if there is no doubt that all students (or nearly all) know that this is a manufactured product. A similar comment applies to the "ceramic tooth" seen by nearly 17% of students to be within the biological world and 7% of students within the mineral world.

The boundary between the biological world and the technological world also remains difficult to resolve in terms of biological food products. While being packaged (canned sardines) or processed (frozen fish) or modified (seedless grapes) contributes to make seen them as artificial entities by a majority of students, others (for 17 to 23%) favor their first ontological nature and see them as biological rather artificial entities. In addition, when the transformed character of such entities is less obvious (cherry tomato) due to the absence of incongruity with

² Original text : « Distinguons ces deux catégories, celle des choses et celle des objets. La pierre, par exemple, appartient à la première –celle de la chose, -tandis que, si elle sciée, polie ou simplement « marquée » et gravée, elle devient un « presse-papier » éventuellement, mais relève alors du monde des produits ou des objets »

the organic product they know, most students do not recognize products that take their existence to human intervention. The results are also intended to be deepened with an extended target.

TABLE 4
Items classed as Biological, Mineral, or Artificial

Item		Artificial	Item		Biological	Item		Mineral
1	Robot	88.1%	1	DNA	89.5%	1	Slate	75.0%
2	Artificial heart	87.3%	2	Hair	87.4%	2	Cut diamond	59.8%
3	Box of aspirine	75.8%	3	Nails	78.2%	3	Volcano	59.6%
4	Tooth ceramic	72.5%	4	Egg	77.7%	4	Menhir	58.4%
5	Canned of sardines	71.4%	5	Virus	75.5%			
6	Frozen fish	64.4%	6	Cherry tomato	73.3%			
7	Honey pot	61.4%	7	Spider web	71.3%			
8	Talc box	51.0%	8	Star	51.5%			
9	Sponge	49.5%						
10	Cherry grafted	44.7%						

DISCUSSION

In this paper we focus on the methodological steps of a research project about the subjective attributions of students between 12 and 14 years about the technical object.

We start from the consideration of the importance to focus on the technical object. Indeed, the socio-constructivist literature focus the attention on the analysis of human activity (Vygotsky, 1934; Latour, 1994 etc...), giving an important place to the tools (technical or symbolic) that serve as instrument of the activity. A widespread term used is “artifact”, used to refer to “anything that has undergone a transformation, however small, of human origin” (Rabardel, 1995) or “any object created, manipulated, shaped by humans to an end” (Albero, 2010). However, it is a widely unusual term in scholastic textbooks. For this reason we don’t use it in the survey and interview.

For a more general theoretical perspective we can consider that the nature of artefacts is basically embedded in dualism (Kroes & Meijers, 2006; Vaccari, 2013): technical artefacts as such are "mixed" in the sense that they combine scientific properties, physical, chemical, geometrical, that characterize the material objects in the margins of the specific social nature of properties related to their intent, their design, their production, their use and, also, their way of deterioration and recycling - generating significant problems in our consumerist societies.

The study brings us back to the importance of handling and knowledge of the technical objects from “inside”, allowing a practical familiarization through experimentation, observation

and manipulation. This is in line with the current discussion on the redefinition and re-organisation of the common core acquisitions for 12 to 14 years old pupils. The French national program called the “The common base of knowledge” promoted an updating of technological curriculum, in continuity between lower secondary school and high school, and with a stronger contextualized approach. The trend is to use different methods of analysis, design and implementation, to allow the children to plan his/her own work, searching multiple solutions to the same process. The intervention of technological education should help to change and improve the “meeting” of students with the technical objects by inserting it in a context ascribed to the production, to the world of work and the technical process. In a complementary way, in future research we will consider to explore also the understanding of teachers on some specificity of technology education - as in the study of Hallström and Klasander (2013) about pre-service technology teacher understanding of technological systems.

REFERENCES

- Albero, B. (2010). Une approche socio-technique des environnements de formation. Rationalités, modèles et principes d'action. *Education et Didactique*, 4(1), 7-24.
- Akrich, M. (1987). Comment décrire les objets techniques? *Techniques et Culture*, 9, 49-63.
- Akrich, M. (1993). Les objets techniques et leurs utilisateurs, de la conception à l'action. In B. Conein, N. Dodier & L. Thevenot (Éds), *Les objets dans l'action*, (pp. 35-57). *Raisons Pratiques*, 4, Paris: Editions de l'EHESS.
- Andreucci, C. (1990). Conservation du volume et non conservation de l'encombrement. *European Journal of Psychology of Education*, 5(3), 309-326.
- Andreucci, C. (2003). Comment l'idée d'instabilité du volume vient aux enfants. *Enfance*, 2, 139-158.
- Andreucci, C., & Ginestié, J. (2002). *Un premier aperçu sur l'extension du concept d'objet technique chez les collégiens*. Lyon: INRP.
- Andreucci, C., & Roux, J. P. (1992). Savoir comparer les contenances pour pouvoir conserver les quantités contenues. *Enfance*, 46, 1/2, 79-98.
- Cannard, C., Bonthoux, F., Blaye, A., Scheuner, N., Schreiber, A., & Trinquart, J. (2006). BD2I : Normes sur l'identification de 274 images d'objets et leur mise en relation chez l'enfant français de 3 à 8 ans. Retrieved from <http://gsite.univ-provence.fr/gsite/Local/lpc/dir/blaye/pdf/CannardetalAnneePsy.pdf>.
- Cazenobe, J. (1987). Esquisse d'une conception opératoire de l'objet technique. *Techniques et Culture*, 10, 61-80.
- Dagognet, F. (1989). *Eloge de l'objet*. Paris: Vrin.
- De Vries, M. J. (2012). In M. J. de Vries & I. Mottier (Eds), *International Handbook of Technology Education: reviewing the past twenty years* (pp. 387-397). Rotterdam/Taipei: Sense Publishers.
- Ginestié, J. (2011). How pupils solve problems in technology education and what they learn. In M. Barak & M. Hacker (Eds), *Fostering human development through Engineering and Technology Education* (pp. 171-190). Rotterdam: Sense Publisher.

- Hallström, J., & Klasander, C. (2013). *Technology Education for systems thinking and sustainability: what Swedish pre-service Technology teacher students know about technological systems*. Paper presented at PATT 27, Technology Education for the Future - A Play on Sustainability, Christchurch, New Zealand.
- Haudricourt, A.-G. (1988). *La Technologie science humaine: recherches d'histoire et d'ethnologie des techniques*. Paris: Éditions de la Maison des Sciences de l'Homme.
- Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures*. New York: Basic Books.
- Impedovo, M. A., Andreucci, C., & Ginestié, J. (2015). Mediation of Artefacts, Tools and Technical Objects: an international and French perspective. *International Journal of Technology and Design Education* (Doi: 10.1007/s10798-015-9335-y).
- Impedovo, M. A., Andreucci, C., Delsérieys-Pedregosa A., Coiffard, C., & Ginestié, J. (2015). Technical objects between categorisation and learning: An exploratory case study in French middle school. *Design and Technology Education: An International Journal*, 20(2), 32-49.
- Ineke, F., Sonneveld, F. W., & de Vries, M. J. (2011). Teaching and learning the nature of technical artefacts. *International Journal of Technology and Design Education*, 21(3), 277-290.
- Latour, B. (1994). Une sociologie sans objet ? *Sociologie du Travail*, 4, 587-607.
- Kuusela, H., & Paul, P. (2000). A comparison of concurrent and retrospective verbal protocol analysis. *American Journal of Psychology*, 113(3): 387-404.
- Kroes, P., & Meijers, A. (2006). Introduction: the dual nature of technical artefacts. *Studies in History and Philosophy of Science*, 37, 1-4.
- Mauss, M. (1936). Les techniques du corps. *Journal de Psychologie*, XXXII, 3-4.
- Perrin, J. (1991). *Construire une science des techniques*. Limonest: L'Interdisciplinaire.
- Rabardel, P. (1995). *Les hommes et les technologies – Approche cognitive des instruments contemporains*. Paris: A. Colin.
- Séris, J. P. (1994). *La technique*. Paris: PUF.
- Sigault, F. (1990). Folie, réel et technologie. *Technique et Culture*, 15, 167-179.
- Simondon, G. (1958). *Du mode d'existence des objets techniques*. Paris: Méot Éditions.
- Vaccari, A. (2013). Artefact dualism, materiality, and the hard problem of ontology: some critical remarks on the dual nature of technical artefacts program. *Philosophy and Technology*, 26(1), 7-29.
- Vygotsky, L. S. (1934/1997). *Pensée et Langage*. Paris: La dispute.