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Bernard Coulibaly, Pascal Marquet

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Education in a Technological World: Communicating Current and Emerging Research and Technological Efforts



A. Méndez-Vilas (Ed.)

The concept of instrumental conflict: an application of the theory of activity to computer-supported teaching-learning situations

P. Marquet¹ & B. Coulibaly¹

¹ LISEC, University of Strasbourg, France

The purpose of this chapter is to define and to illustrate the concept of instrumental conflict, as a tool to a better understanding of the difficulties that learners encounter while using ICT (Information and Communication Technologies). An instrumental conflict takes its meaning within the framework of Rabardel's theory of instruments, which in itself is a part of the more general theory of activity.

The main idea is that VLE (Virtual Learning Environments) associate three different types of artefacts: didactical, pedagogical and technical. These artefacts must be correctly combined, so that learners can have access to knowledge, which is embedded in the device. We point out the usefulness of such a concept. We thus describe how scientific communities, which focus on didactics of Mathematics and computer science, and on ICT in education and training in particular, deal with difficulties of implementation and exploitation of ICT.

It appears that some objects called either didactical objects or pedagogical objects represent a reality, which is similar and extremely wide at the same time. In fact, this ambiguity justifies the distinction between didactical artefacts, pedagogical artefacts and technical artefacts. We finally give some examples of obstacles that can be considered as instrumental conflicts as well as some possible developments offered by the concept of instrumental conflict.

Keywords theory of instruments; theory of activity; instrumental conflict; didactical artefact; pedagogical artefact; technical artefact

1. Introduction

Over several years, a unanimity has grown up around interest in an instrumental approach as a particularly rich heuristic perspective upon understanding human activity, particularly those in which computers are used [1, 2]. It must be remembered, however, that this instrumental approach takes as its conceptual base theories of activity developed by Vygotski since the 1930s, the period in which he advanced the first attempt at a theory conceptualising activity mediated by tools and signs, which Rabardel [3] reframed and extended to contemporary technologies.

The aim of this article is to show how Rabardel's approach can be applied to school teaching situations or to training involving ICT (Information and Communication Technologies). Such situations constructed by design, are often complex and demand that their subjects interact with objects of different natures: didactical, pedagogical, technical. Virtual Learning Environments (VLEs) may be considered in the same way in that they bring together on platform programmes different objects, posing the question of their optimal organisation, in the sense that the user has to some degree acquire the knowledge presented and made accessible by the system.

Initially this article will revisit the principal concepts of instrumental theory and will show how the matter of instrumental conflict arose in the body of theory which it could complete. The main idea is to make a distinction between the three components of a technical system dedicated to teaching, to know, firstly, the content of the discipline being taught, secondly the possible forms for their representation and the scenario for their presentation and, thirdly, the functionalities of the software programme. These three types of components are each the object of a process of adaptation each of which can interfere with the other and produce a conflict.

The second element of this paper will show that the simultaneous presence of didactical, pedagogical and technical objects presents difficulties in terms of theoretical approaches which relate to situations of computer-supported teaching and learning. This is the case particularly with attempts to analyse pupils' activities in Mathematics using certain software programmes, and also with models which depend upon descriptive norms of pedagogical objects such as can be used in computing. It appears that teachers of Mathematics and computer scientists are both confronted with a similar problem, the fact that the concepts that they each propose tend to cover too diverse a set of realities. In this respect, the concept of instrumental conflict offers the opportunity to describe situations and in a more precise manner than other approaches that might be mentioned.

The subsequent element presents the articulation of an extension to the instrumental approach which is proposed to run alongside the instrumental approaches of teachers of mathematicians and computer specialists. It is considered that, without presuming it to constitute a major epistemological leap forward, the concept of instrumental conflict offers greater precision in matters of computer-supported teaching and learning to the extent that it identifies where there may exist a discrepancy between a proposed element of content, a structural format or a presentational scenario and the possible system options for action. In this regard, the developments in pedagogical engineering put into operation for distance learning will gain from this research.

Finally the article concludes by suggesting how and in what circumstances instrumental conflict is likely to arise, such that readers interested in this approach can use the concept to their advantage.

2. Principal concepts in instrumental theory

2.1 The Rabardel approach

One of the Rabardel central concepts concerns the instrument, tool or technical object, this being long the subject of considerable interest on the part of the scientific community. According to Rabardel, the concept generally involves two different facets: the one centred upon the intended function of the instrument in the activity and the other centred upon the activity itself.

Simondon [4] illustrates this first perspective. Simondon established a distinction between instrument and tool. The instrument serves to draw upon information while the tool serves to carry out an action (p. 80). These two dimensions correspond with what he called the technical object. Although taking it in a broader perspective intending to address the relationship between man and his socio-technical environment, he considered that the technical object is always oriented towards the accomplishment of a particular function. He notes: “the beginning of the mediation between the organism and its environment”, which heralds the arrival of biological metaphor to explain the concept of instrument. Running counter to this, Guillaume and Meyerson [5], offered a concept of the instrument centred upon activity. They illustrated their conception of the instrument by analysing the use that monkeys make of instruments in their activities. What was important in this latter context was what the subject did with the instrument and the active power that it conferred upon the monkey concerned. For them, the instrument was an intermediary between the subject and the world whereas for Simondon this intermediation existed between the organism and its environment.

Wallon [6] compared the human instrument with that of the monkeys. He wrote taking the perspective of an instrument centred upon an activity, with, in addition, the idea that the instrument enables the accumulated experience to be capitalised upon. That renders the instrument not only an intermediary, but also an experience and a capitalised knowledge. This perspective is also developed by Vygotski and above all Leontiev in their theory of activity. The fundamental aspect to draw from this conceptualisation of the instrument is that it (the instrument) has no significance except in relation to the subject, a subject engaged in the process of producing an activity.

That is the reason why Rabardel proposed a distinction between artefact and instrument. The artefact is a man-made, material object: “in anthropology, the notion of artefact designates anything that has undergone a transformation, however minimal, of human origin” (p. 39 of the translation), whereas an instrument designates “the artefact in situation, inscribed in usage, in an instrumental relation of action to subject as a means of the action” (p. 39 of translation). The instrument is thus the result of the utilisation of a tool [7]. One can thus say that the tool is itself an artefact, and that the term instrument can be used to establish the artefact as a means of realising the activity of the subject. Hence it is the subject who confers upon the artefact the status of instrument.

Another fundamental dimension in Rabardel’s conceptualisation of the instrument is that it cannot be reduced solely to its material nature: the technical object in the Simondon [6] sense of the term. Thus the symbols, the signs, the language and all the intellectual constructions are also instruments, from whence comes a second, symbolic nature which it may take on. In effect, in his conceptualisation of an extended instrumental theory, Rabardel [8] considered only that the representation of the instrument should not be limited to a particular type of instrument like technical or psychological tools in the sense employed by Vygotski. In this way all constructed material or symbolic objects are artefacts and become instruments in interaction with a subject.

Thus the instrument is considered as combination of attributes in one entity, with two facets relating to subject and artefact. And yet more important, this entity relates also to the subject and society because every instrument has an eminently social dimension. The mode of operation or usage employed by the subject or community refers back to another critical component of Rabardel’s theory, that of instrumental genesis. This results from the dynamics of the subject’s activity and incorporates two processes:

- On the one hand, a process of transformation of the artefact in an activity situation is as much a matter of its structure as its functioning – it is instrumentalisation which connects the attribution of a function to the artefact on the part of the subject.
- On the other, there is the transformation of the subject himself at the cognitive level: this is instrumentation, which consists of the adaptation of the subject’s knowledge to the artefact or in the creation of new knowledge.

These two processes are jointly involved in a reciprocal, two-way relationship. They represent two inseparable dimensions of instrumental genesis.

To synthesise, it is held that constructed cultural objects, be they material or symbolic, possess identical characteristics of which artefacts are made. Whenever a subject interacts with an artefact, an instrument emerges following a phenomenon of instrumental genesis, composed of a process running from the artefact towards the subject (which is instrumentation) and a process running from the subject towards the artefact (which is instrumentalisation) (*cf.* fig. 1).

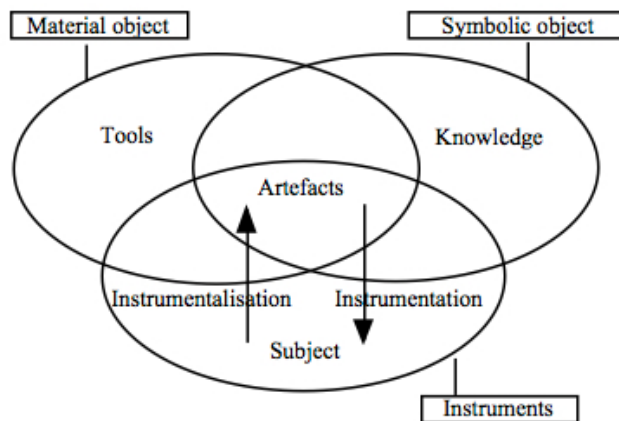


Fig. 1 The concepts of artefact, instrument and instrumental genesis.

2.2 Application to learning and teaching situations

The extension of instrumental theory to symbolic objects as proposed by Rabardel provides the opportunity to consider knowledge in the process of being acquired in learning and teaching situations as much as the artefacts themselves [9]. In all cases, these artefacts need to be sub-divided into didactical artefact and pedagogical artefact. Everyone writing in the field of instrumental theory has to specify that the term didactical is used in a sense far removed from its everyday sense. Here, didactical is neither to be understood in the sense of teaching method, a technical means or a particular pedagogy, nor as the art of teaching... but rather in the sense of content [10]. In fact for Brun [11] the redefinition of the term didactical contains a willingness to refocus upon the importance of teaching content. It is felt that this brief clarification is warranted to resolve any misunderstanding between the terms pedagogy and didactics as the distinction is not always immediately obvious.

Didactical artefact is thus the term used here for all the disciplinary content which needs to be learned in order to become an instrument of the one mastering it. A pedagogical artefact is defined here as being like the formalism for representation and/or the disciplinary content presentation scenario appropriate to its teaching. Formalism for representation is taken here to mean the semiotic processes of the designation of the didactical artefact, and presentation scenario is taken to mean the presentation of the didactical artefact, also called pedagogical scenario [12].

In distinguishing a didactical and a pedagogical artefactual dimension within knowledge taught, this paper makes the same sort of distinction as does Peraya [13], for whom, each time something is taught, he sees it as being taught within a semio-pragmatic context, which understands the signifiers essential to its formulation, and which are situated in a discourse oriented towards the appropriation by the learner of the particular object being taught.

Duval [14] also himself makes a distinction between two aspects of the same element of knowledge. He calls it *noesis*, a term which he borrowed from Plato and Aristotle, taken to mean the cognitive acts like the conceptual understanding of an object, discrimination of a difference or the understanding of an inference, and he indicates by *semiosis* the production of a semiotic representation. In the field of linguistics, this conception corresponds respectively to the signified and the signifier. The nature of expression is built upon that raft of signifiers, i.e. that of the form and nature of that which is signified as content [15].

Two families of artefacts are thus present, one being the knowledge ordained by the situation, and the other the discursive setting for learning. In order for one element of knowledge to be effectively acquired by the learner so that, together, they interact as an instrument, it is essential that the learner takes on board both the didactical understanding (content) and the pedagogical (the formalism for representation and/or the presentation scenario). Were one to risk an analogy here: where some would see water, others in fact see one atom of Oxygen and two atoms of Hydrogen which together constitute a molecule of water.

A fundamental principle is thus proposed here that every didactical object is associated to a pedagogical object in a teaching situation. Each of these objects, considered like an artefact, must be instrumentalised and instrumented suitably by the subject, i.e. that two concomitant phenomena of instrumental genesis have to be in operation. To put this another way, the learner has to attribute the right functions at times to the content and to its formalism for representation and he must also adapt his knowledge and apply it at times to the content and its formalism for representation.

In order to illustrate this didactical and pedagogical duality relating to associated artefacts the example of the multiplication may be used. To help the instrumentalisation of this didactical object one has to typically resort to two formalisms. The first consists in writing in lines and columns the list of results to be recorded (*cf.* fig. 2a). The second is presented in the form of a double-entry table (*cf.* fig. 2b).

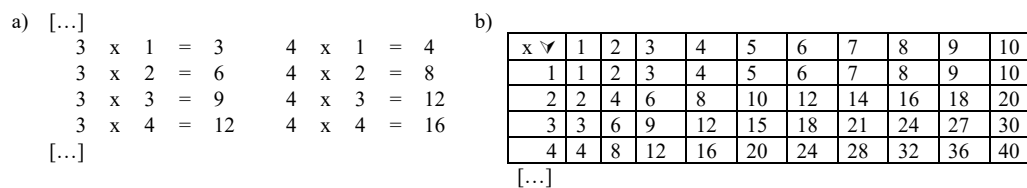


Fig. 2 Formalisms for presenting multiplication tables.

Thus there are the two objects: the one didactical – multiplication, the other pedagogical – be it writing in lines or the double-entry table, which have to be mastered by the pupil at some point in his schooling. The didactical artefact can function very well with one or other of the pedagogical artefacts, and reciprocally, each of the pedagogical artefacts can function very well without the didactical artefact, as is the case when writing on lines is used to represent the results of other calculations, like addition, for example, or when this type of table serves to represent a calendar with which nursery school children are familiar.

In order to complete the matter of the distinction between didactical and pedagogical artefact, it is interesting to reflect upon the follow-up to Duval’s work which was considered above, which describes the existence of two postures in the learning of Mathematics: one being of dissociation and the other of non-dissociation. The first posture, corresponding to the distinction already made between didactical and pedagogical artefact, makes the distinction between mathematical objects, being numbers, functions, straight lines, graphs etc, and their representation, an indispensable condition for better learning. What matters is more the object represented rather than the style or form for its representation, the latter being only ever a means of communication of the object. This point of view postulates that the fact of not distinguishing the content from form leads in the long term to a loss of understanding. The representation of mathematical objects here is then secondary and constitutes a property extrinsic to cognition and the conceptual appreciation of these objects.

The second posture is that of non-dissociation between *noesis* and *semiosis*. The field of Mathematics could constitute the primary domain where semiotic representations are indivisible from the objects represented because the possibility of carrying out applications upon mathematical objects could depend directly upon the semiotic system of representation utilised. The analysis of problems in the learning of Mathematics and of the stumbling blocks students regularly come up against suggests that non-dissociation is a fundamental law in cognitive functioning. Not only does semiotic representation serve as a means of communication, but it is also indispensable to activity in Mathematics. It is, from this point of view, an intrinsic property of mathematical objects.

2.3 Towards a theory of instrumental conflict

The didactical and pedagogical traditions which have arisen owing to the laws and regulations of teaching and consequently since the industrialisation of teaching [16] have progressively determined how the majority of content should be presented in order for it to be assimilated by the greatest number of learners. It is a fact that these traditions are not always a great help when one wishes to introduce ICT into a learning and teaching situation.

In fact, things get even more complicated when didactical and pedagogical artefacts are associated with technical artefacts. For example, a software which teaches multiplication in elementary school is a technical artefact, which, to become a technical instrument has to become a learning object which, in turn, depends upon the instrumentalisation and instrumentation of the user. But as much as it may be a technical artefact, this VLE also brings into play the aforementioned didactical and pedagogical artefacts, which, in their turn, have to be suitably instrumentalised and instrumented in order to become real instruments. That which Peraya [13] terms techno-semio-pragmatic appears similar to what is referred to here as an overlay of three artefactual layers: didactical, pedagogical and technical. (*cf.* fig 3).

Thus, the introduction of a technical system may provoke a disturbance of the balance between didactical and pedagogical artefacts, to the extent that the formalisms representation and/or the representation scenarios which were pertinent beforehand are found no longer usable. These disturbances to equilibrium may be termed instrumental conflicts, suggesting that the processes of instrumentalisation and instrumentation of the various artefacts in question can interfere with each other.

In an instrumented teaching and learning situation, the learner-subject is not only a physical, cognitive or social entity in interaction with a technical system, he is equally a subject who is intentionally engaged in the undertaking of his tasks [16]. In the realisation of these tasks, the learner carries out activities which can be both productive and constructive, to the extent that the subject produces a response to the situation and where the task concerned confers upon him an additional cognitive development. Each time one introduces a technical system, one takes the risk that the different levels of instrumental genesis may interfere with one another and deprive the learner at times of the possibility to respond to the situation and of constructing the didactical instrument as envisaged in the particular situation.

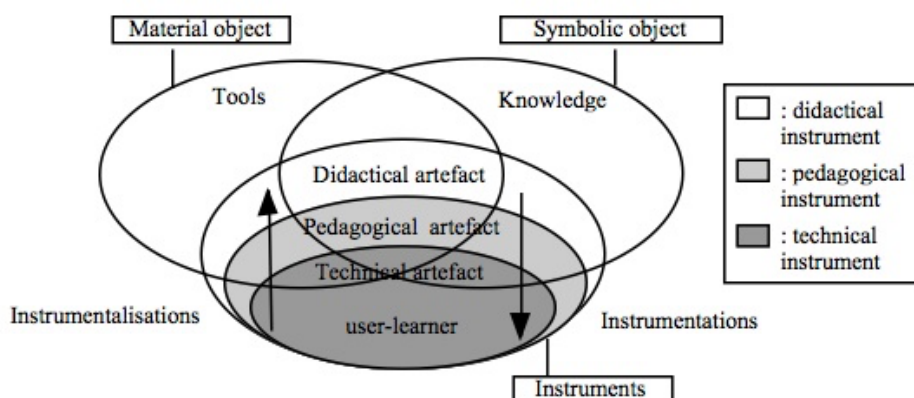


Fig. 3 Relationship of artefacts as sources of instrumental conflict.

It is in this combination and usage that learner-users make of didactical, pedagogical and technical artefacts that the optimisation and efficiency of learner activity comes about, be it productive or constructive and the hypothesis is advanced here that failure to produce the anticipated responses results from what may be called instrumental conflict, in other words, the unfortunate association between one or several artefacts which produces a failure in the instrumental genesis of at least one of the three artefacts.

3. IT-based didactical and pedagogical objects in the teaching of Mathematics

A significant portion of VLEs have been developed by ICT specialists with a view to autonomous learning with the benefit of pre-existing knowledge or competencies [17]. VLE designers not necessarily being teachers or specialist trainers in tutoring learners, the question of the integration and adaptation of these technical artefacts to classic teaching and training practices cannot fail to be posed.

This question is as much, if not more, important than the conception of learning objects, which in the present context of ICT development covers matters which run far beyond the realm of pedagogical engineering. In effect, it is all about normalising teaching content in order to be able to organise it by function relating to the intended learning objectives, given VLE functionalities, the language in which they are presented, the area of knowledge they address, etc. This paper holds to the logic of conception and representation of didactical and pedagogical objects.

Mathematics is the school discipline area where the introduction of VLEs is the most evident, from the very inception of which one often finds a quite animated discourse [18]. According to Guin and Trouche [19], this discourse draws its legitimacy from Piaget's constructivism and is in fact characterised by a twin illusion:

- That of a naturally positive contribution to learning: the environment allows one to see and therefore to understand.
- That of a naturally positive contribution to teaching: this illusion is based upon the principle that the introduction of a VLE results in reducing the cognitive loading upon learners in the resolution of mathematical problems. In effect, the computerised artefacts would lift the technical operations off the learners' shoulders and thereby allow them to focus upon the mathematical objects.

For the IT specialists, putting in place a training structure can be achieved by the successive addition of '*digital building blocks*' of different shapes and sizes, which can vary from a simple document right through to an entire training programme. This vision arises from the engineering of pedagogical objects based upon an object-centred approach, also used in the development of software. What is important in this conception is the internal coherence of the technical artefacts operating in the learning context. But in the particular context here technical artefacts constitute the third element, giving rise to the emergence of instrumental conflicts. What, then, does the didactical object actually signify for Mathematics teachers and the pedagogical object for computer specialists?

3.1 Computerised didactical objects as viewed by teachers of Mathematics

A study of the usage of *Dérive*¹ software programme by Lagrange and Drouhard [20] has shown that the pupils did not automatically manage the transition from the technical to the conceptual and that they did not directly access the

¹ This software programme is just part of the panoply of digital calculation programmes. The originality of *Dérive* lies in the fact that it was conceived as the system covering the broadest possible range of formal calculus. It did not really address a specific teaching need.

didactical objects which could be manipulated by the software. In reality, this process did not work to solve every problem and its operation could only be technical because resorting to *Dérive* did not mean by its very use that a better explanation of processes would be achieved.

From this observation Artigue [18] deduced the existence of two phenomena, that of double-reference and pseudo-transparency, in order to explain the integration complexity of a VLE, in this case *Dérive*, in the context of teaching and learning in Mathematics.

3.1.1 Double reference

The situations observed by Lagrange and Drouhard [20] occurred in two environments: that of the software programme and that of paper-pencil and consisted of factorisations of the polynomial X^{n-1} and of trigonometrical calculation. The phenomenon of double reference thus arises from a confrontation of the traditional environment, paper-pencil, and that of *Dérive* [19].

Artigue [18] thus takes account of the rational factorisation of the polynomial in the penultimate year of highschool: “In the paper/pencil environment the factorisation of the polynomial is linked, at this educational level, to research into real roots [...], to techniques of polynomial division [...]. *Dérive*'s algorithm in the internal workings of the machine worked by intermediary factorisations in $\mathbb{Z}/p\mathbb{Z}$. Evidently these two levels were not accessible to these 17 year old pupils, because *Dérive* was to function as a ‘black box’ producer of various results which would be valid *a priori*” (p. 20). In reality, the fact that the technical system was similar to a ‘black box’ is not unusual. For example, when pupils use a calculator, they do not have access to the way in which the machine does its calculations. The difference between the factorisation of polynomials situation and that of doing simple calculations with a basic calculator lies essentially in the difference in degree of complexity, which is determined by the teacher.

The author shows that in this case there are two possible interpretations: one that for the pupils it is a case of bringing forward ideas of factorisation in the classic paper-pencil model with the help of *Dérive*, and the other in which the pupils would produce results of factorisation coming from *Dérive*. In both cases, the pupils encounter difficulties. These difficulties result from the computer transposition as Balacheff [21], expressed it, and from constraints associated with such a transfer. This will be addressed further later.

The second observation relates to trigonometric calculus with the help of *Dérive*. It resulted in the same conclusions being drawn according to which pupils are confronted with simplification difficulties with the software programme. Although the simplifications that *Dérive* enables are based upon the formulae of classical trigonometry, not least there remains the problem that *Dérive*'s simplifications are difficult to put into practice.

It would appear to be very clear that the integration of a VLE in learning does not make any easier or better teaching and learning situations in mathematics, as the proponents of this discourse would suggest. On the contrary, the computer transposition often comes with constraints which can constitute real handicaps to learning. These constraints thus weaken the mediation capacity of the technical artefact. Under these conditions the software programme no longer plays its role in epistemological mediation such that achieving the didactical objective (in this case the cognitive mathematical objective) is no longer possible.

In her thesis concerning the integration of spreadsheets in algebraic calculations, Haspékian [22] cites evidence of the difficulty teachers have in moving from the traditional paper/pencil environment to the electronic spreadsheet. The difficulty lay in integrating a tool with such variable functions as this. She introduced the notion of instrumental distance which she summed up as “the stronger the degree of instrumentation when compared with the traditional reference environment (paper/pencil), i.e. the greater the distance from ‘habitual scholarly practice’, the more the tool will seem difficult to grasp” (p. 296). She demonstrated that in such a situation, a teacher who is not an expert user of the tool can present an additional complexity to the organisation and management of teaching, because the introduction of the spreadsheet, as in this case, implies that new teaching and learning practices be put in place which take full account of the constraints and properties of the spreadsheet.

It is crucial to assert that instrumental distance as measured by the greater or lesser degree of difficulty in integrating the spreadsheet may be translated as the term instrumental conflict used herein, as the notion of difficulty makes reference to the problematic combining of didactical, pedagogical and technical instruments. In effect the use of spreadsheets implies the introduction within the teaching and learning system of new objects, of a new representation, of new functions and significance, thus new symbolisms. The period necessary to master these new capacities is inevitably going to be one of upset and tension: one of disequilibrium in the teaching and learning process.

The double reference appears very similar to the fact that didactical objects such as defined by teachers according to the posture of non-dissociation between *noesis* and *semiosis* are transposed by the student: such as paper-pencil for the VLE. The fact even that the notion of double reference should be necessary to explain usage difficulties encountered by students demonstrates the consequences of non-dissociation whenever didactical objects are computerised.

3.1.2 Pseudo-transparency

In order to provide an illustration of the notion of pseudo-transparency an example drawn from the work of Guin and Trouche [19] will be adopted, as borrowed from Artigue [18]. He defined this phenomenon as the gap between what is written by the student and that which is shown on the screen: “to enter $(a+2)/5$, certain pupils, having correctly added the pair of brackets around the $(a+2)$, were astonished to find their screen showing the data without brackets and asked if what they had done was right or not. The appearance and disappearance of brackets seemed, to some of the students, to be playing a rather mysterious game which they little understood such that they could not work out what brackets were supposed to be about”. (p. 64)

Artigue [18] points out that the *Dérive* interface did not at a stroke enable students to alter the length of the line between the upper and lower elements of a fraction which they could do all too easily by hand. And yet this information is necessary as it allows students to know where the line in a fraction should go. There is in this a constraint linked to the fact that the keyboard only provides for one keystroke for division. There is unarguably a discrepancy produced by the transition to computer between the traditional didactical object and the computerised didactical object: this is the phenomenon of pseudo-transparency.

This situation represents an obstacle to the identification of mathematical symbols whose function is precisely to enable pupils to develop their capabilities in Mathematics. The lack of the facility to be able to produce these lines with the *Dérive* software programme is an example of a situation in which the introduction of a VLE is responsible for introducing a disequilibrium in the learning process. As symbolic representations, the lines in a fraction, which here are taken as pedagogical objects, only have one role, which is to assist in the resolution of the mathematical problem. They are also a means of more clearly identifying a mathematical object critical to conceptualisation [23]. This aspect is very much in line with a case which in the field of conceptual theory, Vergnaud [23] considered as a rupture of cognitive development. This research, however, considers such a disequilibrium caused by the *Dérive* environment as being instrumental conflict, as the failure in the implementation of the pedagogical artefact and the line between the two components of a fraction act against the pupil’s way of working and thus prevent him from coming to an understanding or of appreciating significance, i.e. from the didactical artefact.

This example of pseudo-transparency provides the opportunity to confirm the existence of a semiotic non-conformity between the traditional and VLE environment. The fact that showing brackets was simply not possible on the *Dérive* interface or that the keyboard could not be given specific functions enabling the writing of differentiated signs of lines duly adapted to a perfect and complete representation of the mathematical contents of division served to disturb the majority of pupils. Such ambiguities could also arise without the use of a computer, but they are normally well dealt with by teachers who can most easily resolve the disequilibrium between the formalisms of representation, that is to say between the semiotic registers and cognitive objects. *Dérive* here creates a disequilibrium which concerns the pedagogical artefact (in this case the line in the fraction or division) and thus the formalism of representation of the didactical artefact which can also create difficulties for the teacher without good anticipation on his part.

It would seem that, beyond the perspective offered by Artigue [18] in proposing this notion of pseudo-transparency as a means to study semiotic non-conformity between the traditional paper-pencil context and that of a VLE in a transposition to a computerised situation, the real problem is to take account of the possible deformation of didactical objects as it arises from the use of technology no matter how well conceived it may have been.

3.2 Computerised pedagogical objects as viewed by computer specialists

It is interesting to note that computer specialists’ thinking regarding pedagogical objects emerged at the same time as the advent of VLEs. The term pedagogical object, synonym of learning object, only makes sense in relation to the latter. This object-oriented approach has gone through three successive phases, which were crystallised in norms: LOM [24], SCORM [25] and EML [26]. It should be recalled before moving on that these three models of pedagogical artefact correspond to three drivers (respectively economic, technical and pedagogical) which preside over object conceptualisation. Moreover, what computer specialists call objects are in reality artefacts in as much as they are not embodied in a VLE and in interaction with a user-learner, they remain symbolic constructions fixed by digital processes.

Pernin [27] highlights the lack of consensus as to the definition of a pedagogical object, and this despite the definition given to it by the work group IEEE-Learning Technology Standards Committee. In effect for the IEEE-LTSC a pedagogical/learning object is defined as “any entity, digital or otherwise, which can be used or referenced in training provided by a means of technological support”. Looked at more closely, the definition which computer specialists give of the pedagogical object is not too far from this. For David [28] a pedagogical object is a digital document allowing the learner to get engaged in an autonomous learning activity regardless of the context of object utilisation. Put another way, it has to be reusable in all learning contexts.

But in order for a digital object to stake a claim to being a pedagogical object, its conception has to integrate the recommendations of pedagogical activity. The model object to which he makes reference is that which complies with

the LOM norm specifications, the structure of which is based upon four levels comprising the course, the lesson, the curriculum and the media. This latter component is supposed to enable a replication of the granular structure in all technological learning environments. What is central to the conception of this model is its characteristic of reusability. It is very much a vision which gave rise to the concept of the inter-operability of VLEs, according to which digital resources have to be able to be compatible with the technical structures where they are likely to be used. However, the LOM model has not enabled convenient and 'universal' inter-operability to be achieved.

Another very computing-based conception of the concept of the pedagogical object is provided by Contamines, George and Hotte [7]. It must be borne in mind all the time that these authors did not use the term pedagogical object but that of educational resource, covering a great variety of learning objects. Beyond the indisputable relevance and interest that can be accorded to their work, it is no less well founded than the meaning – of the rest borrowed from Klassen [29] focusing upon four points – which they give to pedagogical objects, which serves to increase the confusion which reigns around the definition of pedagogical objects. For them, an educational resource is an 'atomic' entity, a video clip or a web page for example. It is also of a composite nature and refers to a non-dissociable whole (didactical multimedia) or an assembly of learning objects (p. 161). It is appropriate to note that this ambiguity concerning pedagogical objects can on the part of learners themselves lead to a situation in which they have altogether different ideas of what constitutes a pedagogical object.

If the construction of the LOM model has not offered much satisfaction in respect of its own expected constituted functions, that is to say the reutilisation of pedagogical objects in all VLEs, one can nevertheless recognise that the SCORM model represents progress in the computing conception of pedagogical objects. It concerns a model by Pernin [27] composed of three well-identified levels:

- The first is that of the basic digital resource, such as an image: JPEG or GIF, a WAV or MP3 sound file, a Web page etc.
- The second level is termed intermediary. It constitutes of a coherent grouping of basic digital resources capable of being shared amongst learners on a distance learning platform. At this level the system allows control of the carrying out of learning activities. It makes possible the provision of information on resources utilisation and the carrying out of activities on the platform by the key players.
- The third level is that of the bringing together of the content. This provides a coherent structuring of content at the core of an entity deemed of higher level, like a course, chapter or module.

The LOM and SCORM models, let it be remembered, serve to facilitate the orientation and indexation of pedagogical objects, and precisely apply this role of the pedagogical object to very diverse entities. The principal consequence of this is that one cannot discern between a pedagogical object and a didactical object, such that this research is left to attempt to do it by separating that which relates to the disciplinary content taught from the formalism of representation or presentation for teaching purposes. This lack of discernment would appear to reside in the fact that the central aspect of the object-oriented approach relies less upon learning activity than upon computing artefacts. In effect, these models consider elementary artefacts to be just as much pedagogical objects (although they are located at different levels), such as images, web pages, content structures, courses, lessons and modules. Yet it would seem necessary to make a distinction between pedagogical artefacts which can be considered as scenarios and formalisms which serve to present the didactical artefacts which are the contents of learning.

4. Relevance of the concept of instrumental conflict

The concept of instrumental conflict draws its relevance from the generalisation of the use of ICT in teaching. As it has been noted earlier in this paper, the introduction of a VLE might disturb the very equilibrium of a classical teaching situation, in which the didactical artefacts can be conveniently combined with their pedagogical artefacts, so that they can be instrumentalised and instrumented by the learners, and so that they thus become socially useful instruments. But the evidence provided herein would seem to indicate clearly that the two scientific communities interested in ICT in teaching are coming up against difficulties in identifying didactical objects and pedagogic objects when they are in computerised form.

4.1 Further notions concerning related objects

For teachers of mathematics, the notions of double-reference and pseudo-transparency take account of the fact that accessible didactical objects in some software programmes do not always work for their pupils whether it be relating to their paper-pencil representation or in accommodating the constraints imposed by the user-interface. From an instrumental perspective, the difficulties encountered by pupils are an inadequacy in the combination of didactical artefacts which are the mathematical objects and pedagogical objects, i.e. their formalisation by mathematical signs in a computerised environment. Although it is always useful to represent mathematical objects by several semiotic systems, what is clear from the classical form of teaching can reveal itself to be that much more difficult, even impossible when a technical artefact is introduced.

For computer specialists, the notions of granularity and inter-operability enable the LOM and SCORM indexation norms to deal with the variety of pedagogical objects that they would seek to describe, but also to conceptualise the difficulty brought about by the absence of a distinction between the pedagogical object as such and its integration within a technical system. Everything happens as if (and this would seem both accurate and to be the norm) the mathematics teachers could not easily computerise certain of their didactical objectives, for lack of ability to conceptualise the dissociation between the taught content and its formalism of representation or its presentation for teaching purposes, and as if the computer specialists could not suitably put pedagogical objects into a teaching mode by reason of also not being able to make the same distinction.

In a way, teachers of mathematics and the computer-specialists are giving two different names to the same objects and are in need of further objects to account for the difficulties posed by their respective nomenclatures (*cf.* fig 4). Instrumental theory and the separation that has been introduced here between didactical objects, pedagogical objects and technical objects provides the opportunity to unify these two conceptions of the integration of ICT in teaching.

The distinction between didactical objects, pedagogical objects and technical objects is not just an exercise in rhetoric which will depend upon conceptual common ground between the teaching of mathematics and computers science applied to VLEs. In fact, if the term object has been used here for the purpose of clarity, it is important to specify that these objects, from an instrumental perspective, are, in reality, artefacts which become instruments in interaction with a subject. Moreover, it is the simultaneous instrumental genesis of these types of artefact which can cause difficulty, difficulties which here have been termed instrumental conflict.

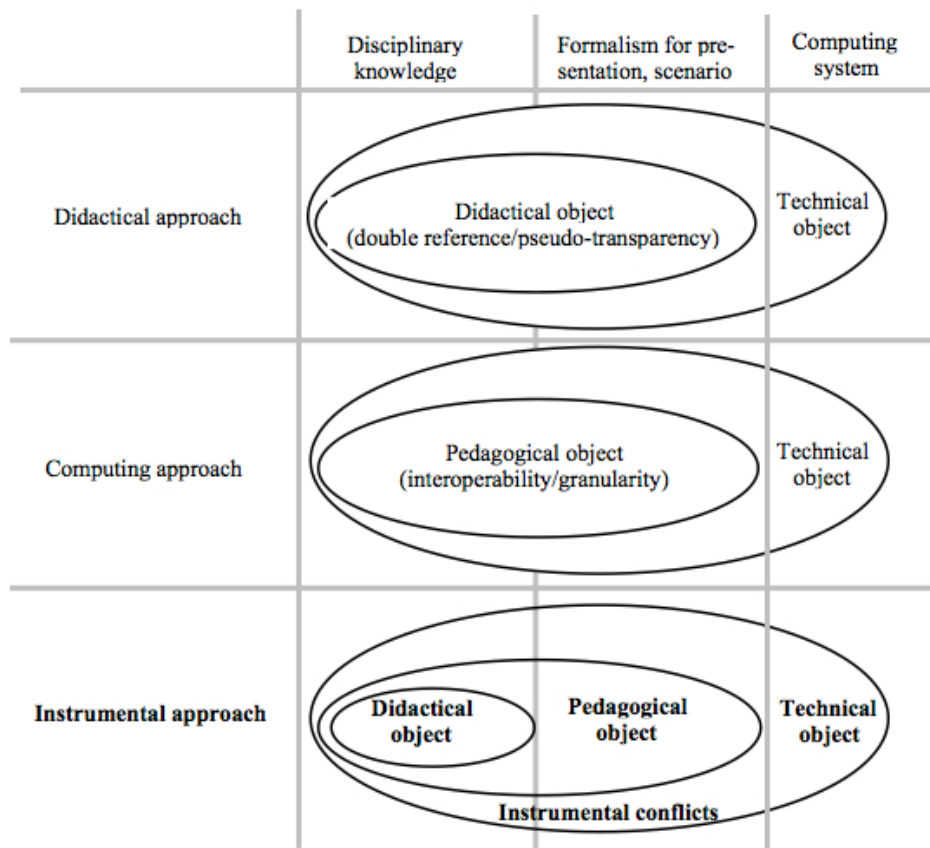


Fig. 4 Distinction between didactical, pedagogical and technical objects according to existing approaches.

4.2 Usefulness in distance learning and pedagogical engineering

The concept of instrumental conflict would appear to be useful in the analysis of current developments in distance education although the action modalities are different from the classic classroom teaching one, even with a VLE included. In fact, in the foregoing, and equally in the conception of mathematics teaching as in the object-oriented approach, it has been seen that the computerisation of learning and teaching is determined more by the objects of knowledge than by learning activity.

In the field of distance education the activities have a central place. This change in perspective calls indisputably for another approach to the conceptualisation of artefacts operating in various situations. For example, the EML (Educational Modelling Language) developed by Kopper [26, 30] which is at the origin of the IMSLD² [31] presents a real leap forward in the pedagogical realm when compared to the LOM and SCORM models already addressed above. This language for pedagogical modelling identifies several types of activity amongst which are learning activities, student support activities and instrumentation activities [27].

This refocusing upon the activity is becoming common while designing distance learning platforms. The majority of VLE platforms draw upon a representation of learner function or teaching model, the object of which is to enable isolated learners, because they are operating at distance, to get on effectively with their learning activities [32]. This effectiveness naturally depends upon the support to which they are entitled, but also and, perhaps above all, upon the combination of didactical and pedagogical artefacts which, after a certain fashion, are seeking a pedagogical engineering approach. The concept of instrumental conflict can at this point be put to the service of practices in pedagogical engineering which have been developed in distance education [33] and contribute to the attainment of specific pedagogical objectives, notably in its capacity of accounting for the imperfection of associations between artefacts.

The concept of instrumental conflict can also be called upon in the evaluation of the introduction of ICT in the practice of teaching and learning. In fact, the recourse to computer-based solutions in the context of pedagogical innovation has often been accompanied by a fierce and impassioned discourse more typical of the political or economic spheres than the pedagogical. As a result, it is not at all unusual that there is a gap between the expected benefit of the introduction of these computer-based artefacts and the actual impact in teaching and learning situations. Having a concept of instrumental conflict enables the review of possible inadequacy in the articulation of didactical, pedagogical and technical artefacts where ICT is involved. In enabling the failure of instrumental genesis to be identified, this concept offers the opportunity for the adjustment of one or more of the artefacts concerned in such a way as to ensure their harmonisation with the learning outcomes desired.

5. Discussion

Although it is agreed with De Vries and Baillé [34] that bringing together other existing theory can offer support to the concepts of VLEs and describe the mechanics of learning in action, this paper has attempted to demonstrate the value of reflecting upon the concept of instrumental conflict in order to explain certain dysfunctions in computer-based teaching and learning situations, and in so doing, has tried to help avoid user problems in a distance learning pedagogical engineering approach.

Instrumental conflict only applies in the case of instrumental theory, the principal elements thereof being addressed herein, and identifies interferences between the simultaneous processes of the instrumental genesis of didactical artefacts (disciplinary content), pedagogical artefacts (formalisms of representation and presentation scenarios) and technical artefacts (VLEs, platforms). The main argument, which is singled out from prior analyses of computer-based teaching and learning situations, lies in the explicit distinction between the three families of objects which can bring about an instrumental conflict in many possible forms.

The first of these manifestations and without doubt the most usual is what has been termed a rupture in the equilibrium between a classical situation and an instrumented one. This happens when combinations of didactical and pedagogical artefacts, tried and tested by academic tradition, find themselves no longer to be properly instrumentalised and instrumented once embodied in a technical system. This can come about each and every time that the disciplinary content is delivered within a VLE without modification being made to its presentation format or its role in learning. How many supposed e-learning solutions turn out to be barely disguised slides or photocopies reformatted for the menu systems? No matter how much care has gone into the taught content, the computerisation of such matters requires that the learning and teaching scenario be adapted, in order that it can work with the constraints imposed by the system. In the absence of such precautions, the addition of a technical artefactual layer to a relevant combination of didactical and pedagogical artefacts is bound to lead to instrumental conflict. This is what Lagrange and Drouhard [20] identified in their research into the use of the *Dérive* teaching software, although they didn't call it this.

The second type of manifestation of instrumental conflict corresponds with what can be observed when disciplinary content has not been suitably adapted to the generic application which diffuses it. This is the case, and unhappily it is not altogether rare, when a distance education platform not only imposes its own functionalities, but also forces a particular pedagogical scenario. In effect, a certain number of LMS (Learning Management Systems) are built around modes of organisation of pedagogy which do not suit all academic disciplines or all professional training contexts. These modes of organisation of pedagogy cover a broad range, which extends from the downloading of files to print and be read in complete seclusion to systems of collaborative learning with tutor support and computer sessions. Neither these extremes nor the possibilities between are, *a priori*, good or bad. They can become one or the other

² IMSLD: Instructional Management System Learning Design.

depending upon the functioning of the content presented when they fail to accommodate the nature of the teaching concept and the learning vehicle provided by the platform.

The third and final manifestation of instrumental conflict comes about when a technical system dedicated to a family of didactical objects is inappropriately used by the learner or the trainer. In this instance, neither the contents involved nor the VLE functionalities are to blame, but rather the pedagogical expertise of the teacher. This happens, for example, when teachers are delivering sessions on dynamic geometry in relying upon scenarios developed for paper-pencil geometry. In doing this, pupils cannot access the properties of the geometric objects that the software emphasises, since it is precisely these properties that are not updated in the same way in relation to how the software is used or how one produces figures by hand.

From the moment that one of the didactical, pedagogical or technical artefacts is not in place, or, to put it another way, is not in harmony with the two others, the processes of instrumentalisation and instrumentation necessary for the construction of knowledge risks becoming the object of instrumental conflict.

This represents the sum total of the knowledge arising from this research which can be passed on and applied to the computer-based teaching and learning situations which have been investigated, in so far as care can be taken to bring together in an optimal arrangement, content, formalisms and functionalities and to verify them by means of studies of actual use.

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