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Innovative Approach for Renewing Instructional Design Applied in the Context of e-Learning

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Abstract

This research aims to present an overview of an innovative approach for renewing instructional design by offering new form of research in e-learning design. Instructional innovations need to stand back and review the design of innovative components for e-learning system. We postulate in this chapter that the design of learning devices requires the design of complex multifaceted object which supports adaptive learning and lets learners bring into play their knowledge in order to carry out the prescribed tasks. Our approach is centred on the design of this complex object called pedagogical instrument, whose molecules are the smallest collection of the components retaining the properties of that material (according to the teaching intentions). The goal that we have set ourselves is to create the first specification of the micro-instructional engineering design. This specification aims at micro pedagogical technology which needs various types of competencies; our discussion implies that instructional innovation is better likely to succeed if it takes into account the actors, the constraints and the standards required to describe the tools allowing the integration of ICT.

Keywords: learning object, learning activity, instructional material, activity theory, instrument, instructional design, instructional engineering, knowledge object, instructional innovation

1. Introduction

The question that we propose to raise in this work is to know what advantage can be gained from a new type of design based on infrastructure. In the light of this question, we formulate the definition of instructional engineering as specified in Paquette et al. [1]. Thus, instructional engineering is what designers do as they construct and preserve

global learning systems that focus on engaging learners in two main processes: knowledge extraction and knowledge dissemination.

In fact, this definition let us think that instructional engineering is a particular case of knowledge engineering applied in education domain. Instructional engineering should present tools offering multi-views of instructional material models. Micro ID (Instructional Design) has to integrate these perspectives by the principles of divide and conquers. The designer should differentiate clearly the features of the instructional materials and its contents (with all models being able to represent the various aspects of the instructional material). The outcome of the presented approach should be the convergence of cognitive, didactic, interface and content designs.

Our proposition is focused jointly on the innovative and routine designs. The innovative micro-components of the pedagogical instruments are designed to be used and reused within the principles of an object-oriented paradigm. Our approach is intended to renew ID methodology to support the creation of reusable artificial objects for learning systems in order to operationalise the theoretical foundations.

The purpose of this work is to present a new current of learning activity design based on activity theory where its design means the specification of its specific teaching materials called pedagogical instruments; this material has the role of mediator between the learner and the objects presented in the activity. Vygotsky [2] proposed a point of view based on the subject-object-artefact triangle. The main problem is to know how learners interact with content using mediating artefacts (pedagogical instrument). All the higher psychological processes are mediated through a tool.

In reality, the application of activity theory to ID is not new; Jonassen and Rohrer-Murphy [19] have taken up and applied activity theory to the domain of ID. This theory has now spread and is applied to many educational domains [3–5] (Schmitz, 2010; Levy, 2008). All these works are applying activity theory for modelling the learning activity without taking into account ICT constraints. The micro-design shows how to represent and use artefact and instrument in the context of e-learning. Research in activity theory was continued in another way according to the instrumental approach called the psychological approach to education by Rabardel [6] in which he proposes to specify the instrument as something constructed by the user during interaction. We will review Rabardel's [6] work in what follows and make a theoretical comparison with our own specification of the pedagogical instrument according to what we call micro ID.

2. Theoretical foundation of micro-instructional design

The instrument is defined as an intermediate entity situated between two other entities which are the subject, actor and user of the instrument and the object on which the action is performed. This instrument can be called a pedagogical instrument if there is pedagogical intent behind its use.

A pedagogical instrument is defined as being any entity (symbolic or not), capable of operationalizing an action of the system. This entity can be used, reused or referred to in the course of a didactic activity in order to carry out a task with an underlying pedagogical intent.

According to the instrumental approach Rabardel [6], the instrument is composite; it contains components from artefact and components from users' utilization schemes. The artefact part comes from the designer and from his/her anticipation as to the future use of the artefact. The users' utilization schemes part comes from the subject's involvement in the completed activity. Thus the instrument is not only part of the world which is external to the subject but also the result of the subject's personal involvement in the action.

When we look at instrumental approach from the computer science perspective, we find that schemes of use are not prescribed but dynamically constructed by user during the process of the utilization of the tool. In our approach, instrument would thus be an object (within oriented object paradigm) which includes an artefact part (as properties of the object) and a scheme components part representing all possible prescribed uses of the tool (as methods representing its scheme of use called in our case scenario of use).

The design of the learning activity means the specification of the nature of this mediation by the design of different instructional material layers. The instructional designer should specify the elements used for modelling each layer of pedagogical instrument (**Figure 1**) to be constructed by other actors (the pedagogical and didactic layer, the cognitive layer, the knowledge objects model and the interface layer).

The pedagogical instrument is characterized by five criteria corresponding to its different roles (**Figure 1**):

- Its pedagogical function as pedagogical artefact: this corresponds to the pedagogical intentions represented as: <action, knowledge unit> or <Action; status-of-learner's-knowledge; knowledge unit>.
- Its scenario of use: the life cycle, number of tests, imposed or proposed help, etc.
- Its content to be taught.
- Its effects as cognitive artefact: this concerns the learner's behaviour with the instrument (its effects on the progress of its knowledge and cognitive states).
- Its form: the shape of the instrument as digital resource (buttons, text fields, word, letter, image, colours, size, etc).

The problem of e-learning design is that knowledge is of different kinds. Consequently, a single person cannot manipulate precise knowledge in all domains. The main role of the team is to allow the learner's knowledge to progress according to his/her preferences, the identification of the knowledge actually used by the learner, how to manage and activate certain learner strategies and the translation of the collected results in terms of the effectiveness of the techniques used. The issue at stake is the "divide and conquer" principle which makes teamwork an absolute requirement. The various actors involved in the design process are:

- *The instructional designer*: he/she defines the general characteristics of the pedagogical instrument; his/her role is to specify the shells for the other specialists to integrate the various standard specifications.

- *The learning domain theoretician*: his/her role is concerned with the specifications of each knowledge object and its micro-components within his/her domain of work. In the learning to read domain, this actor is the linguist (various sub-fields: semantics, psycholinguistics) who specifies the knowledge object of this domain (letter, sentences, texts, etc.).
- *The domain expert*: is the teacher who is in contact with reality (learners), whose role is to fix the limits of acceptance of tests. He/she also prepares a critical report, which may contain a lot of rejections.
- *The cognitiician*: there is, therefore, much communication between the different design actors, the cognitiician and the domain expert even if in certain cases he/she could take care of the final specifications himself/herself. His/her role is to identify the individual knowledge, the cognitive structure, the strategies implemented by the learner and the various stimuli according to the learning style envisaged.
- *The ergonomist*: the role of ergonomics in the project is to design the pedagogical instrument as being a medium of knowledge as well as an interface tool. This articulation should create a better comprehension of the effects of the knowledge object to be taught and the other types of practical knowledge used by the learner (for example, the logic of use of the interface, etc.). For this reason, the knowledge effectively used must be specified by including facts or learner's behaviour which could be characterized by other models.

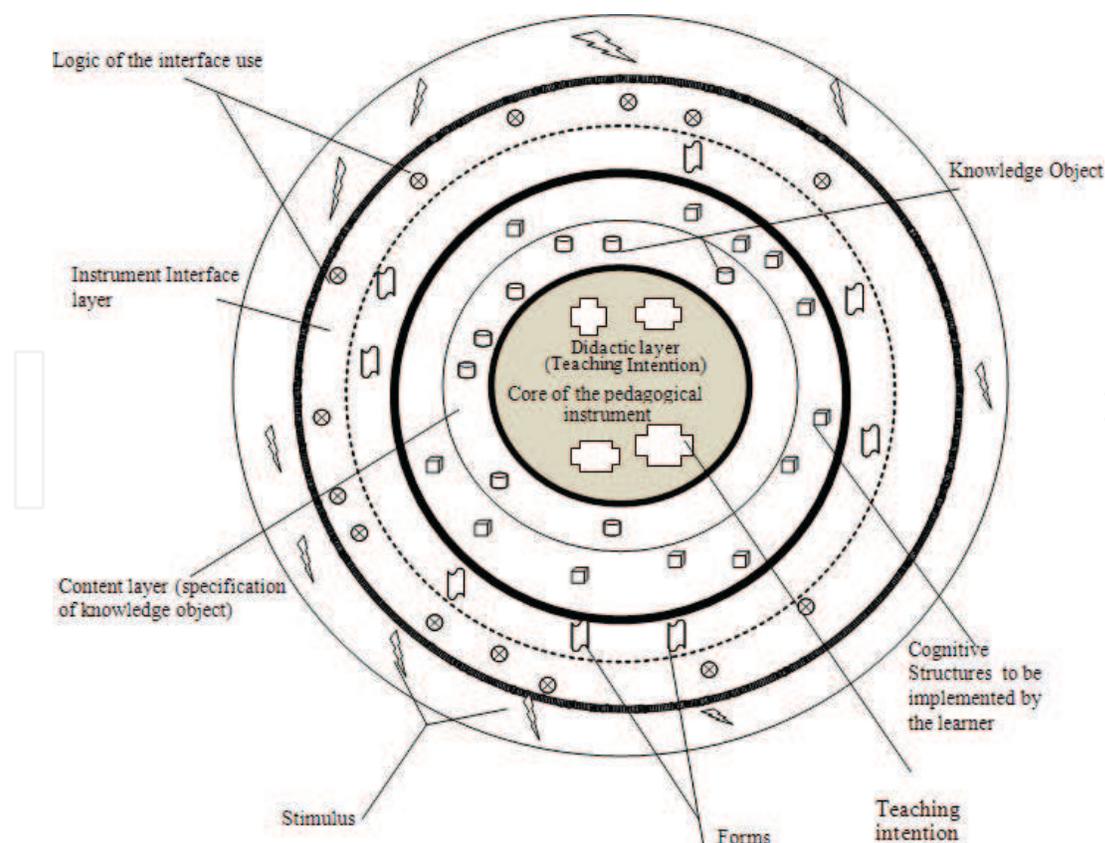


Figure 1. Pedagogical instrument structure.

- *Finally ontological engineer*: he/she should have a high level of technical ability in order to be able to manage the knowledge projects and dialogue with all the design actors. Ontological engineering play fundamental roles in understanding artefacts by computer, through providing more structural knowledge for using formal models expressed in languages with computational semantics [7, 8]. In reality, whereas we are looking at this from the research standpoint, many actors of the design process can wear several caps.

The divide principle is based on the projection technique to have a multi-view of the pedagogical instrument. That means to create more elaborate models for pedagogical instrument taking into account all aspects of acquisition of knowledge by the learner. The conquer principle is done by connecting these different models for individualizing learning activity. These models can be described in terms of four projections (**Figure 2**): (1) content projection model, (2) a pedagogical and didactic projection model, (3) a cognitive projection model and (4) a delivery model describing the interface projection of each pedagogical instrument. The realization of these models needs to share pluridisciplinary knowledge between the various design actors to arrive at the specification of the pedagogical instrument.

2.1. Pedagogical projection model

The entities manipulated and adopted in the pedagogical model have progressive degree of smoothness (macro-, meso- and microscale); the entities presented in macroscale are the objective units, these entities are the objective units which can be represented in the form of couples of information: <action; knowledge unit>; or triplets: <action; status of learner's knowledge; knowledge unit>. The objective units represent the properties part of the learning object. For example, in the learning to read domain the following are valid information couples <Make acquire; sentence limits> or <verify; Known; word>. In the mesoscale, we use classes of didactic situation. The entities represented in the microscale are the individualizing elements of the instantiated didactic situation which is considered as a learning object.

By instantiating parameters of the contents, words will be instantiated. These couples and triplets are used to report the progress in the state of the learner's knowledge of reading but with the hypothesis that this takes into account the different pedagogical factors and policies used within a learning theory (our case is concerned with activity theory). Consequently this model is defined to provide to our system the possibility to adapt the pedagogical behaviour to a specific student. From this point of view, the choice of pedagogical actions with respect to learning strategies will be more adaptive.

2.2. Interface projection model

We distinguish between the model of use of the interface which is a sub-model of the cognitive model and the interface model. The model of use of the interface can be considered as a set of functions that allows communication and finalizes the form by which the system transmits information. The use of the artefact associated with the instrument is interpreted by a logic implemented by the learner to be more familiar with the instrument (**Figure 1**). This process is called instrumentation of the learner [6]. Know that learning is defined as

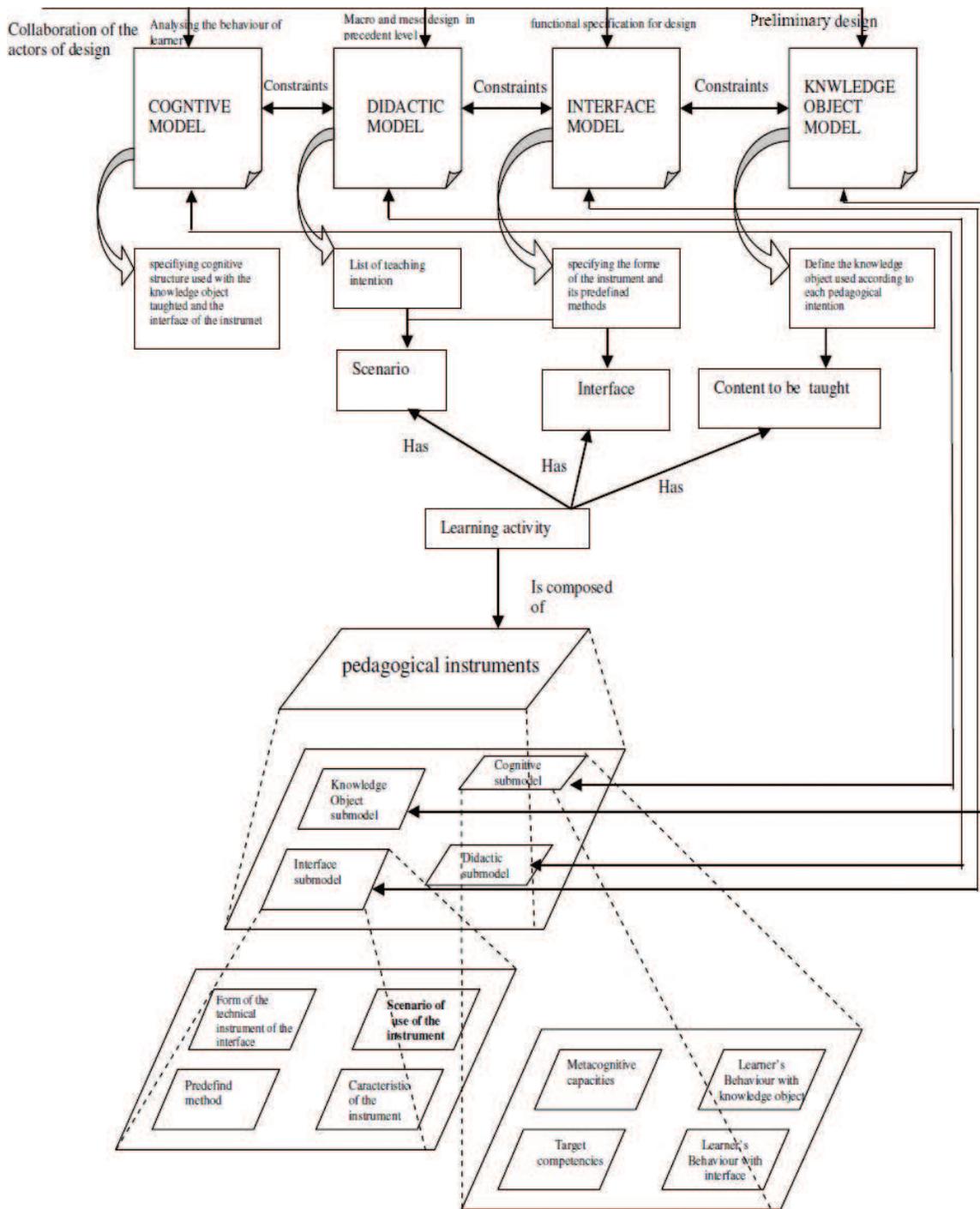


Figure 2. Multi-view projection technique for the design the pedagogical instrument.

transformation of information into knowledge [9–11]. The learner uses his technical skills for processing all information presented in the interface to transform it into knowledge. This model works coupled with the pedagogical, cognitive and knowledge object models. This model deals with appropriate pedagogical instrument to be used in order to propose the final form to the learner corresponding to his learning style and preferences.

The interface model incorporates all the elements of adaptation (how it can be adapted to a given learning style). The most popular technologies are hiding for adaptive navigation support. Hiding technologies are commonly used for adaptive navigation support. The idea of navigation support by hiding is to restrict the navigation space by hiding links to nonrelevant pages [12] or if it presents materials which the user is not yet prepared to understand (see Section 5).

2.3. Knowledge object projection model

The knowledge object framework is the same for different subject matter domains [10]. Knowledge object of “learning to read domain” are letters, words, sentences and texts; the micro-component of a knowledge object sentences are the components of words (letters). It would be necessary to characterize the differences between knowledge object as entity and its proprieties, for example: The knowledge objects sentences have two types of knowledge (Figure 4):

- Knowledge associated with properties of the object “sentence” as theoretical space for example: “The association between written/spoken sentences” —association grapheme/phoneme, the noun indicates letters, the grapheme representing the word, structure of word, syntactic categories, the relation between the verbs and the subject and the correspondence written/spoken words. These objects are highlighted systematically each time that a written sentence is spoken out.
- Knowledge associated with an entity as a semantic unit, which requires the knowledge of the learner about the property of this object (conceptual representation of the sentences).

2.4. Cognitive projection model

Many cognitive psychologists have proposed a diversity of theories of how knowledge is represented in memory [13]. Schema theory postulates that learners represent knowledge in memory as some form of cognitive structure. A knowledge structure has a form of a schema representing the information that is required by a learner to be able to solve complex problems.

The processes of activation of a cognitive process for learner could be defined as a complex knowledge based on the cognitive structure implemented at the time of learning. Thus, artefacts are carriers of strategies, processes and the logic of the manipulation of its interface. These knowledge is manifested in both the structural properties of the tool and in the way the tool should be used. Hence, knowing how to use it is a crucial part of the artefact (symbolic or physical artefact). The notion that cognitive artefacts amplify the cognition of the learner has been adopted by [14]. He finds that this notion is fairly commonplace. “If one focuses on the products of cognitive activity, cognitive artefacts do seem to amplify human abilities”. When the learner uses cognitive artefacts, he can easily achieve his actions. For example, noting down all information by using a pen is considered as a tool used to amplify his abilities. We will explain in the following how use symbolic instrument to amplify the knowledge of learner in the context of learning to read domain.

3. Application of microscopic approaches in the learning to read domain

Our approach is applied in the context of a theoretical and development project for a multi-agent and knowledge-based computer for teaching and learning reading. It's related to the mother tongue (French) and addressed to children in normal schooling in their first year of primary school. The microscopic approach to design is centred on the components of learning object which is characterized, firstly, by knowledge being brought into play for learning and secondly by materials considered as the medium for this knowledge (**Figure 1**). The basic idea is that the learning objects would be staged, (instantiation of the content, preparing the list of the instrument to be used and finally specifying the scenario of each pedagogical instrument), a process referred to as "sequencing".

Our proposal lies in the use of the rational agent, which individualizes its parameters according to the student model and using three types of rules (didactic rule related to the learning domain, pedagogical rules concerned by the general teaching rules independently of learning to read domain and finally linguistic rules). So the sequencing of the learning object reveals the various aspects of learning activity: (1) its contents which represent the primary teaching matter, (2) its interface which is represented as a set of pedagogical instruments constituting the teaching equipment and finally (3) the scenario of use of each pedagogical instrument.

The sequencing is done by the learning object sequencing agent. It uses its dynamically built knowledge bases starting from the agents of the environment and the knowledge defined the contents to find all suitable methods for creating the scenario of each pedagogical instrument. The detailed modelling of the agent and its reasoning is not the subject of this article. Our goal is to specify the micro-design of the instrument as multifaceted artefact by the application of projection technique.

3.1. The pedagogical instrument as a didactic artefact

The didactic characteristics of the pedagogical instrument are related to teaching intentions calculated in precedence levels. Pedagogical knowledge concerns all didactic knowledge, which does not depend on the domain of reading. The pedagogical characteristics of the instrument relate to the holding information about the didactic usage and quality of the entities belonging to other domains. Its elements are all the entities including a certain number of didactic attributes. There are two kinds of didactic entities, related to either conceptual or instructional entities. Each entity has a priority depending on its importance as part of the learning process (a measure of the importance to the student). For example, the pedagogical intention: <"Present text without reading"; "display the word on the screen"; "suggest help" > is associated with the "Visual comparison strategy" to be implemented by the learner.

The instrument is to be considered as an artefact representing the pedagogical material to be used by the learner. As for the symbolic characteristics of the instrument, it is difficult to show in a detailed way the exact nature of the cognitive instruments that the learner uses or the role of the didactic artefacts used in the text reading activity. Such a process is by nature very complex requiring a definition of not just the instrument's components but rather its actual

molecules according to an advanced microscopic design approach. Thus, the instrument as a didactic artefact means in our view a meta-instrument enabling the learner to construct his/her own cognitive instruments as the didactic activity progresses. Variation in the mode or time of the instrument's intervention may have different effects according to its pedagogical function, for example, a help instrument which intervenes only after a certain number of mistakes. So the didactic role here can address different kinds of skills (the intervention mode of the help instrument, when left to the learner's initiative, may increase his/her metacognitive skills, for example). The pedagogical instrument is individualized after using the basis firstly of the knowledge collected from the student model and secondly on that illustrated in the properties of learning object (its content). An example of a pedagogical instrument is "the text field" that can be considered as a support of the text. The text is considered as knowledge representing its content associated with its different scenarios of use. Among the examples of cognitive instruments constructed by the learner in the presenting of text activity, we will mention the following:

A dictionary access instrument (decoding—dictionary access): a tool that the learner constructs in order to access the dictionary; the activation is both automatic and on two levels: (1) activation of the spelling and phonological information of the word to enable reliable and accurate coding and (2) activation of the semantic information followed by a selection of the information which is relevant to the context.

A morphological processing instrument: such instruments are constructed and used by learners in a text reading situation, during the reading activity, which is a special situation at the limits of the recognition and comprehension processes. According to the specialists, morphological analysis skills are poorly developed prior to learning how to read. Directionality in writing involves greater processing of words according to their morphological structure; furthermore the morphological structure of words is more explicit in writing. The mediation of this instrument constructed by the learner depends on one of the following prospective outcomes:

- The morphologically complex words are systematically analysed in order to be recognized, and in this case the morphological analysis is clear;

Or

- All the derived forms have their own unique access code obviating the need for morphological analysis.

There is a strong assumption that the vocabulary is morphologically organized with, however, each derived form having its own entry. According to different parameters (frequency, position of the affix), however, morphological analysis actively contributes to the selection of a given item and takes its place at the early stages of development (the semantic and syntactic roles of suffixes in word recognition and in comprehension).

The other cognitive instruments involved in the activity are linked to each interface instrument. This principle has been presented above according to the theoretical foundations of activity theory. Thus, each artefact is associated with an object of the activity which becomes an instrument in the course of the didactic activity.

3.2. The micro-components of a knowledge object

The text is the most complex knowledge object related to the learning to read domain; it acts of as a complex task to be accomplished by the learner during his/her reading of the text. The learning is in the form of a syntactic analysis of sequences of identified words, a realization of their significance and the combination and integration of the clauses deduced from the various clues (morphological, morpho-syntactic and pragmatic). The status of the knowledge for learning could be regarded as a combination of other statuses of knowledge at the same time as it could be for a single status; this status would be given according to the various statuses of the different micro-components of the knowledge objects. The focus on these micro-components can explain some micro-complications arising when the learner starts to recognize the letters using micro-components of this knowledge corresponding to the learning activity.

3.3. The pedagogical instrument and cognitive structures

The pedagogical instrument is designed to conduct the learner's strategies. An example of this conduct is to allow the learner to identify words by using in the first phase syntactic analysis of word sequences without ambiguous syntactic structures; the second phase is to let him/her learn the development of the syntactic structure of the various components starting from various clues (morpho-syntactic, morphological, sets of themes and pragmatic) and exactly establishing the coherence between inferred clauses starting from its knowledge bases in memory.

The cognitive model contains all the processes that are used by the learner to handle the interface and to learn for example: how to use the logic of reading: (left to right; top to bottom) and how to apply the logic of correspondence: (spoken word/ written word, spoken sentence/ written sentences). More generally, this model takes care of communications between the student and the system. In the microscopic approach, the instructional designer must specify in collaboration with the other design actors the knowledge that learners use by exploiting short-term memory and the knowledge which the agent proposes as being knowledge of the long-term memory. The other types of knowledge, "knowledge of the world" or rather everything that will be implicitly used by learners, are in fact considered as "practical knowledge".

An example of cognition amplification with the help instruments of the activity: Supposing we want to activate the semantic-spatial strategy of word recognition, the desired cognitive state would be represented as follows:

Desired cognitive state (action = activate word recognition strategy, knowledge = semantic-spatial strategy, status = high (degree of mastery)).

Desired cognitive state (action = activate object-strategy, knowledge = problem solving started, status = mastery).

Desired cognitive state (action = activate cognitive competencies, knowledge = content analysis, status = very high (degree of mastery)).

Knowing that the status of the degree of mastery is very low, low, average, high, very high, using the help instrument may amplify the learner's skills which may also improve his/her

metacognitive competencies. After the use of the help instrument by the learner, the system saves the news cognitive state of the learner in its knowledge bases as follows:

Cognitive state (metacognitive competencies, skill at using help, high (degree of mastery)).

3.4. Pedagogical instrument and the scenario of use

The instrument is described by the interface model by specifying its shape and its different way of use, which can be described as methods in the object-oriented paradigm where the pedagogical instrument is an object and the predefined methods for this object can be regarded as possible scenarios for its use. For example, if we have the text field in the didactic situation “presentation of the text”. The different methods of presentation of this text can be considered as the possible scenarios to be presented to the learner (global reading of the text, reading sentence by sentence, reading word for word,). These different ways of reading the text give details of the tasks progress of the system which are associated with the constraints calculated from the student model. For example, if we detect from the behaviour of the learner that he/she has an impulsive character (the Answer validation button and next activity button should be hidden until the end of the tasks proposed by the system (**Figures 3** and **4**)). The interface model of the instrument must integrate this element as a property of the interface instrument (the Answer validation button). The interface of the instrument should be adapted to the kind of learner; the reflective learner will have different types of interface [15, 16].

3.5. Pedagogical instrument surrounded by different types of stimulus

The visual style is characterized by the more effectiveness for the learner’s memory by using vision; the auditory style is related to audition and the kinesthetic style concerns everything we touch. The difference between tactile and kinesthetic styles is that tactile style is characterized by a fondness for sense of touch. Kinesthetic learners need body movement and frequent breaks in activity [17]. The intervention modes of the interface instruments for visual learners should be centred on the visual aspect rather than an oral aspect (an example is the intervention mode of a Re-read Sentence instrument by blinking instead of providing an oral message for auditory learners). It is very difficult to apply kinesthetic stimuli because we haven’t yet integrated touch screens in our system. As discussed above (Section 1) this difficulty shows a relationship between the micro-design and ICT. We need to integrate kinesthetic stimuli in the interface model of the instrument, which introduces a new type of problem in relation with new technology. The pedagogical instrument is the tool that activates these stimuli and allows the learner to make the most of his/her abilities to understand and to learn.

3.6. Connecting different models of the instrument

When the total design is sufficiently advanced, work can begin on the design of individualizing the process of learning materials by connecting different models. We will demonstrate this by specifying the decision variables of our illustrative models. Knowing that each knowledge object has possible statuses in the student’s model: known, un-known, recognized and possible context where the student has constructed this status or modified its value, the

in the student model text with status which is related to the learner's familiarization level with the text (the number of times where the text has been used by the learner, the number of sentences and words which have been used before by the learner). In the pedagogical model, the decision variables associated with each kind of text (for example, the pedagogical intention: present text, narrative text; status, new) are precised.

The objective of this specification is to give a successful manner for personalizing these components taking into account the complex dynamism of the learning activity presented by the relational model of the learning object (**Figure 4**).

In **Figure 4**, the four components of the activity are Instrument, Knowledge, target Skills and teaching intentions. The entity "Instrument" is related with the entity (target skills) by the relation (instrumentation/instrumentalization), the instrumentalization is related to four variations of the instrument (its interface, the content to be taught, the mode and the moment of intervention), and so the enhancement of the instrument by these variations gives it more interactivity and makes it adaptive to the advocates teaching intentions.

Different profiles of learners should be taken into account by the system to instantiate the parameters of instruments; for example, the moment of intervention of the instrument during the activity of training provides the learner with more time to identify all what is required to solve the problem. That lets the learner make a decision to use its metacognitive skills (let the learner request the help (instrumentation process)). The system can disable certain kinds of instrument (Instrument-state.disable) to be activated by the learner (for example: listening instruction (Instruction button **Figure 3**)) that makes the learner more autonomous and increase its cognitive skills. We can distinguish three types of knowledge (declarative, procedural and contextual knowledge); the internal relation between these kinds of knowledge serve as tools used to clarify the resolution of the problem by the learner (activating instrument by using its methods according to object-oriented paradigm principles). The entity "Progressiveness of knowledge" has a direct relation with teaching intentions defined by the expert of domain and the learning model used by the system.

In all cases, the overall scenario of the teaching activity is considered as a group of predictive scenarios corresponding to the time or mode of intervention of each instrument. The modelling of pedagogical scenario is a difficult task; it concerns the interpretation of a prior description of how the teaching activities given by the designer of the learning activity. The unwinding of the word in context activity UML activity diagram interprets the prior description given by the domain expert.

4. Conclusion

In this chapter, we have presented an overview of an innovative approach for renewing instructional design by offering a new form of research in e-learning design. The biggest advantage of the micro-design approach is obviously that of simplifying the administration of the e-learning system within an organization by improved delivery and tracking of content

and components. That provides insights into how an object-oriented paradigm can be applied and further developed in a variety of problem areas and fields: cognition, linguistics, psychology, etc. The solution is to represent the learning activity as learning object within the object-oriented paradigm where its structural components are the reusable objects representing the pedagogical instruments.

In general, we have found that the micro-design is highly theory-based, but for us this is opportunity of open innovation for designer in making analysis process more of an art form. So the micro-design offers multi-views of instructional material analysis models. At the same time it has allowed us to better describe the elements which contribute effectively to implementing the process of individualization of learning, which is at the heart of our research practices. More research in various domains is required to attain a higher level of technology able to discover all the micro-components of the key to e-learning design, the pedagogical instrument.

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