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IAM & PNA: FROM INSTRUCTIONAL DESIGN TO A USABILITY TEST FOR LEARNING. UNDERSTANDING, DESIGNING AND ANALYSING THE TECHNOLOGY APPROPRIATION PROCESS

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Experiential learning is considered as the most efficient learning activity; nonetheless, numerous situations exist in which real experience could represent a risk for the learner. In these situations, ICTs can be a used in order to reproduce virtual environments in order to train for it. By then, the concept of Instructional Design has assumed an important place to design those simulation tools. Nevertheless, the existing literature lacks adequate methods to access the user's learning process and to make it explicit. For that reason, in this paper, we propose the IAM (Instrumental Adaptation Model) and its operationalization in the PNA (Process Network Analysis). This is a new usability test that specifically applies to learning situations, and aims to better identify the appropriation process of each category of users.

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1 Introduction

Since many decades it has been shown that experiential learning is the most effective strategy of learning (Kolb, 1984). This approach allows learners to experience a certain situation in order to go through a process of reflection on it. Nonetheless, some situation exists in which a direct experience in the field is not possible because of the risks that a mistake could cause to the environment, to human's life or safety, or because of economical issues (e.g. the expensive cost of the engines). For that reasons, in recent years, and with the introduction of ICTs (Information and Communications Technologies), a plethora of simulation software has been designed in order to train in dangerous or rare situations (e.g. simulators and serious games). The design of these learning environments needs a very complex Instructional Design (ID), a process of conceiving a learning situation, which actually fulfills the needs of the learner to achieve knowledge or a competence (Paquette, 2014). In this case, the instructional designer has to think learning situations in which aspects of real life can be scenarised in order to develop skills. For that reason, ID sees its application in consider every learning situation, now also involving digital technologies.

A plethora of models has been developed to improve the practice of instructional designers, some of them focussing on the interrelationship between context, content, learning and instruction and the components of the learning system (Dick & Carey, 2005) others focussing on design of simulations and performance activities (Esseff & Esseff, 1998).

If we look carefully at these models, we realize that even if they can direct an instructional designer in how to design a learning situation, unfortunately, they cannot give information about the way the user experiences a learning process. The actual learning experience keeps being a black box in which is not possible to identify the learner path in his/her learning process into the system. Consequently, the learner's activity into the learning situation cannot be explained or measured and adapted.

How would it be possible to investigate, measure and understand the way the users learn with ICTs? Consequently, how can the instructional design be improved?

In this contribution we present, on the one hand, the IAM, which is able to design experiential learning using ITCs and, on the other hand the PNA, able to make visible and measurable the learner's learning process and consequently improve the ID and his/her learning experience and learning outcomes in terms of effectiveness.

2 Problematisation: How to construct a learning situation? Toward the definition of the Instrumental Adaptation Model (IAM)

To design a learning situation, it is important to take into account every component of the learning experience. When experiential learning meets ICT (because of the impossibility to make the experience "real"), the ID of the learning environment becomes a real challenge.

Humans construct artefacts, material or symbolic objects to answer a specific need. These artefacts become instruments only if they assume an application in the world, which either solves a precise problem or achieves an aim (Latour, 1987). When in front of an unknown artefact, one might be able to guess its function, depending on its degree of affordance (Gibson, 1977) and its ergonomics (Rabardel *et al.*, 1998). Since the use of an artefact is not innately understood, every new user of the specific artefact has to learn how to deal with it. Only when its use is fully comprehended, this artefact can be considered and employed as an instrument and used to achieve a goal. Rabardel (1995) called this process *instrumental genesis*. The same process of appropriation has to be achieved for any learning situation since they are built on symbolic and material artefacts (concepts and physical artefacts). For instance, to learn how to write, a student has to learn first how to manipulate a pencil, second, how to manage each symbol of the alphabet. The instrumental genesis describes the emergence of a mental representation of the main use and the main meaning of the artefact realized by the learner (*instrumentation*) and, at the same time, defines the possible modifications and the possible uses that learner can perform with this artefact (*instrumentalisation*).

By looking closely at a learning situation, we may observe the existence of three main categories of artefacts:

1. the technical artefacts, which permits access to the learning (e.g. a pen, a computer, an abacus, etc.) and can present different degrees of difficulty for acquisition according to their degrees of transparency (Koehler & Mishra, 2009; Bruce & Hogan, 1998);
2. the pedagogical artefact, in other words, the story and the formal representation that is constructed to make the learner understand the topic (a storyboard, a scenario, the definition of a problem, if we consider the experiential learning approach); and
3. the didactical artefact, which is the aim of the learning (e.g. the multiplication technique, a historical date, etc.) (Marquet, 2003; 2011).

The integration of these theoretical frameworks allows us to formulate a new model, the *Instrumental Adaptation Model* (IAM).

The IAM describes the ID from the perspective of an effective learning (Figure 1). This model is based on six main assumptions:

1. According to Marquet (2003) and the TPACK (Koehler & Mishra, 2009), we highlight the presence of three main artefacts composing the learning situation. Artefacts included in this situation are either symbolic, when working with concepts, or material, when manipulating some objects to access the content.
2. To construct effective learning, the instructional designer must take into consideration each artefact - technical, pedagogical and didactical - in order to adapt them to each other. This same issue has been affirmed by the theory of the TPACK (*Ibidem*). The place where the three artefacts intersect with each other is where they achieve the best harmonization (in the middle of the scheme, *cf.* Fig. 1): this shared area represents the best adaptation and, thus, the most effective learning. Therefore, we point out the importance of analyzing and choosing the best adaptation of artefacts in order to create effective learning.
3. In order to achieve efficient learning, the learner has to perform an instrumental genesis for each artefact included in the learning situation. The non-appropriation of an artefact can result in a conflicting situation and might lead the learner to an ineffective learning.
4. The instrumental genesis is a hierarchical process. The user's learning process starts with the appropriation of the technical artefact, continues with the pedagogical artefact and ends with the didactical artefact. Thus, the instrumental genesis, applied to the learning, requires the acquisition of every artefact that composes the learning situation.

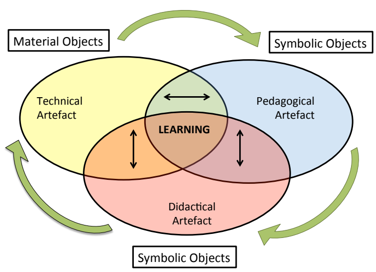

Fig. 1 - The instrumental adaptation model

5. The global learning process is cyclic: to acquire knowledge, the learner

needs to experience more than one cycle of acquisition of the three categories of artefacts.

6. Adjacent artefacts share an area, an "adaptation area," in which the learner is exploring the successive artefact while still appropriating the previous one (Figure 1).

This model has, simultaneously, two main functions: 1) by giving a clear definition of the artefacts included in the learning situation, it allows the instructional designer to carefully identify, analyze and choose the artefacts that will be included into the learning situation, and adapt them to each other in order to build efficient learning (Denami, 2016a; Denami & Marquet, 2015); 2) it gives the ability to investigate the user's learning process by operationalizing the *Process Network Analysis* (PNA) (which method we will explain below). This Usability test applied to learning situation in useful to avoid any possible instrumental conflict and improve the learning situation (Denami, 2016b).

On a practical way, we applied this ID model to design a 3D virtual simulator able to train professional skills for working in an aseptic environment and producing medicaments. As understandable, experiential learning and learning by doing is the only possibility for achieving those professional skills, nonetheless, the training into a real environment seems not to be possible because of the risks that a mistake might have. For that aim, technical artefacts (hardware, interface), pedagogical artefacts (the scenario in the simulator) and didactical artefacts (rules to realize the work) must be chosen and adapted in order to create a learning experience (on an experiential approach) able to develop professional skills.

3 Process Network Analysis: a new usability test applied to digital learning situations

If, on the one hand, the IAM permits to design experiential learning through ITCs, on the other hands there is still a lack of methods able to make explicit user's learning process into the learning environment. On that purpose, we have designed the Process Network Analysis (PNA).

The PNA usability test is inspired by the Social Network Analysis (SNA), which describes the social relations such as links between some main knots as social actors. In the same way, the PNA describes the learning activity as a network representing the direction of the process that links the knots, corresponding to the artefacts included in the learning situation. With that understanding, the tracking of the learning process and the consequent appropriation/non-appropriation of artefacts during the learning situation results in a scheme in which arrows, their thickness and the dimension of the knots, describe the learning process. Indeed, this scheme is able to highlight the possible existence of instrumental conflicts, which can appear during the user's learning activity.

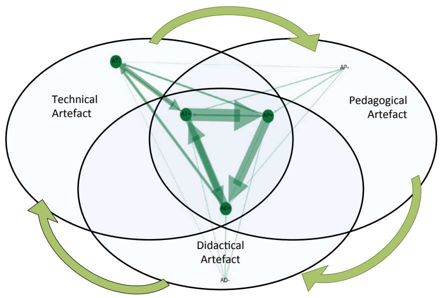

Fig. 2 - Example of the Process Network Analysis (PNA) (Denami, 2016b)

Following, we will present the PNA, the tool that will be employed to analyze the learning process with ICTs. Here, we explain its steps and how this method can be performed.

3.1 Data collecting

The PNA needs an accurate data collection because of the consequent categorisation of artefacts that the researcher must perform. The user's activity inside the learning system has to be video-audio recorded.

3.2 Data preparation for coding

Every action performed by the user in the environment has to be accurately transcribed and correlated with the frame of the learning system. For instance, a table can be completed in which the left column describes the exercises or the frames of the learning environment explored by the user, and the right column describes the realized actions and the comments of the user.

The first and second columns of Table 2 show an example of the transcription of the user's activities in the learning system.

3.3 Data analysis

The data analysis of the learning process requires the application of four main steps, which are needed in order to perform a PNA:

1st step: the identification/categorisation of artefacts

At the beginning of the coding, the researcher has to clarify the definition of the three artefacts included in the process. In that aim, every step of the learning situation has to be declared as technical (AT), pedagogical (AP) or didactical artefacts (AD). The knowledge of these definitions is the base for the subsequent coding. The activity of the user during the learning process, which is visible by the actions performed on the device, which are video-audio recorded (e.g. 1. the learner clicks on the menu to display the content; 2. the learner reads out loud the content and tries to solve a problem; 3. the learner gives the answer, correct or incorrect).

2nd step: coding and correlation of actions and comments

Every observed and transcribed action connected to a specific artefact (*cf.* data preparing for coding 3.2), has to be codified as Appropriated (+) or Not Appropriated (-) by using the criteria explained in Table 2. Here we present the meaning of the acquisition and not just the acquisition of an artefact. In order to do that, we take as an example the study of the Serious Game LabQuest (Denami, 2016b). According to Rabardel's theory (1995) by acquiring an artefact, the user acquires the ability to use it as an instrument in order to achieve the learning aim. The codification has to be determined by answering two basic questions:

1. To which artefact is the user's action directed? (Identification of the column of table 1);
2. Is the action successful? In other words, has the artefact been appropriated? (Identification of the line of table 1).

The first question is useful to identify the artefact to which the action is directed; the second permits the identification of the status of appropriation of the artefact.

Table 1
EXAMPLE OF APPROPRIATED AND NOT APPROPRIATED ARTEFACTS ON LABQUEST

	Appropriated (+)	Not Appropriated (-)
AT	The user clicks on the object to grab it	The user doesn't remember how to grab objects.
AP	The user observes the image concerning the rules explain how to clean a surface.	The user opens and closes the image without spending enough time to observe it.
AD	The user executes correctly the task of cleaning required by the learning situation	The user doesn't execute the task required by the learning situation

When the whole process has been codified, a count of every connection between the artefacts has to be performed.

Table 2
CODING THE LEARNING PROCESS

Frame into the learning system	User's actions and comments	Appropriation/ NonAppropriation of artefacts
Pièce NC, devant le lavabo	Je lui dis « tu vois ce PIN, tu dois cliquer dessous pour accéder aux informations ». Elle clique sur le PIN et elle prend le temps pour le lire. Elle clique sur le lavabo + savon + Labavo. Elle me demande « pourquoi ils s'activent les deux même si je clique un seul » je lui explique « une fois c'est le nettoyage, l'autre c'est pour la désinfection » Elle clique sur le distributeur pour prendre les serviettes	AT+ > AP + AD +
Armoire des habits d'usine	Elle essaye d'abord de cliquer sur les objets entourés en jaune. Puis elle s'approche des objets car elle le souvient qu'il faut se rapprocher. Elle clique sur le POI « règle d'habillage haut-bas » je lui fais remarquer que s'il veut elle peut cliquer sur l'image pour l'agrandir. Elle dit « mmmmhhh… je connaissais pas ça »	AT – >AT+ AP + AD +
Volet « avatar » pour l'habillage	Je lui dis « tu n'est pas déshabillée donc il faudra le faire, donc pour le faire tu retourne en arrière». Elle retourne en arrière et elle se dirige vers l'armoire des habits de ville	AP - > AP +
Armoire des habits de ville	Elle clique sur les habits mais pour les activer mais elle ne clique pas bien dans les contours verts. Elle fait *drag n drop* pour endosser le t-shirt + pantalon Elle dit « et ça aussi, la capuche ? » je réponds « si tu veux ». Elle prend la cagoule et la fait glisser sur l'avatar.	AT - AT+ AP + AD +

Researcher's comments
User's comments
Researcher's interpretations

3rd Step: counting connections

The 3rd step consists of counting the number of connections between artefacts. If we look at table 2, we can count in the last column to the right that, during the first frame "Pièce NC, devant le lavabo" AT+ is connected with AP+ and directly after, AP+ is connected with AD+. This first cycle of artefacts shows a good learning by the user. In the second frame, the user faces a problem: in the "Armoire des habits de ville," he experiences difficulty in acquiring the technical artefact (AT-). Nonetheless, we observe that the user corrects his behavior and finally succeeds in its acquisition (AT+). The analysis requires the same process for every artefact. Every connection will be noted simultaneously in a table, as shown below (cf. Table 3).

TABLE 3
TABLE OF CONNEXION OF ARTEFACTS

	AT+	AP+	AD+	AT-	AP-	AD-
AT+	0	10	0	2	2	1
AP+	1	0	10	3	1	0
AD+	3	0	0	6	1	0
AT-	10	0	0	0	1	0
AP-	0	5	0	0	0	0
AD-	0	0	1	0	0	0

4th Step: Gephi, data input and output

The table has to be imported into a program for network analysis: *Gephi*.

An output of the graphic will represent the connections between the artefacts Appropriated and Not-Appropriated.

The entire process of learning and its progress will appear. Figure 3 shows an example.

4 How to interpret the PNA?

Similar to the SNA, the PNA required an interpretation of its results. In that aim, it is important to pay attention to the thickness of the arrows, their direction, and to the dimensions of the knots composing the internal and the external triangles. A successful learning process, for instance, should be described by a thicker connection of the knots that construct the internal triangle. Every arrow connected with external knots represents a conflict that the learner experienced during the learning situation. Nevertheless, for a correct interpretation, it is necessary to pay attention to the direction of the arrows. Indeed, if the number of connections going from the internal to the external triangle is more than those having the inverted direction, it means that the learning is not efficient. The contrary situation proves that all the conflicts have been solved by the user-learner.

Figure 3 shows a situation in which the user performed an effective learning.

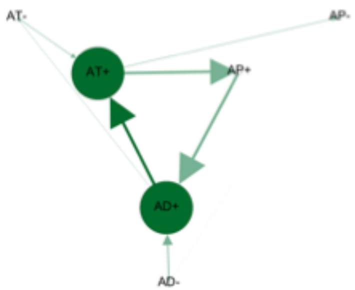

Fig 3 - PNA output on Gephi

Indeed, we can observe a strong connection between points composing the internal triangle, representing the acquisition of the three categories of artefacts. Some connections exist between the external triangle, but two pieces of information tell us that the difficulties have been solved: 1) the connections to the external triangle are less numerous than the ones of the internal triangle; 2) the arrows from the external triangle to the internal one are thicker than the ones running in the inverse direction.

5 Which advantages for experiential learning? A first test of the PNA.

The IAM and the PNA have been formalized in the occasion of the design of LabQuest simulator. The results concerning its effectiveness for developing users' skills have been already published (Denami, 2016a). Nonetheless, new data shows a correlation between the post-test performances of users trained with the simulator and the graphic resulted by the PNA. Moreover, we can affirm that the PNA have been used in order to improve the effectiveness of the simulator. The interpretation of this data, need a fine comparison between quantitative data and qualitative data. Our purpose to continue this research is to standardize the PNA usability test in order to achieve a fully quantitative method able to measure user's learning process and specifically the conflicts that make more difficult the achievement of the learning.

Concerning the experiential learning approach realized with simulative or virtual devices, we can observe how the PNA can identify, classify and make explicit the appropriation/non-appropriation process of the artefacts included the virtual environment.

To conclude, we consider the IAM and the PNA as two complementary methods: on the one hand, the IAM, used as ID method, makes possible the design of learning environments able to reproduce a virtual and safe experiential learning. On the other hand, the PNA permits to explicit the learning process and to improve it in the case some difficulties avoid an effective learning.

Nevertheless, the PNA can see its use in different contexts aiming to understand how users learn with digital learning environments. A forthcoming application of the PNA will take place in order to evidence differences between students and teachers on their appropriation in ICTs. By then, following the literature concerning "Digital Natives" (Prensky, 2001; Oblinger & Oblinger, 2005), we expect to highlight the key factors or the main differences between those two generations of learners.

Conclusion

The PNA, as a usability test, is able to investigate the user's learning process, is a powerful method, which can be applied in different fields of learning, some of them already mentioned. For that reason, and as already explained, the aim of this contribution is to present a tool that can be applied to different domains in order to solve some of the plethora of open questions concerning ID and ICT use. Is in our interest to highly encourage the application of the PNA both to validate its scientific reliability and to improve the employment of that usability test applied to learning situations, along with all its benefits, some that already have been mentioned in our contribution. It will be in our interest to broaden the applications of that usability test in order to highlight its relevance.

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