A digital pedagogy model

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Abstract

For a Virtual Learning Environment a Digital Pedagogy is required, otherwise learning will be the same as usual with the only difference being, that reading and writing will be on the computer, and therefore the opportunity to use the Computer Science and Technology to empower the student's learning is lost.

The Digital Pedagogy needs to be Multi-Referential, which means that different knowledge areas have to converge to produce the innovative vision for a powered e-learning.

In the Digital Pedagogy Model (DPM) this multi-referential level is defined as Ontology and in this level Areas such as Philosophy, Sociology, Psychology, is integrated with Artificial Intelligence, Neural Artificial Networks, Automata Theory, Modelling Visual Languages and Software Engineering.

These converged areas define, on a second level, a Digital Pedagogy with a Constructivist approach and a Scientific Methodology, in an Integrated Capability Maturity Model for a Digital Pedagogy that evolves in a Continual Improvement Process

This improved Digital Pedagogy is applied to a knowledge area to be taught in order to define a Digital Curriculum which is defined using a Unified Modelling Language (UML) for an Object Oriented Curriculum with two main learning purposes: to learn the computer and the area thinking, i.e., if the knowledge area is Mathematics, it would be Computer and Mathematical thinking.

Finally the Digital Curriculum defines a Didactic Planning focused on building digital resources for Activities of Cognitive Interactivity with the Technological Resources. The activities follow an IDEF0 structure, with: Control, Content, Product and Method components.

The Modelling of a Virtual Learning Environment can be accomplished through the modelling of states of a Touring Machine, where learning takes place through the transition of states in which knowledge products are built.

In one state, a Touring Machine reads and as a result of this action may or may not write, and may or may not make a state transition.

In the learning process modelled by states of a Touring Machine, the student reads, processes the information, builds a product of knowledge through actions and finally changes his state or remains in the same one.

The knowledge products, the operations performed in the actions, and the type of contents read are determined by the abilities of the Structure of Intellect Model (SOI) ensuring in this manner that learning takes place.

The modelling of states is the key to displaying and summarizing the curriculum designed by an UML object-oriented modelling, where a Use Case represents a unit of cognitive resources that is developed by the student.

Each use case is developed through an UML state diagram, and then is validated by a Touring Machine modelling state.

It is expected that, in a virtual learning environment, a student should be able to open his own threads of learning with different contents, conduct state transitions determined by his own learning process and produce his knowledge products, which becomes a case of non-deterministic automata, showing the benefits of adopting the modelling of states of a Touring Machine as a learning model. .
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1. Introduction

In the field of education the main question about using the digital technology is not why, but how.

This research is an attempt to solve that question. In the present approach a model has been built up as a framework that can evolve, due to the nature of the technology.

The purpose of the Framework is to build up a Knowledge System, either the one of the Subject Matter to be taught or the Referential Area to be integrated. Each Knowledge Area is processed with the same principles and following the functionality of the Model, so the first process is to analyse the Area as a Use Case in the referential perspective, or as a Case Study in the pedagogical one.

The Case Study is analysed with UML because, at the end, a Knowledge System is going to be design.

There are some principles in which the Pedagogy is to be developed, which are established at first.

Secondly, it is important to deploy the Architectural Structure, and based on it to describe the functionality of the system. Again, the Computer Science is used and the Model for this Architecture is The Open Systems Interconnection (OSI) model (ISO/IEC 7498-1). This Model applied in an Educational context becomes a standard procedure of characterizing and standardizing the functions of a Knowledge System in terms of abstraction levels. Similar knowledge Areas are grouped into logical levels. A level serves the level above it and is served by the level below it.

The model intends to represent the flow of the information from the top level to the bottom, and also horizontally with the products that it generates.

The main product is the digital learning process and the teaching one that serves it.

As far as it has been built up to now, it only applies to be used at the pre-university and university level.

The digital learning process is described in every level, with differences in the abstract level.

One of the main characteristics of the Digital Technology is its evolution; due to this characteristic it seems almost impossible to have a standard learning processing in a virtual environment and it is less attainable if for a virtual environment it's just considered the technological aspect.

2. Principles

The digital pedagogy is based in some principles:

Multi-referential. According with Ardoino (Ardoino & et. al., 1991) it is necessary to understand that the multi-referential analysis is the one that is needed for an integrated Educational Science, where allegedly different Reference Systems represent different approaches to understand a complex phenomenon as the Digital Education.

A Digital Pedagogy assisted by the Science and Computer Technology. Currently the Digital Pedagogy is assisted by the ICT (Information and Communications Technology), and the use of this technology tends to be solely for information exchange and communication. The approach of the DPM is that the technology mainly has to be used for a cognitive interaction, being the Information Technology, Communication and Knowledge (ITCK). But at the ontological level the Computer Sciences and the Software Engineering can be the references that enrich the Digital Pedagogy Concept.

Convergence. All the referential areas along with the content of the subject matter have to produce an integrated vision of how to integrate the technology intro the curricula states of knowledge and the didactic activities (Solomon & Schrum, 2010). The model emphasizes the integration of computer science's knowledge, technological knowledge, referential area's knowledge and content knowledge to produce the cognitive interaction sought.

Constructivist approach. The learning process is intended to build knowledge products defined by the SOI (Structure of Intellect) Model. So, the digital pedagogy doesn't use Bloom's taxonomy, it uses the products' SOI Model as the one that establishes what has to be accomplished.

The main product's knowledge of every course is a cognitive operational scheme in terms of Piaget, and a structure in terms of the SOI Model.

This product is associated with every Case Study of the subject matter. In terms of an intellectual ability every Case Study develops a cognitive resource, which is the integration of attitudes, abilities and capabilities.

All of the Case Studies of a course integrate cognitive resources to develop a Knowledge System.

Competence approach. In a technological context knowledge rapidly becomes obsolete and it is necessary for the individual to update knowledge and competence in a continuous process of learning. The constructivist approach where the individual acquires and develop cognitive resources, has to be applied to real situations where all of the cognitive resources develop are mobilized to solve real-life problems. The problems that occur in a real-life time period constitute the semantic content of the SOI Model which is reach through a translation process that starts in a symbolic content, in this sense, the semantic content constitute a context where knowledge is applied and acquired a specific meaningful for the individual.

Semiotic approach. Every individual is surrounded by a group of symbols in every instance of its life, this symbols that surround the individual change from time to time, to the extent that are interpreted and applied to resolve situations of his life. This is the main reason of the importance of the cognitive resources acquired in his/her education; they become guidance for a correct interpretation of the symbols.

3. The Architectural Structure and abstraction levels

The Digital Pedagogy Model is a framework used to build up Knowledge Systems and the learning process that can assimilate and accommodate the cognitive operational schemes that allows the construction of the system.

Every knowledge system has to be analysed in the four levels of the framework, either system being a reference or a subject matter. In every level of abstraction of the framework different purposes have to be served.

At the first level the purpose of the model is the integration of the system with the others already being assimilated. The system has to integrate with the two referential areas involved: the human-social sciences and the computer sciences.

At the second level the purpose has to be that the cognitive resources that are going to be develop in the individual creates the attitudes, abilities and capabilities that are expected in the educational vision of the digital pedagogy.

In the third level it is expected to develop a way of thinking, the one that the system by its own natures creates the capacity to do things in a certain manner, with the ability to follow certain procedures at using technology tools and with a certain attitude in front of the learning task and the technological tool.

In the fourth level of abstraction the main purpose is that the student performs the activities designed in the learning process at their own pace, regardless the time, and can accomplish the construction of the knowledge products as expected, including peer interaction within the process.

3.1. The ontological level

The first level is the ontological one; it locates the referential areas, which constitute at first two areas of expertise:

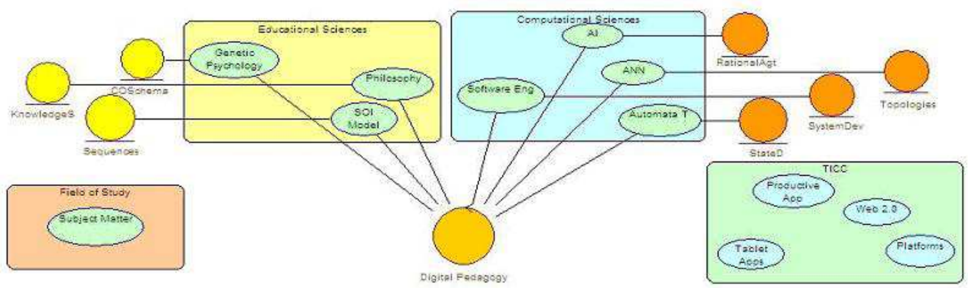

Figure 1: The ontological level of the DPM

Genetic Psychology. The constructivist approach is based primarily on Piaget' studies (Piaget, 1972). The main concept is what we call cognitive operational scheme, an operational structure of the knowledge area being studied. This scheme allows not only the generation of knowledge, but the knowledge system that represents.

The first problem is to divide the area of knowledge in case studies to be analysed in order to develop the conceptual structure associated which evolves to be the cognitive operational scheme as the process of analysis concludes.

SOI Model. Guilford (Guilford, 1959) creates a Structure of Intellect Model, where each intellectual ability is defined by three variables: content, operation and product. This ability's definition resembles a mathematical function, being the dependent variable the product and the independent the content. In the digital pedagogy model the product variable is assumed as a sequence of knowledge products where each predecessor is taken to generate the next one: units or entities; concepts, classes or categories; relationships; structure or scheme; system; transformation or process and implications or inferences. This sequence shows how the learning process is going to build up the cognitive operational scheme of Piaget. Precisely, this scheme or structure is the primary learning objective in each course designed using the Digital Pedagogy Model. Each knowledge product in the SOI's scale is created through the operation sequence given by the SOI Model: cognition; memorization or data and information storage; divergent production; convergent production and evaluation.

The content variable is the strategic one, because creates a rationalization of the learning process for the subject matter to be develop. The contents can be: figurative or images or videos or audios; symbolic or icons or language; semantic or context of application; and behaviour of every kind available, human, system, etc. It becomes a key factor to interpret this type of contents for the subject matter. The learning process will play with the transformation or translation between types of contents, because it is this kind of transformations that develop the individual's thinking on the matter in question.

Automata Theory. The operation in automata is through "States", the automata can change state due to what is read or perceived. In every state, the automata reads a character and depending on the transition function of the automata, shifts to another state, write a character and advance to read the next character. In the digital pedagogy, the student transitions to another Knowledge State every time he or she generates a knowledge product. In every state the product is created through realizing the operational sequence of the SOI Model. This model allows the designer (the teacher researcher) to visualize the entire learning process at layers of abstraction and to develop an evaluation process associated, the necessary technological resources to be allocated, the necessary time, etc.

The automaton designed is the one that allows seeing all the transformations performed within the contents involved.

Artificial intelligence. The focus on this area is in the (RA) Rational Agent's approach to create intelligent devices. There are certain characteristics and behaviour of the Rational Agent that are relevant to the Digital Pedagogy. First of all, the Rational Agent's purpose is to learn, which means that he performs an action when he receives a perception. Cognitive psychology considers the brain as an information processing device, whose perception involves an unconscious form of logical inference (in this case, perception-action), specifying three key steps of a knowledge-based agent: 1 stimulation results in an internal representation (or content), 2 representation is manipulated by cognitive processes to derive new internal representations, and 3 who in turn re-converted back into action. The Rational Student interacts with a medium (SW programs) through perceptions (given by the senses) and perform actions through its actuators, to learn in a progressive process. Programs (artifacts) provide incentives that allow you to build knowledge products: entities, concepts, relationships, operational structures (Piaget), systems, processes and inferences (SOI model).

There are different models of agents that are used and interpret for the learning process, as for example, the one that memorize, because an agent cannot learn if he/she don't memorize, and in this context, what is memorize is the association perception-action.

The other significant model to be used is the one that uses a model in order to increase the visualization of what has to be learned, which at the beginning it is not totally perceived.

Artificial Neural Networks (ANN). While the student is building up a knowledge product, he or she follows the operational sequence of the SOI Model, which is first cognition and secondly memorization or registering. In a digital environment the student can store the data and the information in such a manner, than when he or she wants to generate a divergent production, which is the next operation to be performed, they have to navigate relating the data and the information creating in its own neural networks precisely a cognitive scheme. If the teacher creates files where the student is going to store the information that follows certain ANN's topologies, he or she is promoting a process that relates to data and information in order to produce new knowledge products. The student creates his own navigation's paths with the topology that stores the information that he or she has to relate for its divergent production. So, the ANN's topologies are important because they induce some thinking and processing paths.

Software Engineering. In this constructivist approach the first goal is for the student to generate an information structure that allows him to construct knowledge products. With that purpose the teacher that wants to design a curricula course assisted by the TICK (technologies of information, communication and knowledge) can use the DPM. So, he or she is designing an information system for that course, first the curricula and then the didactic planning. As the DPM references the Software Engineering whose primary goal is to construct an information system, the teacher uses UML (Unified Modelling Language) to analyse and then design both the curricula course and the didactic planning course.

UML serves as a template to perform the analysis and design with the artefacts in every diagram that guides the process.

In the analysis process performed with UML, every Case of Study is treated as a Use Case, at this level several Study Cases are related for a sole subject matter, each Case of Study is analysed independently to the others. All the Study Cases are integrated within an artefact "system". The Case Study has associated a class (or concept) which serves as the control concept for the learning process.

Later on, each Case Study is analysed in a UML's State Diagram where each of the knowledge products associated with the control concept is constructed by the student.

The analysis process continues in the State Diagram where each State is decomposed into a sequence of actions, where each operation of the SOI Model is realized as an action. Every action is associated with a student's perception of the interaction with some technological artefacts and apps.

In another level of analysis the actions associated with a State Knowledge are analysed in a sequence diagram where it is described the interactions of the student with technological artefacts, lectures, writings or anything that is needed in order to perform the SOI's operations.

A sequence diagram is transformed into a collaboration diagram which describes the same interaction but seen as collaboration; both diagrams are known as interaction diagrams.

This is where the analysis concludes and the design begins.

The first task of the design is to evaluate the collaboration diagram seen as a pattern of interaction.

Once the collaboration is evaluated the interaction is transformed as a set of activities.

In the DPM the activities are not described with UML, instead it is used an IDEF0 diagram, where each activity is modeled with four arrows representing: control, mechanism, content and product. The control aspect of the activity is the purpose of the activity, the content and the product don't need an explanation, and the mechanism or method is the operation performed to transform the content into the product.

3.2. Pedagogical level

All of the referential areas in the ontological level determine the components in the digital pedagogy along with the referential areas at this level, which are: Constructivist Pedagogy and a Quality Model. This is another set of principles of the Digital Pedagogy which are:

Multithreaded. A multithreaded process is inherent to the fact that the student needs to learn to use the technological tool besides the subject matter, but also, the use of the tool allows the student to follow his or her own learning path in the environment set by the technological environment. If he or she needs to access a word meaning that another doesn't is an example of this phenomenon, and so by following other links are determined the learning threads needed by a specific student.

This is associated with a parallel thinking that has to be developed by every student that interacts with technological artefacts in order to construct knowledge. This parallel thinking is the one that integrates capabilities to cognize, abilities to perform and attitudes toward individual and socials values.

Knowledge Product oriented. The learning process is focused on the construction of knowledge products, determined by the SOI Model. The main purpose of a course is the student to develop a cognitive operational scheme of the subject matter. This process is determined by a state of knowledge, where each state constructs a knowledge product.

But the knowledge products are interpreted by the teacher-researcher from his/her own knowledge and experience on the subject matter.

This interpretation is oriented by the Educational Ends derived from the Ontological level, the Institutional Goals of their Educational System, the purposes of the Area of knowledge of the subject matter and the learning Objectives or Cognitive Resources to be developed in the students.

A hierarchy of learning objectives. As each abstraction level of the Model (DPM) has his own objectives, all of them are integrated from top to bottom. In other words, the Educational Ends derived by the teacher-researcher in an individualized manner are integrated with the Institutional Goals of the Educational System where he/she serves, and this integrated goals are also integrated with the Knowledge Area's purposes of the subject matter, which in turn integrates with the Learning Objective or Cognitive Resources to be developed in the students.

This process of integration of ends proceeds first horizontally, that is each abstraction level produces their own ends, and once they are developed they are integrated from top to bottom, which assures the direction of a course.

This integrated Cognitive Resources are used to interpret the Knowledge products to be produced in the learning process with detail, because along with the Knowledge Products are derived a rubric used to evaluate the knowledge products.

Competency-based education. The curriculum is defined as a set of cognitive resources which can be used as needed in the solution of a problem. Every cognitive resource is an integration of a set of capabilities, abilities and attitudes that are assimilated through the construction of an operational cognitive scheme. The learning process defines a sequence of knowledge states that can accomplish the goal. As the learning process is knowledge product oriented the scheme serves as cognitive scaffolding in order to construct a knowledge system which is the integrated product of several cognitive resources and where every cognitive resource is a function to use and construct the knowledge system.

The competence acquired can be described as a set of capabilities, abilities and attitudes to manage a knowledge system.

Continuous improvement process. The DPM uses the CMMI, a quality model that functions in cycles, where the results of a didactic planning serves as a feedback to the ontological level, where these results are analysed and then produce some changes in the lower levels of the model. Also, if there are changes in the referential areas or other areas are integrated, the model can be changed and so the digital pedagogy. Nevertheless the principles remain.

In a context of an education that uses a technological infrastructure the courses have to be changed in a continuous process. It has been studied that the cost is higher for the one that remains obsolete in a technological context.

This aggregates a research-evolution orientation in the education performed, every time a course is implemented in a classroom a cycle is performed, every instance represents an iteration that reviews all of the abstraction levels.

The same occurs when a subject matter or a referential area are integrated. The DPM is continuously developed in a software engineer methodology called increment iteration.

This represents an ideal infrastructure to perform educational research, due also to the integrated facility to register the student's outcomes.

A hierarchy to determine a Digital Learning Process. Every abstraction level of the DPM produces some version of the Digital Learning Process.

At the Ontological level every referential system produces its own particular Learning Process with some characteristics that are relevant for the Digital Learning Process.

The DPM's pedagogical level determines a Digital Learning Meta-Model with a constructivist approach that produces a knowledge product's sequence which is represented by a knowledge state; in each state the student constructs a knowledge product following the intellectual operations of the SOI Model.

At the Curricula Design Level, the purpose for each course is determined by the Knowledge Area Thinking, the Digital Learning Model focused on the assimilation/accommodation of a cognitive operational scheme that allows the student to construct a knowledge system where the functions needed to use it are developed by a set of different curricula programs.

In the Didactic Planning level the interaction system analysed and designed is transformed into a sequence of activities, developing a Digital Learning Process, which can be described as a template, because it is the same Digital Learning Process for every course designed, what it changes are the variables of contents, resources and technology used, as well as the Thinking System and the Knowledge System.

Non-deterministic learning paths. As it has been said the main difference between the traditional learning scenario with a teacher performing one learning process and the digital-technology based learning is that the student in the second one can follow his or her learning path and so can create several learning threads.

The use of the Automata Modelling allows to design these differentiated learning paths, in order to create the necessary resources and the environment that allows for a student to follow his/her own decisions.

Cognitive interaction. The use of the technology is focused on the interaction that the student perform with its artefacts in order to produce knowledge products.

The UML's analysis assured that the Digital Learning Process be an interaction system to produce knowledge.

The teacher-researcher can visualize the pattern of the interaction and evaluate it.

The importance of the technology is not only to facilitate the information processing but to facilitate the information storage, the individualized interactions that every student can perform at their own pace, the use in every student of all the learning threads that he/she needs specifically.

The use of the technology produces a Digital Individualized Learning Process that in an obvious manner is the best possible scenario.

3.3. Curricula design

Using the DPM, first of all the subject matter is defined as a Case Study (Use Case in terms of UML) which being analyzed is divided in as many cognitive resources as needed to construct the knowledge system of the subject matter. Every Case Study represents a cognitive resource for the competence needed to use the knowledge system; each cognitive resource is a function to use the knowledge system.

Every Case Study is analysed in its state sequence in a state diagram, but first with a state diagram of a touring machine the type of contents that are going to be used are decided, following the SOI Model, which are: figurative, symbolic, semantic and behaviour. Following the states of the touring machine the states are defined in the UML's state diagram. Every UML's state diagram is defined to construct knowledge product according to the SOI Model and following in every state the sequence of operations defined by the same Model and according to the contents being analysed by the touring machine. Within every state the technological artefacts that are going to be used are also defined in the construction of the product according to the operations that are going to take place.

As the analysis proceeds, every UML's state defined is analysed by a UML's sequence diagram where the cognitive interaction is described as a sequence of messages between the student, the technological artefacts, contents, other resources, their peers and his/her teacher were defined in the UML's state diagram as actions. The interaction is defined as a sequence of messages with some associated data or information. The sequence diagram is converted into a collaboration diagram where in an orthogonal arrangement the cognitive interaction is shown more properly. The interaction is evaluated using UML's interaction patterns.

At this point the curricula design specifies a curricula program with a learning path of knowledge products which ends in a cognitive operational scheme, where different type of content can be used to achieve it. A strategy with technological resources is established in the interaction/collaboration scenario. Each strategy describes the cognitive interaction between the student, the technological artefacts and other resources, as well as their peers and their teacher.

3.4. Didactic planning

At the didactic planning level another modeling language is used, which is IDEF0. Particularly, this structures modeling focuses on the activity and its related associates: content, learning objective, method of processing and knowledge product obtained; precisely the relationship between a learning objective and a knowledge product is described in this diagram. At the beginning of the didactic planning the context has been established in the curricula design, that is, summarizing, the cognitive resource which is a knowledge unit that has been analyzed from:

A case study to different states of knowledge, 4 in total, which analyse: units, concepts, relationships and structure.

Each state has also been analysed in a sequence of operations that lead to the construction of the correspondent product, 5 in total, which determine: cognition, memorization (storage in an ANN), divergent production, convergent production and evaluation.

Each one of the 20 cognitive operations integrates: capabilities, abilities and attitudes. Each one of them is analyzed in two interactions diagrams.

These 20 cognitive operations can turn into 25 if it is the goal to assimilate/accommodate/use a knowledge information system.

In the didactic planning level each of the 20/25 cognitive operations are transformed into classroom activities, which are based in the pattern interaction designed. The activities designed can interact with each other, producing the required scenario for the student to decide his own learning path and its several learning threads.

4. Applications

The Digital Pedagogy Model is applied to develop:

- Mathematical courses.
- A programming course.
- Learning subject text.
- A digital pedagogy master degree.

5. Conclusions

The Digital Pedagogy Model is a digital education research framework, which can evolve through new technologies.

References

1. Ardoino, J., & et. al., *Sciences de l'education, sciences majeures*, "Recherches et Sciences de l'education", 173-181, 1991.

2. Guilford, J. P., *Three faces of intellect*, "American Psychologist", 469-479, 1959.

3. Piaget, J., *Psychology and Epistemology, towards a theory of knowledge*, Middlesex: Penguin Books Ltd., 1972

4. Solomon, G., & Schrum, L., *Web 2.0 how-to for educators.* Eugene: International Society for Technology in Education, 2010.