Expert System Prototype for Evaluating Training Activities with Writing in Natural Language Experiences during the Design Phase in a Healthcare Administration Case

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Abstract

A healthcare system, in addition to providing treatments and services that address the population’s health needs, is the sum of human capital, institutions and organizations, financial, material, information and mobility resources, as well as guidance and direction, among other aspects. (WHO, 2020)

Despite the diversity of operational models existing in each country, the general nature of a system’s organizational complexity places the directive, administrative, and managerial function in a transcendental position for the sustainability of a national healthcare system.

The relevance and transcendence of training for healthcare administration and management places the higher education institutions that provide it "[...] before fundamental challenges: the need to train new specialists and professionalize the work of the managers who are currently performing activities in healthcare organizations" (Valiente y Galdeano, 2019).

Online education and training activities that place professionals in specialized training in virtual situations in which they need to show their competences to make decisions and solve situations in the field of management and administration meet the aforementioned challenge. For these activities, expert knowledge-based information systems are resources that assist in the practical implementation of virtual reality for students and support automated assessment carried out by faculty members, specifically in activities based on writing in natural language.

The design of these systems requires organizational transformations that include the standardization of instructional design and IT governance during the knowledge engineering process for the definition of teaching requirements. Furthermore, these systems contribute to quality improvement, knowledge management and increasing an institution’s intellectual capital.

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Introduction

To address the challenge of training, the MA Programs in Health Management and Administration typically involve the development of training activities to develop conceptual capabilities and professional skills that make the student -virtually- responsible for the function of management and administration in charge of solving scientific or transnational needs in health institutions. The student being required to justify and design the implementation of a Translational Research Program in Healthcare Units in order to participate in International Projects of Innovation in Medical Practice is an example of this situation.

With this type of activities, the competences stated in the undergraduate curriculum are developed, is appreciated in the educational field because they promote comprehensive training by developing soft, professional and managerial skills. However, activities based on writing in natural language challenge faculty members to issue an evaluation due to the subjectivity implicit in natural language, such as free writing during the participation in forums or the drafting of texts.

Expert Systems for natural language recognition are proposed from the field of Educational Technology as a resource for the automated evaluation of activities based on writing in natural language.

In this paper we present the experience of a group of teachers who are designing a prototype of an expert system for the evaluation of these activities within the framework of an online higher education institution.

This experience is found in the first phase of the software engineering process, consisting of the definition of user requirements, a phase called knowledge engineering in the specialized field of expert systems.

The preliminary results show the needs for teaching organizational transformation aimed at standardizing instructional design and establishing a IT governance that facilitates the formal representation of explicit knowledge as a resource to develop the multidisciplinary capacity for meaningful interaction between faculty members specializing in the knowledge to be evaluated and the knowledge engineers responsible for software design. Also, by incorporating activities of various disciplinary specialties in the expert system, the software engineering process demands the implementation of broader processes in the organization to promote knowledge management in the multidisciplinary group, involving a structure and operation that ensures a context of creative chaos for the production of knowledge- and information-based resources, which constitute the intellectual capital of an educational institution.

Expert Knowledge-Based Information Systems

Natural language recognition is an area of artificial intelligence the instrumentation of which is widely developed by expert knowledge-based information systems.
This type of systems is based on pattern recognition and inferences made by knowledge engineers through various constructive processes and interaction with specialists in the disciplinary field of interest. These specialists hold the implicit knowledge they use for decision-making in their field of expertise, and knowledge engineers recognize and systematize the patterns of the assumptions determining the decisions made by specialists in order to then transform them into explicit knowledge. For this, knowledge engineers use explicit representation modalities the formats and nomenclature of which have been normalized and standardized by scientific and technological communities in this field of scientific knowledge.
The usefulness of normalization and standardization lies in the possibility of deploying collaborative and multidisciplinary work to design, develop, and implement expert information systems based on <explicit> knowledge, automate activities that involve decisions and require objectivity and transparency.
Despite the obvious commercial benefits, this type of scientific and technological knowledge transcends into the social sphere the use of which is addressed in this article and is aimed at benefiting the technology-based interdisciplinary research-teaching sector.
With this exploratory exercise, and the evidence of the technological implications, we assume the feasibility of development in the telematics field, which integrates knowledge of computer science, informatics and telecommunications.
In contrast, the differential amplitude between different knowledge specialties poses the challenge of transforming the specialist's implicit knowledge into explicit and systematized knowledge, understandable by software system developers whose functionality corresponds to an expert system. This challenge can be overcome when the conditions and decisions correspond to repetitive tasks easily expressed with data and information associated with operations based on linear and elementary mathematical models such as statistical, Boolean, financial, accounting and some chemical models, among others.
The difficulty persists when the components of specialized knowledge and their relationships must be recognized in order to establish the structure and functionality that ensure the feasibility of its systematization and computer automation because these components and relationships underlie the specialist's subjectivity [and unconsciousness], i.e., the difficulty consists in recognizing the logic of meanings that determine the scheme of action during the decisions made by an individual, which in this case is the faculty member with specialized knowledge.

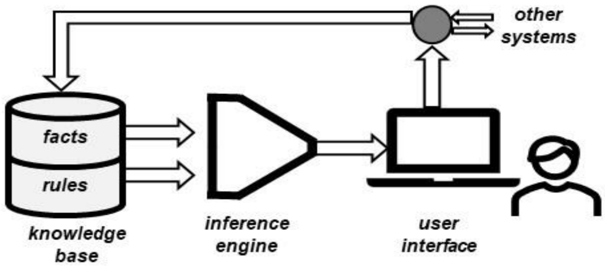
Benchmarking framework

In order to support the analysis process and interpretations presented here, we established a multidisciplinary benchmarking framework integrating fundamentals from information and computer science, administration and management as well as pedagogy.

a) Architecture and development of an expert system

The basic architecture of a software in which its functionality is based on an expert system is integrated by three fundamental components: knowledge base, inference engine, and user interface (see Figure 1).

Figure 1. Basic Architecture of an Expert System



Source: http://inteligencia-artificial-unsxx.blogspot.com/p/sistemas-expertos.html

The knowledge base is a repository storing specialized knowledge that defines the domain of facts underpinning automated decision-making as an <<artificial specialist>> based on decision-making rules.

The inference engine is in charge of checking that the rules are fulfilled and implementing the decisions; the interface or interfaces are the means by which users, both faculty members and students, interact with a system.

To develop an expert system, several methodologies have been documented that implement a specialized generic process from the disciplinary field of software engineering.

Software engineering proposes three stages for the development of an expert software system: design, development, and transition.

The design phase witnesses the execution of a process that allows an understanding of the system and its explicit representation in what will become its architecture and functionality. During the development phase, programming is carried out and during the transition phase, software is implemented so that the user can test its usefulness or make necessary adjustments.

This article focuses on the first phase, in which it is essential that there be interaction between the specialists in the technological field and the specialists -faculty members- determining the requirements and ideal functionality to be implemented in the system.

The specificity of an expert system consists of the explicit representation of the specialized knowledge and reasoning that determine decisions, which is a natural construction of a complex resulting from the specialist's subjectivity, as opposed to numerical or alphabetical data and basic operations used by other types of software systems. This specificity implies the execution of a process called knowledge engineering, in which the expert systems specialist has the task of translating the specialist's knowledge -that of the faculty member- into some form of explicit representation understandable to specialists in charge of software programming.

The challenge faced by knowledge engineering becomes more complex when the source of specialized knowledge is located among multiple specialists in different disciplines, as in the case of an expert system that supports the automated evaluation of different training activities based on writing in natural language. In order to address this complexity, the implementation of another specific knowledge management [sub]process is proposed as the first activity of the design process during knowledge engineering.

b) The knowledge engineering process understood as an organizational knowledge management process

Knowledge management is understood as a strategic process, used by administration and management, for the construction of shared knowledge within an organization. This strategy focuses on individual and group knowledge, because this knowledge as a whole can become an accounting value and property of the organization referred to as Intellectual Capital. The implementation of knowledge management requires ensuring and providing the organizational, structural, and functional conditions, known as the context of creative chaos. This context is suitable to promote knowledge transformation during a complex process that simultaneously integrates three particular processes: creating, evaluating, and communicating knowledge.

As aforementioned, knowledge engineering is a specialized area of artificial intelligence. Its field of professional activity consists of the "extraction of specialized knowledge" from specialists in multiple areas. This process is executed through reiterated analysis and interpretation processes using different formal representations of knowledge, generally based on formal representations associated with the field of specialty. For example, flow charts or flow diagrams are translated into formal representations of the expert systems field, such as tree diagrams and neural networks, among others.

From the perspective of knowledge management as an alternative to establish the necessary organizational conditions in the University to implement knowledge engineering, the purpose is to implement the context of creative chaos and the process to build a socialization instrument, which, in turn, enables its automation, since it guides the systematization and translation process of the specialist's explicit knowledge, towards the implicit knowledge of computer, IT, and telecommunications specialists.

c) The process of transforming expert knowledge into explicit knowledge through formal representations is essential in a multidisciplinary context of creative chaos

Subjectivity is the unconscious understanding or expression of the personal and partial perception and valuation of an object, event, process or phenomenon of reality. Subjectivity is individual, since all humans present a specific point of view or scheme of action, which is determined by the unrepeatable logic of meanings. In other words, this refers to the significance of the components of reality and the individual way in which the relationships between these components are structured.

The knowledge engineer faces the challenge of "translating their own subjectivity", as well as the subjectivity of both the specialist holding the knowledge to be automated and the specialists in charge of implementing the telematic automation systems.

Overcoming the challenge of translating the subjectivities involved implies proceeding with the aforementioned pattern recognition and the corresponding inferences, i.e., transforming the subjectivity or unconscious logic of meanings into "conditions" and "decisions", a "tree", or the pseudo-code of a knowledge-based information system or "if" and "then" in a software program.

However, from the knowledge management approach and from a training perspective, which affects the social dimension, we emphasize the necessary execution of collaborative processes for interdisciplinary constructions with an understanding of the complexity of organizational systems to face the challenge of the explicit systematization of implicit knowledge that is located in the logic of meanings of individuals and groups.
In the individual dimension, questioning is based on the inverse perspective of the constructivist epistemology theory that locates the specialist with implicit knowledge as an individual who constructs knowledge based on the interaction with external objects. The repeated actions of these objects generate action schemes, as organized wholes based on two basic functional processes, assimilation and accommodation, in order to give way to the evolutionary construction of assimilation of objects into an action scheme and later into a conceptual scheme. The new arrangement of these schemes to the characteristics of the new objects and the corresponding assimilation involves the construction of new structures and the arrangement of the previous ones, as well as of coordination between them. This assimilation entails the subjective appropriation of reality in the individual.
Given the specialist's knowledge subjectivity, we set out to understand and solve the complexity of the knowledge engineering process in different cases associated with different disciplinary specialties.

Methodology

Our proposal consists of designing a prototype version of an Expert System with information based on the specialized knowledge of different faculty members for the Automated Evaluation of Training Activities with Writing in Natural Language in the different subjects and degrees. We are at the design phase of software engineering, specifically defining the requirements for the system's functionality that lies in providing the faculty member with the suggested evaluation of activities based on writing in natural language in an automated manner.

a) The Method: Case Studies

We analyzed a set of case studies in order to experiment with integrating knowledge from specialists from various disciplines that will be housed in the expert system's knowledge base. The disciplines of the case studies correspond to four disciplinary fields and degrees: healthcare administration, business administration, communication, and education.
The case study is conducted in three phases with reiterated interactions for each phase. In this paper, we document the first phase, corresponding to the pilot case to validate and refine the methodology and research pre-notions.
The first advance consists of executing the knowledge engineering process, the preliminary result of which, using the pilot case study, is documented with the formal representation in this first installment. This is the case of an activity in the field of healthcare administration.
The final implications, and third phase of the research, will consist of the integration of the different activities in a single expert system that will document the process of knowledge management during research-teaching with interdisciplinary perspectives and the

complexity of the systems carried out by the team involved in healthcare, business and communication at the International University of La Rioja in Mexico.

b) Constructing a Creative Chaos Context

Although the institutional context is a factor that determines the team's resources and motivation, given the evident technological progress, we must acknowledge that the automation of human processes simulated by artificial intelligence is based on the instrumental capacity to simulate knowledge based on the inferences that determine decision-making. However, the issue lies more in the human awareness of this knowledge and its inferences. If the research problem lies in how to recognize knowledge in order to make it explicit in formal representations of knowledge that "bridge" between diverse subjectivities and disciplinary paradigms that derive in an associated issue, we must ensure that researcher-professors have the essential soft skills for the collaborative work that this process implies. In this sense, we recognize the need to build a context of creative chaos, favoring and motivating the autonomous and consensual participation of each of the members of the collaborative and multidisciplinary team integrating this research experience: the faculty members specialized in the discipline associated with each training activity, on the one hand, and the specialists in the technological field in charge of software engineering, on the other. For this purpose, the action consists of recognizing and fostering the soft skills required by a permanent multidisciplinary research seminar associated with a broader project called IDEA (the acronym in Spanish for research and development in learning-focused education). We have also connected with the technologists of the PLENTAS group (the acronym in Spanish for natural language processing for semi-automated task evaluation).

c) Competences of the professor-specialist for collaborative work in a knowledge engineering process

Considering that the reiterated processes carried out during knowledge engineering are based on "[...] collaborative work [between the faculty member who is an expert with specialized knowledge and the knowledge engineer, this work] requires knowing how to do and knowing how to be in order to communicate, cooperate, and share [...]", as these are indispensable skills to create, evaluate, and communicate collective knowledge during the knowledge management process (Echeverría et al. 2008). We propose these skills as determining observables to identify the basic competences of faculty members immersed in collaborative and multidisciplinary work, as well as their professional and technical knowledge:

1. to make knowledge and inferences conscious and explicit;
2. to build and systematize a meta-knowledge that integrates explicit knowledge;
3. to develop explicit representations.

Results

The initial purpose of our research is located by natural association within the field of artificial intelligence. However, we recognize that educational technology must be integrated into the students' learning needs and the faculty members' teaching skills as well as into the organization's structure and functioning within a dynamic social environment. We, therefore, observe the complexity of developing an expert system prototype for automated evaluation of writing in natural language-based activities from an interdisciplinary perspective. The initial results, described below, are based on this perspective and located within the territory of educational activity.

a) The need to standardize instructional design for training activities

The pilot case study refers to the Healthcare Administration training activity described in Table 1. Although the instructional design was not part of the benchmarking framework, one of the results showed the need to standardize instructional design in the IES training activities.

We note that the wording of the activity lacks the minimum scaffolding and evaluation criteria referred to in instructional design (UV, 2010: 7).

Table 1. Pilot Case Study. Educational Activity

"Focusing on the context and situation of the unit, service or center in which you work, develop the following:

Set forth a matrix based on the SWOT analysis methodology regarding the capacity and orientation to conduct translational research projects at your service, center or unit.

Aspects to consider:

This matrix is a double-entry table (with 4 boxes). Think about each of the criteria and dimensions and how you would get the information to represent it in the table. Establish the contents of each of the 4 boxes in the table".

Source: prepared by the author

The lack of support elements, such as mind mapping, questionnaires or examples, among others, is a specific problem scaffolding faces. This shortcoming derives in the evaluation activity that should include "[...] explicit knowledge, strategies, and mental processes that come into play to solve the task, as well as the expected skills, attitudes, and values and carrying out performance evaluation, [analysis criteria] are required in order to describe the output to be examined, such as oral or written answers, the choice of a distractor in a multiple choice test, implementation of one task or a set of tasks to be carried out" (UV, 2010: 8 & UV, w/d).

The absence of the aforementioned analysis criteria encourages "infinite" breadth, naturally associated with human language, in the student's answers, and hinders the faculty member's evaluation activity, mainly because they lack clear criteria to recognize what they will be grading and therefore make it difficult to give a grade. To make things worse, it hinders the possibility of issuing concise feedback and gives way to the possibility of repeating generic comments that are not directly related to the particular achievement of a student's specific achievements, performance objectives, or the specific output that should be generated. Both specific and individual criteria should serve to provide feedback to students about their progress and allow them to correct or improve their problem-solving strategies during a training activity that this pilot case study proposal would expect.

Consequently, for the purpose of designing the expert system prototype, the first interaction between analysis and interpretation of the pilot study's knowledge engineering process, in which a specialized faculty member was asked to explain the process they use to make the decision about the grade they give their students for the activity. The specialist's response was immediate, which demonstrates the degree of subjective appropriation of implicit knowledge. The result of this first interaction is described in Table 2.

Table 2. Pilot Case Study. Knowledge Engineering. 1st Analysis and Interpretation Process: Activity Assessment Inferences.

1. To know the basic concepts applied to the provision of healthcare services.
2. To understand how the student interprets the laws, norms and clinical guidelines in order to establish the necessary processes for the provision of healthcare services.
3. To analyze the relationships that the student establishes between the concepts according to the context of the healthcare units in operation.
4. To integrate the knowledge acquired through their professional and academic education to validate that the student has applied the knowledge acquired during the development of the sessions to find a solution to the problem set forth.
5. To discriminate ideas and value theoretical application based on reasoned arguments using the evidence available.

Source: prepared by the author

Derived from this first interaction, we proposed standards for training activities to incorporate support elements for the student and thus meet the scaffolding criteria of instructional design. These norms consist of incorporating the notions of "Case Study" and "Guide for Practical Case Study Development" as one of the different forms of training activities among professor-specialists with expertise.
Following the guidelines, the following sections were integrated as indispensable requirements: purpose, learning objective, methodology, structure of deliverables, and evaluation criteria associated with the learning objective, as well as questionnaires and tables as support resources, as well as data systematization and basic information. The methodology section requires the student to perform the activity, as shown in Table 3 and simultaneously requires the faculty member to structure and systematize their implicit knowledge, as well as transform it into explicit knowledge through some kind of formal representation, matrixes, mind maps, diagrams or questionnaires, to mention a few examples.

Table 3. Instructional Design Standardization in Activity Guides.
Pilot Case Study: Educational Activity for Healthcare Administration

I. CONTENTS

Purpose of Activity
Learning Objective

1. Methodology to develop the activity [specify type of activity: practical case, forum, among others]
2. Structure of the Deliverables
3. Evaluation Criteria

4. Evaluation Headings

b) The need for IT governance

The incorporation of standards for instructional design and the corresponding formal representation of explicit knowledge resulted in a significant advance in the interaction process between the professor-specialist and the knowledge engineer because this formal representation of scaffolding resources adopts a fourfold purpose. It serves as a guide for the student working on the training activity, establishing clear analysis and evaluation criteria for the faculty member, as well as knowledge objects for the systematization performed by the knowledge engineer and even used as graphical user interfaces implemented by the computer scientist for software development.
We proceeded in this direction to establish the rules for translating this instrument into formal representations, which would allow the "translation" of the specialized knowledge into the specialized field of knowledge engineering and the resulting software engineering that is the basis for the design of the expert system, specifically for the knowledge base and the inference engine.
The standard stipulated the use of flowcharts and tree diagrams associated with a mathematical language, mainly Boolean logic, as formal representations. The results in this pilot case study are documented in Table 4, which explains the objects and their corresponding knowledge domains.

Table 4. Pilot Case Study. Design of an Expert System Prototype for the Evaluation of Training Activities based on Natural Language. Objects and domains of knowledge

1 **[FACTS AND RULES] objects and domains of inference**
2 **[INFERENCES] DOMAINS OF KNOWLEDGE OBJECTS [FACTS AND RULES]**
A. Description of the Organization (Context)
1.Classification according to the healthcare model; 2. Healthcare level; 3.Geographic location
3 **DOMAINS OF THE EVALUATION CRITERIA [INFERENCES]**
a. Activity Score
{if a.1>=0.7 then (a.2*0.3)+(a.3*0.7); if a.1<=0.7 then (a.2*0.3)+(a.3*0.7)-2}
a.1. Context Matrix Score {a.1= a.1.1+….}
a.1.1 Healthcare Model Score
{if A.1=A.1.1 or A.1=A.1.2 or A.1=A.1.3 then a.1.1=0.25 otherwise a.1.1=0 }

Source: prepared by the author

Once the rules of our IT governance have been applied, part of the flowchart and the tree diagram are presented as a sample, being the formal representations of the explicit knowledge of the relationship [rules] between knowledge objects [or facts], both basic to apply the automated evaluation criteria [Inferences] of the training activities based on writing in natural language.
With this knowledge management exercise, during which implicit knowledge of the specialist faculty member is translated into explicit knowledge, the usefulness of formal knowledge representations is demonstrated since both the "infinite" breadth and the natural breadth of human language are reduced in order to form a language and conceptual model that is visually, semantically and syntactically common to all interested parties.

In turn, the norms of instructional design and IT governance lay the foundation for the context of creative chaos that enables knowledge management characterized by dialogue and interaction during collaborative work, even among specialists from different disciplines.
Furthermore, this knowledge management model, as well as the prototype of the expert system, understood as information- and knowledge-based resources, contribute to the organization's intellectual capital as they apply to organizational evaluation and performance from an administrative perspective.

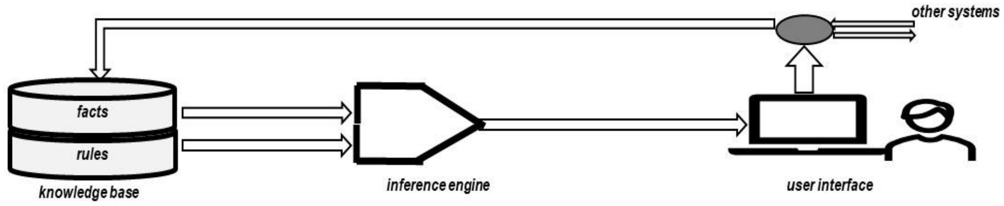
c) The need to develop competences for multidisciplinary collaborative work

Although we achieved significant results and progress, it is evident that the design process and subsequent development of this type of educational technology entailed the need to train those involved in various competences: i.e., faculty members with specialist knowledge, on the one hand, and, technologists responsible for technical development, on the other. It is important to distinguish soft skills for dialogue, communication and collaborative work from a multidisciplinary perspective.

d) Design of an expert system prototype

The final result of this pilot study is shown in Figure 2, in which the explicit knowledge of the specialists involved is integrated into an organized whole, focusing on the first phase of software engineering, corresponding to the design of an expert system prototype for the automated evaluation of educational activities based on the recognition of writing in natural language.
This progress shows the usefulness of our methodology to promote collaborative and multidisciplinary work for an understanding of the system as well as the value of the formal representation of what will be the system's architecture and functionality since it makes visible the explicit knowledge of the faculty member's subjectivity.

Figure 2
Prototype of an Expert System for Automated Evaluation of Natural Language Based Activities
Software Engineering, Design Phase



Dominio de los Objetos de aprendizaje [facts and rules]	***Dominio de los Criterios de Evaluación [inferencias]***	***Matriz de contexto para el andamiaje [interface de captura]***
*A. Descripción de la Organización **(Contexto)*** ***A.1.**Clasificación según el **Modelo de atención a la salud*** *{ A.1.1: Público, A.1.2 Seguridad Social, A.1.3 Privado* *A.2. Nivel de atención a la salud* *{A2.1 primero or prevención or (primero*	*a. Calificación:* *{si a.1>=0.7 entonces (a.2*0.3)+(a.3*0.7);* *si a.1<=0.7 entonces (a.2*0.3)+(a.3*0.7)-2}* *a.1. Calificación Contexto*	

and prevención), segundo or curación or (segundo and curación), tercero or rehabilitación or (tercero and rehabilitación)}	*{Si A.1=A.1.1 or A.1=A.1.2 or A.1=A.1.3 entonces a.1.1=0.25 …. Entonces a.1=a.1.1+a.1.2+…}*	

Source: prepared by the author

Conclusion

The result of this pilot case study has demonstrated the usefulness of the proposed methodology and leads us to solve the organizational transformation needs as the first essential step to proceed with the development of the educational technology that we propose as the final scope of the broad research project.
In the context of the complementary findings and lessons learned, we can identify three fundamental aspects that lead us to incorporate interdisciplinary perspectives and the complexity of organizational systems into ongoing research.

1. Educational Technology, like that of Expert Systems, is a vector of organizational complexity [IES], which is integrated into the vectors' Organization [teaching structure and functioning] and End-User satisfaction [learning] objectives.
2. Educational technology development specialists are part of the multidisciplinary team of the IES and should be aware of the organizational objectives and participate in collaborative work.
3. The process and the resulting knowledge- and information-based output of multidisciplinary collaborative work translate into knowledge management and intellectual capital for IES.

References

Bádaro, Sebastián; Ibañez, Leonardo & Agüero, Martín. (2013). Sistemas expertos: fundamentos, metodologías y aplicaciones. In Ciencia y Tecnología.ISSN 1850-0870, ISSN-e 2344-9217, Nº. 13, 2013, págs. 349-364

Echeverria, B. (COORD.) Isus, S; Sarasola L. & Blazquez, B. (1996): Orientación profesional. Barcelona: Universitat Oberta de Catalunya.

Universidad Veracruzana. (w/d) 3. Componentes del diseño instruccional. In Proyecto Aula. Estrategia para la innovación de la práctica docente [Internet]. Available at: http://www.acet-latinoamerica.net/aula_taller/index.htm

Universidad Veracruzana. (2010) Pasos para el diseño de tareas/proyectos de aprendizaje para el desarrollo de competencias y pensamiento complejo. [Internet]. Available at: https://www.uv.mx/personal/joacosta/files/2010/07/4-Pasos-D.I.1.pdf

Valiente A, Galdeano C. (2009) La enseñanza por competencias. *Educ Química* [Internet]. 20(3):369–72. Available at: http://www.scielo.org.mx/pdf/eq/v20n3/v20n3a10.pdf

WHO. What is a health system? (2020) [Internet]. Features. Ask the expert. 2005 [cited June 23, 2020]. Available at: https://www.who.int/features/qa/28/es/