Techno Neuro Pedagogy System: *an instructional design methodology for customized online courses*

(*Virtual Customized Environment Learning*)

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***Abstract*— The Techno Neuro Pedagogy System (TNPS) is a systemic process with interrelated activities that allows you to create environments that facilitate the mediation processes on knowledge construction in virtual environments. Similarly to life cycle in software development, it consists of eight phases: analysis, design, development, testing, implementation, documentation, maintenance, and evaluation. TNPS incorporates a life cycle model of incremental and iterative software development that is an essential part of software engineering. TNPS integrates *Education*, *Neuroscience* and *Technological* dimensions, which facilitate the development of cognitive profile of student thinking in order to customize his/her learning activities. In our experiments, an increment in the weights of thinking style used by the students on a Structured Programming course was observed.**

Keywords*— Instructional design; Neuropedagogy; customized learning; Customized Virtual Environment Learning.

I. Introduction

Learning occurs from a combination of multiple factors or preconditions to be applied including: activation of prior knowledge, personalization of learning activities, various multimedia materials, cognitive skills, attitudes, iteration mechanisms, interest, motivation, evaluation and technologies. If teaching and learning planning is not made from an instructional design model is almost impossible to consider these factors [1]. From this context [2] Instructional Techno System Neuro-Pedagogical (TNPS) is presented as a systemic process with interrelated and customized learning style and way of thinking for student activities. TNPS allows to create environments that facilitate the mediation processes for cooperative knowledge construction in virtual environments.

The objective for TNPS is to facilitate students' cognitive development through out virtual learning environments based on cooperative work in learning communities mediated by information technology, project learning and customized learning activities based on an ontological model [3].

II. Theorical Framework

A. Instructional Design

Instructional design (ID) is responsible for the planning, preparation and design of appropriate resources and learning environments [4]. ID seeks to define optimal methods of instruction that generate changes in student knowledge and skills [5]. ID also integrate stages for the development, implementation, evaluation, and maintenance of situations that facilitate learning at different levels of complexity [6]. Finally, ID facilitates the instructional environment creation with materials that will help students to develop their abilities on the effective performance of certain tasks [7].

More comprehensively, it is a systematic instructional planning including needs analysis, development, evaluation, implementation and maintenance of materials and programs [8]. Finally, Fields & Foxon ([8] pp. 181) propose a "*…systematic instructional planning including needs assessment, development, evaluation, implementation and maintenance of materials and programs…*"

For purposes of this paper, the instructional design will be understood as a systematic planning that involves the analysis, specification development, implementation, maintenance and learning environments evaluation, educational resources and all those activities that facilitate student learning.

B. Instructional Design Models

Based on the techno-instructional design proposed by Coll et al., [9] which considers the technological and pedagogical dimensions, an analysis is performed on the technological, educational and Neuroscientific dimensions: 7 instructional design models are considered: 1) ADDIE (AD) [10]; 2) ASSURE (AS) [11]; 3) Dick and Carey (DC) [12]; 4) Gagne

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978-1-4673-9795-7/15 $31.00 © 2015 IEEE
DOI 10.1109/CSCI.2015.166

and Briggs (GB) [13]; 5) Jonassen (JO) [14]; 6) 4C / ID (4C) [15]; and 7) rapid prototyping (RP) [16].

In the Table 1, seven instructional models and TNPS are compared under a technological dimension. The comparison shows that the model JO and PR, are models that integrate and incorporate more technological components of digital content production, communication and collaboration tools. While TNPS incorporates all the technological features mentioned in the analysis.

TABLE I. TECHNOLOGICAL DIMENSION

Characteristics	AD	AS	DC	GB	JO	4C	PR	TNPS
Sistemic Approach	✔	-	✔	✔	-	-	-	✔
Learning Enviroment mediated by ICT	✔	-	-	-	✔	-	✔	✔
Content or Material Production	✔	✔	✔	✔	✔	✔	✔	✔
Cognitives Tools	-	✔	-	-	✔	-	-	✔
Conversation y Collaboration Tools	-	-	-	-	✔	-	-	✔
Prototypes Development	-	-	-	-	-	-	✔	✔

Table II an analysis pedagogical dimension is integrated, that shows AD [10] and GB [13] pedagogical models incorporate four components out of 6 components considered in TNPS model. AD integrated assessment process that is essential for continuous improvement. DC model [12] and AD consider dividing the content into units or lessons. However the analyzed models leave out important pedagogical considerations (as ongoing evaluation and improvement process) that are integrated into the TNPS.

TABLE II. PEDAGOGICAL DIMENSION

Characteristic	AD	AS	DC	GB	JO	4C	PR	TNPS
Life Cycle (phases)	4	6	10	4	6	2	6	8
Field Tests	-	-	-	✔	-	-	✔	✔
Units or lessons Division	✔	-	-	✔	-	-	-	✔
Process Evaluacion	✔	-	-	-	-	-	-	✔
Formative Evaluacion	✔	-	✔	✔	-	-	-	✔
Summative Evaluacion	✔	-	✔	✔	-	-	-	✔
Professor Skills	-	-	-	✔	-	-	-	✔
Learning Scenarios	-	✔	-	-	-	-	-	✔
Cases, Problems, Projects	-	-	-	-	✔	-	-	✔
Social Context	-	-	-	-	✔	-	-	✔

Finally, regarding the Neurosciences dimension (Neuropedagogical), 4 items are analyzed (as shown in Table III). It is noted that only the AS [11] and DC models are considering the student profile, and it serves for learning diversity. Moreover, the model of AD includes learning activities. TNPS includes the customization of learning activities and cooperative work from Ned Herrmann's total brain neuroscientific theory [17].

The pedagogical approach for JO and AS models are student-centered, while DC has behavioral approach, JO has constructivist approach, 4C is focusing on develops the critical thinking and finally, TNPS model has constructivist student-centered approach.

TABLE III. NEUROSCIENTIFIC DIMENSION /NEUROPEDAGOGICAL

Característica	AD	AS	DC	GB	JO	4C	PR	TNPS
Student Characteristics	-	✔	✔	-	-	-	-	✔
Focusing on Diversity	-	✔	✔	-	-	-	-	✔
Learning Activities	✔	-	-	-	-	-	-	✔
Neuroscientific Theory	-	-	-	-	-	-	-	✔

The comparative tables I, II and III show that TNPS integrates all the characteristics analyzed in all three dimensions, which make it a complete instructional model that pursuit to meet students' learning diversity through out virtual learning environments.

Based on this context, the Techno-Neuropedagogical System also integrates neuroscience dimension. TNPS has the objective to address teaching and learning processes by combining neuroscience with other disciplines such as graphic design, multimedia, systems engineering and information technology (which are part of neuropedagogy) to design and to deliver different appropriate solutions to a diverse learning situations. (Neuropedagogy).

III. METHODOLOGY

The methodology contemplated to carry out 5 experiments in which the TNPS is applied as instructional design model. The experiments were carried out during the 4 quarters included in the period of Spring, 2012 to Fall, 2013.

The experiments were performed in the Structured Programming course with the paticipation of 752 students from 10 Engineering bachelor programs at the Autonomus Metropolitan University AZCAPOTZALCO, in Mexico.

We applied TNPS and started from the starting phase in which a prototype that serves as technical support for course delivery was built. Educational resources for self-constructed, learning activities are customized, and asynchronous communication mechanisms were established between the students conformed into learning community. In each iteration proposed by the TNPS cycle, instructors identify areas of opportunity to generate lessons to be learned and all corresponding adjustments to enter into a cycle of continuous improvement are made. Students thinking styles scores from start to end of the course were recorded.

IV. TECHNO NEURO PEDAGOGY SYSTEM

The Techno Neuro Pedagogy System (TNPS) is an instructional design characterized by having systemic approach that integrates features of instructional design as ADDIE, ASSURE, Gagne and Briggs, Jonassen and fast prototyping, as well as ICT integration [18]. Further proposes the use of neuro science brain theory is to determine the overall student's thinking style: a) logical style, characterized by being analytical, mathematical and based on facts, it is qualitative and critical, focuses on reasoning; b) processes style, planned, controlled, organized, sequential and detailed, very process oriented; c) relational style, more interpersonal, empathetic, collaborative, humanistic, emotional and sensory; d) creative style, imaginative, takes risks, holistic and comprehensive. It is responsible for integrating, while synthesizing, artistic, spatial, visual and metaphorical. [17]

The stages and activities that integrates TNPS were:

A. *ANALYSIS. This stage will describe the educational problems to be solved*

- To determine the characteristics of the course: objectives, content, duration, etc.
- To know students' learning profile (by applying instruments from Neuroscience theories, specifically from Herrmann' Brain Total Theory).
- To identify the technological infrastructure that is available.

B. *DESIGN. Solution strategies for the educational problems is addressed.*

- To set learning goals.
- To select the exercises, case studies, problems and projects needed for the development of the course.
- To set the types of learning activities that should be developed.
- To develop educational resources for learning content.
- To define evaluation tools.
- To select the technological tools that will allows adequate communication and collaboration process.

C. *DEVELOPMENT. To built all what been established in Design Stage.*

- To develop the tutorial guide. Its objective is to define the learning paths that students shall be followed.
- Development of all educational resources needed.
- Development of learning activities especifically designed for student's thinking style. It was necessary to clarify whether if activities were either individual or cooperative nature.
- Establishment of assessment tools. These tools can be written, oral, practical exams. It should indicate whether if the product and process, or both, are evaluated.
- The selected collaborative prototype are integrated and technological tools user's manual is produced.
- If it is needed, you may need to return to previous stages to collect missing information or to design changes on detected new needs or omissions.

D. *TESTS. In this stage, tests are carry out in order to check the adequate performance of the virtual learning environment.*

- To assess collaboration activities by using the assessment tools that are been selected in the *Design* stage.
- To perform the integrated testing of the selected technological tools.
- To approve the virtual learning environment.
- Depending of the tests results, it is very likely to be necessary to return to some stages to redesign, and to adjust the development and retest again.

E. *IMPLEMENTATION. The prototype that was developed in the Development Dtage and approved at the testing stage will be implemented in site.*

- The replication of the collaboratory prototype will be used by students according to the programmed groups.
- Teacher's training is responsible for guiding the teaching and learning process.
- Student are enrolled under the mode of Cooperative Learning System (CLS) groups.
- The Induction session will lead the teaching and learning process.
- Application of tools for determining students' learning and thinking styles.
- Students are registered in the virtual learning environment (collaboration).
- Creation of Learning Communities.

F. *DOCUMENTATION. Registration of learned lessons will allows you to start a mechanism of continuous improvement and facilitate future modifications that might be made in the maintenance stage.*

- The record of learned lessons (comments and feedback received by teachers and facilitators).
- The analysis and design documentation is a document containing description of the problem, the strategy and the technology used.
- User Manual describes how to use the technologies and tools designed for the course.

G. *MAINTENANCE. Includes all adecuations needed for the prototype.*

- To maintain a structure that facilitates verification, validation and update, as well starting the cycle of continuous improvement.

- All adjustments needed to meet the identified requirements in the learned lessons are made.

H. EVALUATION. The objective is to assess the relevance, effectiveness and efficiency of instructional design.

- Evaluation of the virtual learning environment and integrated technological tools.
- Evaluation learning resources.
- Evaluation of customized learning activities.
- Evaluation of student's learning assessment tools.
- Evaluation of implemented communication and collaboration strategies.
- The results evaluation completes the new requirements to start the next TNPS cycle iteration. (ver Fig. 1 and Fig. 2).

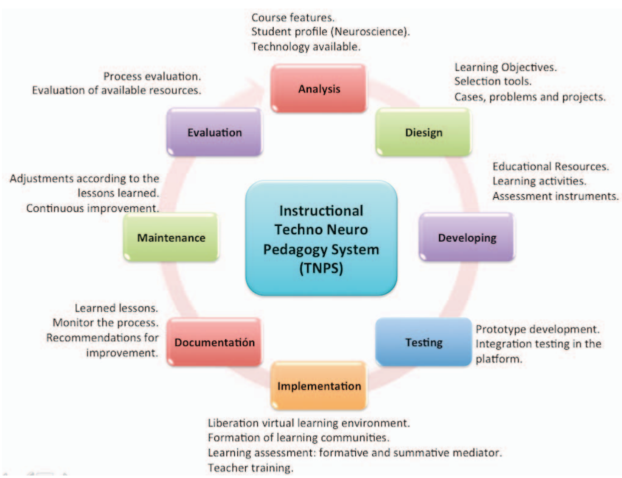

Fig. 1. Techno Neuro Pedagogy System (TNPS).

For the case of TNPS instructional model, incorporating the iterative-incremental process allows the possibility to address the problem in the short, medium and long term. Teacher and facilitators are more involved and focused on detecting possible areas of opportunity that can be improved, entering a cycle of continuous improvement. Also is reducing the costs because a great investment for the initial implementation is required, the possibility of success, the quality and robustness of the solution is tapering at each iteration.

The iterative-incremental process includes three phases: initialization, iteration and project control list (in our case, learned lessons).

V. APPLICATION CASE

The field work was carried out with a total of 752 engineering students of Structured Programming course.

To determine the student learning profile their own learning style is considered (visual, auditory and kinesthetic) based on Neuro Linguistics VARK programming theory proposed by Fleming [19], and its thinking style from Total brain neuroscientific theory proposed by Ned Herrmann, which proposes the division of the brain into four quadrants [17].

The course organization is established from a basic set of learning activities related to each of the four quadrants Herrmann's model, as shown in Figure 3.

The on-line collaborative work was done through out the use of 4 forums, one for each style of thinking: 1) thematic forum for students with "software" dominant quadrant; 2) organizational forum for students with "processes" dominant quadrant; 3) discussion forum for students with "relational" dominant quadrant; and 4) creative forum for students with "creative" dominant quadrant.

Course's syllabus were developed based on thinking style that students are expected to develop during the course.

The implementation of learning activities associated with course development section shown in Figure 4.

In addition, the learning styles diversity is attended through different educational resources[20][21]; animations, audio and interactivity are included. Based on the proposal of Ali *et al.*,[22]. Several educational resources such as multimedia presentations, video lessons (with approximate 1 hour) and finally, knowledge capsules (short videos of 5-7 minutes, focusing on the explanation of a particular topic) were designed.

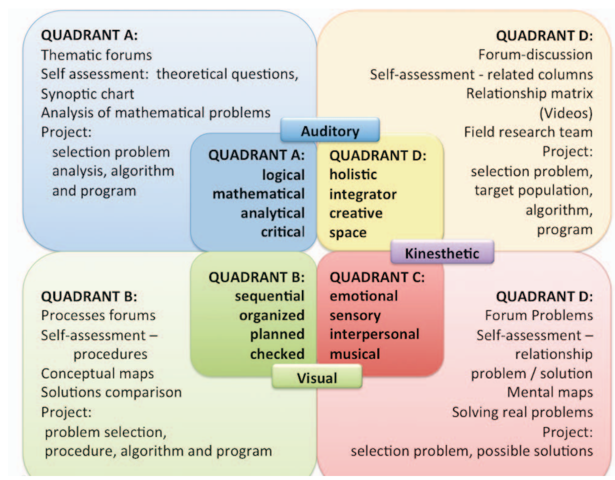

Fig. 2. Customized Learning Activities.

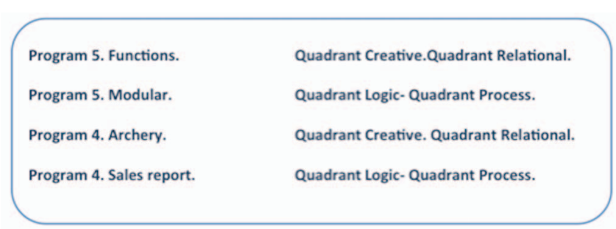

Fig. 3. Courses implementation matching keeping student's thought style.

Finally, all evaluation tools considered for UEA Structured Programming course are listed [23]:

- *On-Line self-evaluations*. This evaluation tool allows students to self-assess their learning before submitting their written exam.
- *Face-to-face assessments. 3 reviews distributed at 4th, 7th and 11th weeks. These assessments allowed validation of student learning and to identify recurring errors were made.*
- *Practices assessment (final projects presentation). This evaluation tool is performed at the end of the quarter, which allowed assessing problem solving and decision making student' skills.*

From Neuropedagogical specifications a computer system based on an ontological model of student learning profile [3] was developed in order to generate recommendations for customized learning activities, and then, a cloud computing solution [24] is implemented. This solution integrates a customized virtual PVEL learning environment [25].

VI. Results

An important contribution of use of TNPS as an orderly and systematic building a customized virtual learning environment that includes an ontological model that makes recommendations for customized learning activities [25].

By applying the methodology of TNPS during Structured Programming for 4 consecutive quarters it shows that during the initialization phase, the weighting of thinking style during the quarter 12-Q does not significally increased. However, when the iterations, proposed by TNPS interative-incremental methodology were applied, prototype details was refined causing a positive impact on the weights in the successive quarters, as shown in Figure 5.

Given the course characteristics, the student is expected to develop skills associated with the thinking style: logical and creative processes. It is observed that highest weights are given in thinking process style, followed by the use of creative logical, and relational style at the end (see Fig. 5). So the initial objectives for the course were meet.

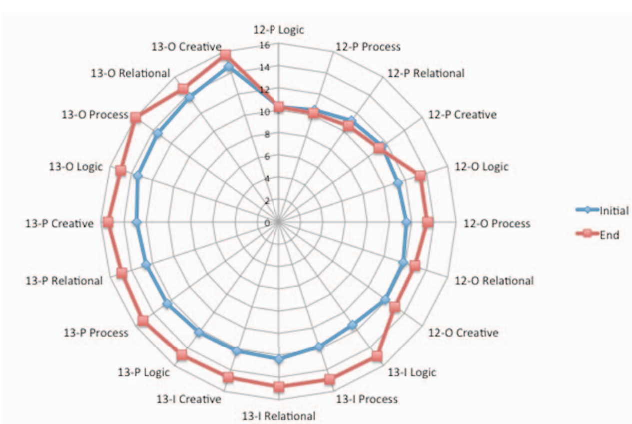

Fig. 4. Average score of students thinking styles by quarter.

VII. Conclusions

The TNPS is an instructional system design that considers three dimensions: (a) teaching, which is dealing with the customization of learning activities and with the educational resources development for self-study and the creation of learning communities. (b) Neuroscience, Ned Herrmann' a total brain theory is applied. And (c) technology, to build the customized Virtual Learning Enviroments integrated under a ontological model for customizing learning activities and implemented in Cloud Computing.

The results show the initial prototype, it was initial approach, required adjustments that were carried out on the following 4 iterations. In each iteration, learning activities, courses and learning communities composition, which reflected on the weights of increments in students' thinking style, were adapted.

Based on the obtained results from findings, it can be concluded the application of TNPS as a model of instructional design in a course whereas information technology was used has increased the weights of thinking styles over those expected to be developed by the student during the Programming structured course.

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