# Strategic Learning Meta-model (SLM): Architecture of the Regulation Model (RM) Based on the Cloud Computing

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**Abstract.** In this work we present the architecture of the Regulation Model (RM) as a third layer of the Strategic Learning Meta-model (SLM). The SLM conforms a personalized virtual learning environment that consists of three layers: *The Intelligent Layer* that includes a virtual learning environment, *The Infrastructure Layer* based on the Cloud Computing, and *The Regulation Model*. The RM is based on the Ned Herman's Whole Brain Theory that divides the brain into four quadrants associated to thinking styles. The RM considers six components: (i) The teacher; (ii) The learner or student; (iii) The process facilitator; (iv) The emotional facilitator; (v) The didactic material; and (vi) The learning activities. Our experiments implement the RM and consider five test cases. The experimental results show an improvement in the final scoring of *creative*, *logic* and *process* thinking styles of undergraduate students.

**Keywords:** Regulation Model · Personalized virtual learning environment · Cloud computing · Strategic learning · Virtual learning environment

## 1 Introduction

In the context of Virtual Learning Environments (VLE), the integration of a Regulation Model (RM) is relevant once it facilitates the feedback mechanism and the learning monitoring of students. This is based on the hypothesis that the involvement of the dominant thinking style of each student in the RM facilitates the development of personalized activities and allows to define a relationship between the students and the teacher, and opens the possibility to develop cognitive abilities of the students to promote the *strategic learning*.

In this paper we present the architecture of the Regulation Model (RM) as a third layer of the Strategic Learning Meta-model (SLM). The SLM conforms a personalized virtual learning environment that consists of three layers: *the intelligent layer* that includes a virtual learning environment, *the infrastructure layer* based on Cloud

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Computing, and *the regulation model*. The RM is based on the Ned Herman's Whole Brain Theory, where the brain is divided into four quadrants (thinking styles). The RM considers six components: (i) The teacher; (ii) The learner or student; (iii) The process facilitator; (iv) The emotional facilitator; (v) The didactic material; and (vi) The learning activities. Our experiments implement the RM and consider five test cases with undergraduate students enrolled in language programming courses. The experimental results show an improvement in the final scoring of creative, logic and process thinking styles of undergraduate students.

The paper is organized as follows: In Sect. 2 we present a conceptual framework that support the development of SLM, in Sect. 3 we present our methodology that considers the design of the architecture for the Regulation Model as the top layer of the SLM. In Sect. 5 we present cases of study that describe the implementation of the RM in language programming courses for undergraduate students. In Sect. 6 we present experimental results, and finally, in Sect. 7 we present our conclusions and comment about future work.

## 2 Conceptual Framework

In recent years, the research on didactic models have become an important factor for the success of online courses. For example, Mödritscher, et al. [1] applied *learning curves* to measure the error rates when the users interact with educational adaptive systems, and their results show that the learning error rates follow a Power Law Distribution. The use of learning curves to evaluate the teaching model is valuable because of the feedback given to teachers and educational content generators for online courses. Authors such as Mödritscher, et al. [1]; Mizoguchi, et al. [2]; Salaheddin Odeh, Qaraeen [3]; Tedman, et al. [4] and Samarakou, et al. [5], have focused their researches on issues associated with the assessment of teaching models [1] and have proposed methods and techniques to evaluate e-Learning environments [3].

### 2.1 The Conceptualization of the Learning Assessment

Knowles et al., identify learning as: (a) product, the final result of a learning experience; (b) process, composed by all the events that it happens on learning experience in the course; and finally, (c) function, that enhances critical aspects such as motivation, retention and transfer that generates behavioral changes in human learning [6]. Furthermore, the learning is also conceptualized as the participation in activities that allow sharing knowledge. Peñalosa [7] proposed the Theory of Situated Action and the Theory of Situated Cognition focused on the subject participation to achieve learning.

Also, Peñalosa [7] makes a comparison between the three learning conceptualizations that he calls metaphors: (1) acquisition, (2) construction, and (3) participation. Peñalosa, concludes that the acquisition is *objectivist*, where the student has a passive role. On the other hand, the metaphor of the construction is *constructivist*, *psychogenetic* and *cognitive*; where the student plays an active role and in this case Peñalosa interprets the knowledge as the result of an interaction. The metaphor of the *participation* has a social and constructivist orientation where the student is active and is involved in cultural practices also it assumes socialization processes, mediation, and cultural activities.

Peñalosa believes that learning is an *appropriation of the knowledge* that gives place to the interaction between students (subjects) and the didactic material (objects) of interest that is adapted to their needs [7].

## 2.2 Paradigm Shift in Learning Assessment

Some authors such as Lafourcade, Carreño, De Miguel-Diaz and Diaz-Barriga [8] agree that the evaluation is a stage of the educational process that aims to evaluate student's achievements systematically. Ryan et al. [8] introduces a *student self-regulation*, where he or she becomes aware of his or her learning.

In one hand, according to Hoffmann [9], the whole process should seek the student's observation individually, to analyze and understand his learning and thinking styles. Additionally to get data and to define strategies to foster their learning. This approach makes clear how important is the personalization in order to improve the learning process.

On the other hand, when the evaluation comes from online learning it requires a sensible strategy and a valid performance evaluation.

Peñalosa recommend three phases in the learning evaluation: (a) the initial evaluation, at the beginning of the course to know the knowledge level and the abilities of the students; (b) the formative evaluation, along the docent activity, and for large and continuous periods, and (c) the final evaluation, at the end of the course. The importance of the continuous evaluation of the learning resides in the feedback given to the student [10].

Peñalosa presents a classification of the kind of evaluations for online education: (a) automatic evaluation, evaluation when concluding; (b) elaborative, where the student generate a deliverable product, and (c) collaborative, where the student is evaluated from the collaborative work. Besides, this assessment considers that the interactivity plays a fundamental role for the student feedback to produce a scaffolding effect in the student's performance [10].

## 2.3 Mediator Evaluation

From the Hoffmann's point of view, the mediator evaluation process seeks to observe students individually in order to analyze and to understand their learning differences. Its objective is to define strategies that may improve students' learning [9].

Therefore, the evaluation is a process that involves three stages: *to observe, to analyze and to offer* better opportunities for the student. When the teacher understands the learning and thinking techniques of their students, he or she modifies his o her pedagogical behavior, so the students may increase intellectually their outcomes.

The principles of the mediator evaluation are: (a) The ethical principle of valuing students' differences*: all the students always learn*; (b) The pedagogical principle of the teaching-researching action: *the students learn in a better way with good learning* *opportunities;* and (c) The dialectic principles of temporariness and complementary: significant learnings becomes lifelong learning [9].

### 2.4 Neuroscience Whole Brain Theory

The regulation model is based on the *Neuroscience Whole Brain Theory* proposed by Ned Herrmann. This author presents the integration of Sperry's brain hemispheres, and the MacLean' triune brain theories. Herrmann proposes that the brain is conceptually divided into four quadrants that determines dominant thinking styles.

Ned Herrmann, presents the problem of the cerebral dominance based on two theories, the *Cerebral Hemispherical Theory* of Sperry and the *Triune Brain Theory* of MacLean, as well as his own experimental results with biological feedback equipment (bio-feedback) and electroencephalography [11].

Herrmann builds a metaphorical model of the brain by proposing its division into four quadrants: two upper cortical quadrants and two lower limbic quadrants. Each quadrant is associated to a particular style of thinking, creating and learning. Each thinking process might be described in terms of preferences or quadrant dominance.

The whole brain model considers the diversity of all possible preferences and behaviors as the response to several learning situations, both individual and organizational, and determines the problem solving and the decision making strategies. Hence, the quadrants depend of genetic predispositions, and are modelled by the social learning and the cultural influence, so the individuals develop their preferences throughout life.

One of the most important aspects of the Herrmann's model is the proposition that the creative process requires a full activation of the brain. All its potential must be activated as a set of multiple interactions, and all forms of information processing are possible and they are associated to genetic predispositions basis, the environment and the culture [12].

The model identifies how the individuals perceive, learn, solve a problem and make decisions. Each of the cerebral quadrants have different functions, as is shown in Table 1.

**Table 1.** Characteristics of cerebral quadrants.

| Cerebral quadrant | Location | Characteristics |
|---|---|---|
| A | Left upper lobule | Logical thinking style: analytic, mathematic, based on concrete facts, qualitative and critic, and focused on the reasoning |
| B | Left lower lobule | Process thinking style: A controlled, organized, sequential, detailed, and process oriented |
| C | Right lower lobule | Relational thinking style: emotional and sensorial (musical), symbolic, from interpersonal to spiritual |
| D | Right upper lobule | Creative thinking style: Theoretical, conceptual, holistic and global. Integrates, synthetize, artistic, spatial, visual, metaphoric, and creative |

## 2.5 Strategic Learning Metamodel

In this section, we propose an architecture of the reactive layer of the Strategic Learning Metamodel (SLM) [13]. SLM integrates the principles of the Mediator Evaluation, the learning activities customization, the assessment, the supervised and personalized attention, as well as the collaborative work in the learning communities that aims to provide the reinforcement of abilities for the workgroup, the leadership and the trading, among others. The SLM optimizes the physical and human resources from an institution, through the reduction of the desertion and aiming to increase the students scoring. In Fig. 1, we show the meta-model that includes the infrastructure layer, the intelligent layer and the reactive layer.

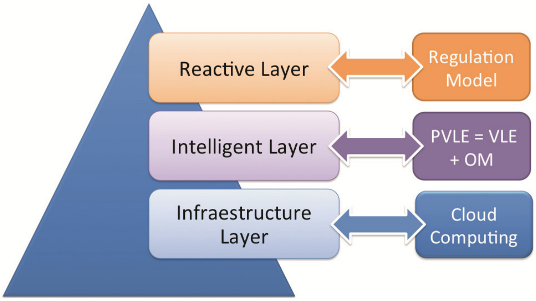


**Fig. 1.** Strategic Learning Metamodel (SLM)

The infrastructure layer is based on the cloud computing [14]; the Personalized Virtual Learning Environment (PVLE = VLE + OM) that merges a Virtual Learning Environment (VLE) with the customization of learning activities supported by an ontological model [15] (OM); and the Regulation Model that is focused in the assessment, monitoring, feedback and motivation of the students.

In Fig. 2, we show the general architecture that includes the technological aspects and the psycho-pedagogical approach of the SLM [13]. Also, in Fig. 2, we identify the VLE component supported by: the LMS (Sakai), the Application Server (Tomcat), and the virtualization infrastructure (VmWare).

The LMS requires an Application Server that uses a database (PostgreSQL, MySQL), a framework (Hibernate) for Object-Resource mapping, a Business Logic Server (Spring), a Model-View-Controller (Struts) and the file storage system that depends of the operating system.

Also, in Fig. 2, we identify the inference motor (ontologies) and the virtualization infrastructure. The inference motor includes the Apache web server, and the Protégé framework. Both, the application server and the inference motor are supported by the virtualization infrastructure.

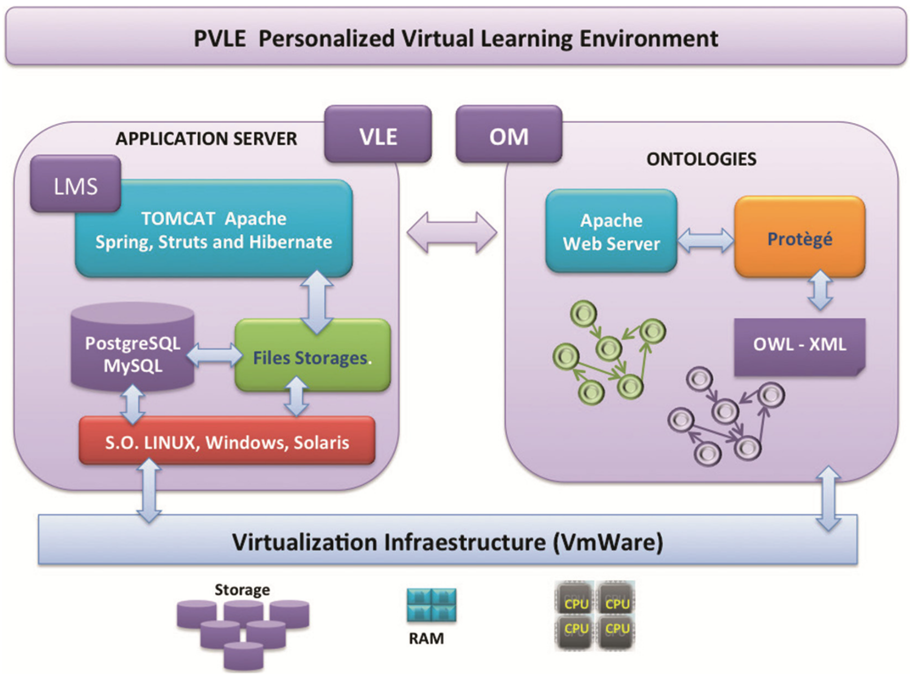


**Fig. 2.** Architecture of the Strategic Learning Metamodel.

## 3 Methodology

Our methodology considers: The empirical referent, the design of the architecture of the regulation model, and the design of the ontology for activity recommendation.

The *empirical referent* describes the context of the learning environment that, in this case, corresponds to Structured Programming courses for undergraduate students of the Metropolitan Autonomous University at Azcapotzalco, Mexico.

The design of the architecture of the Regulation Model (RM) is inspired by the Ned Herman Whole Brain Theory and considers the next components: (i) the teacher, (ii) the learner, (iii) the process facilitator, (iv) the emotional and motivational facilitator, (v) the content, and (vi) the learning activities. The RM corresponds to the top layer of the SLM and because of its relevance is described in Sect. 4.

The ontology is a recommendation system associated to learning activities that uses the Graphical Ontology Design Methodology (GODeM) [16], and the notation of *Onto Design Graphics (ODG)* [17]. We apply the ontological model for learning activities customization for specific courses.

As a first stage the *concept-proof* is developed without learning activities customization.

As a second stage, the customization of the learning activities is developed and the theoretical concepts are applied.

Finally, the results of the first stage are compared with the results of the second stage.

# 4 Regulation Model Based on the Neuroscience Full Brain Theory

The research of Ross J., Pintrich, Zimmerman y Schunk, Andrade, Du y Wang, is cited in Rebeca Anijovich [18], and shows that the academic performance of the student is improved when the relevance of monitoring and self-regulation of the learning of the student is considered. Hence, the learner should take an active role in the self-regulation that leads to the increment of opportunities to improve his performance of the learning activities.

Is desirable that the student knows his learning style and his thinking style to become an autonomous learner with the self-assessment ability, as is referred by Rebeca Anijovich [19]. Hence, one of the first activities assigned to the learner is to answer the quizzes associated to the learning and thinking styles provided at the beginning of each course. The facilitators and the teacher must know the learning and thinking style of the learners to achieve a higher customized feedback.

## 4.1 Components of the Regulation Model

The components of the Regulation Model are: (i) the teacher, (ii) the learner, (iii) the process facilitator, (iv) the emotional and motivational facilitator, v) the content, and (vi) the learning activities. The main goal is to supervise the student activities in order to promote his participation and to identify errors in a collaborative environment.

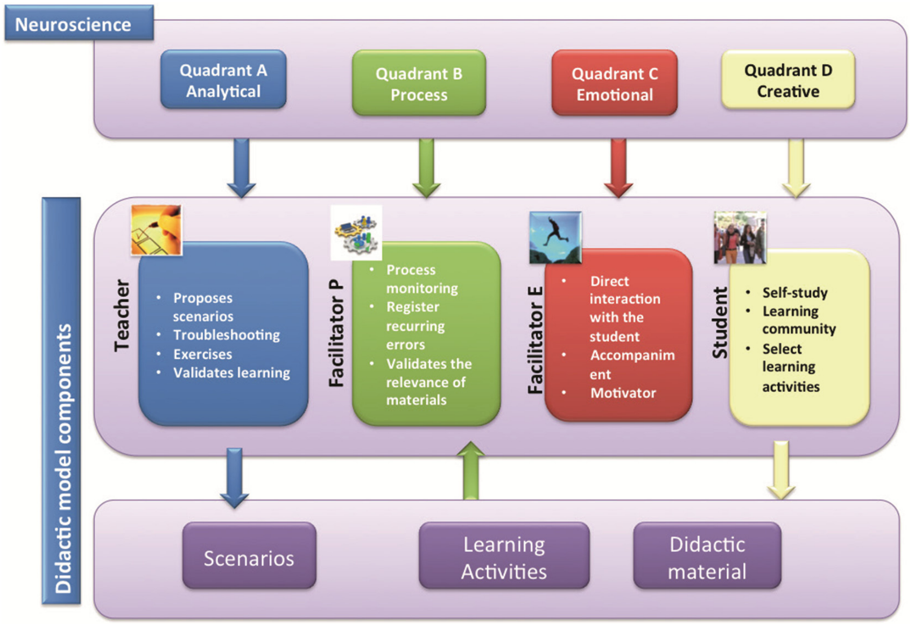


**Fig. 3.** Regulation Model.

In the RM, each component is associated with a cerebral quadrant as is described by the whole brain theory. The teacher is associated with quadrant A (analytic), whereas the learner is associated with quadrant D (creative), the emotional facilitator is associated with quadrant C (interpersonal), and the process facilitator is associated with quadrant B (organizational), as is shown in Fig. 3.

The teacher leads and supervises the teaching-learning process by sharing experiences. The teacher makes the feedback to the learner through online sessions in real-time that are complemented with classroom sessions each week.

The teacher meets the students at the classroom once a week, gives place to doubt solving, make exercises and then a final evaluation is made up to validate the global learning, that is reported as a final note. The role of the teacher is strongly oriented to the cerebral quadrant A (Analytic), under the approach of offering information, solving problems and exercises, among other activities.

On the other hand, the students enrolled in a course are notified of the date, time, and specific classroom to participate in an initial induction session. The students resolve the quizzes to identify their thinking style that allows to conform the learning communities. The student must be registered in a virtual learning environment to be ready for the initial activities that have been programmed previously for the course. The student must assist to all the classroom evaluation that the teacher applies to validate the learning performance. The role of the student is oriented to the cerebral quadrant D (Creative), under the approach of solving problems, make decision, and to propose solutions, among other activities.

The facilitator E, aims to reach a tradeoff between the harmony and the cooperative environment of the learning community, and is focused on the student motivation as an assistant along the formative process. The role of the facilitator E, is oriented to the cerebral quadrant C (Interpersonal), under an approach oriented to offer a motivational support, performs a continuous interaction given by a strong communication with the learner, and must conceive to the student as a valuable person.

Facilitator P focuses on the process, identifies recurrent errors of the student when learning activities are performed, and notifies to the teacher of those errors in order to make corrective activities. The role of facilitator P is oriented to the cerebral quadrant B (Processes), under the approach of supervising the activity execution according to the instructional design, checks the time limits for an opportune activity deliberation, checks the appropriate accomplishment of activities and focuses its attention in the learning process.

The diversity of learning styles is attended with a set of educational resources that includes: animation, audio and interactivity. For this purpose, mental maps, conceptual diagrams, summaries, synopsis, videos, audio, fast reading, chat, blogs, social networks, interactive resources, digital blackboards, games, among others resources are available (see Fig. 4). The didactical contents are elaborated as reusable learning objects (contents).

The learning activities are customized according with the learning styles in such a way that the learner has a large pool of learning activities to make a good choice based on their own thinking styles.

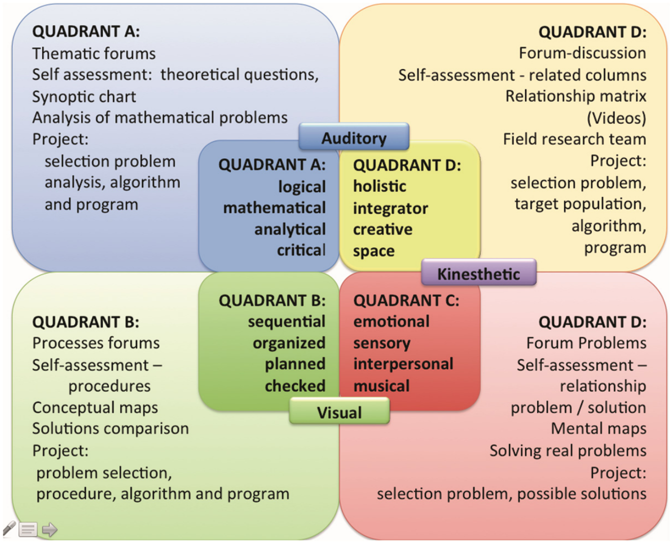


**Fig. 4.** Customization of learning activities for a language programming course.

## 5 Case of Study

The case of study consists of experiments that involves to undergraduate students enrolled in Structured Programming courses of the Faculty of Engineering at Autonomous Metropolitan University (UAM) Azcapotzalco in Mexico, Mexico. The main goal is to increase the logical cognitive abilities, to increase the creativity, and to promote the analytic ability for solving problems by proposing solutions, designing algorithms and implementing the corresponding programs in a specific programming language.

We develop five experiments with a duration of twelve weeks each one: at spring 2012 (12S), at autumn 2012 (12O), at winter 2013 (13I), at spring 2013 (13P) and at autumn 2013 (13-O). To validate the proposed model as well as the architecture, the courses were registered with the modality called *Non-Classroom Course (NCC or 100% online)* and with the modality of C*ooperative Learning System (CLS, 50% online, 50% cooperative),* with a capacity between 70 and 250 students.

### 5.1 Design of the Learning Activities in the Regulation Model

Now we comment about the learning activities that conform the organization of the Structured Programming course as an example of *forum* design that considers a given quadrant, implements thematic forums, discussion forums, problem forums and process forums.

The orientation for the final project, for specific quadrants define a set of approaches, some oriented to the analysis and the logic, and some other oriented to the procedures, to the creativity or to the benefit of a group of persons. The purpose is to identify mechanisms that allow to a student to be identified with the activity to be developed. However, it could not be applied along all the course, since it must integrate other activities that allow a student to develop other abilities that does not match with the dominant quadrant, in order to achieve global course objectives.

The learner has a set of established activities according to a cerebral quadrant to be stimulated, and simultaneously the learner can choose from a large pool of learning activities.

## 5.2 Feedback Mechanisms of the Regulation Model

One of the main goals of the Regulation Model is to collect information of all the process that are developed along a course trying to improve the teaching-learning process. All the historical information (positive and negative) is stored to keep records of previous lessons.

Rebeca Anijovich proposes some recommendation to perform an appropriate feedback: (a) to establish a clear and simple communication, by validating what the student understand compared with what the professor teach; (b) to include messages about the product and the collaboration method in the workgroup; (c) to correct the errors with the students and to suggest a mechanism to improve the results; and (d) to provide positive comments.

The learner must be aware of his errors, and to proceed to fix and improve the results considering the feedback, moreover there must exist an *Improvement Planning*. Is

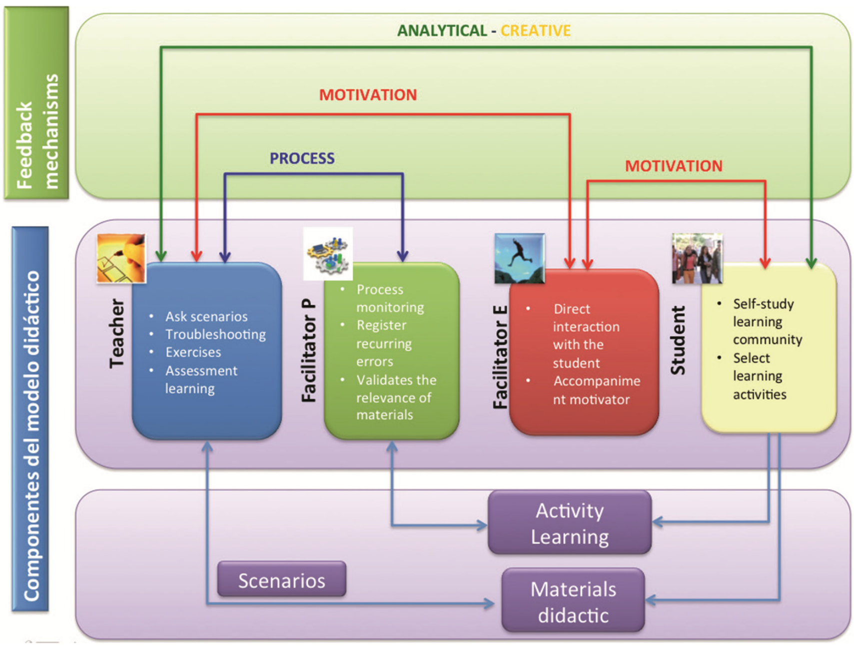


**Fig. 5.** Feedback mechanisms in the Regulation Model.

convenient to generate a *digital log (keep records)* with all the feedback of all the activities to become a reference for the rest of the participants.

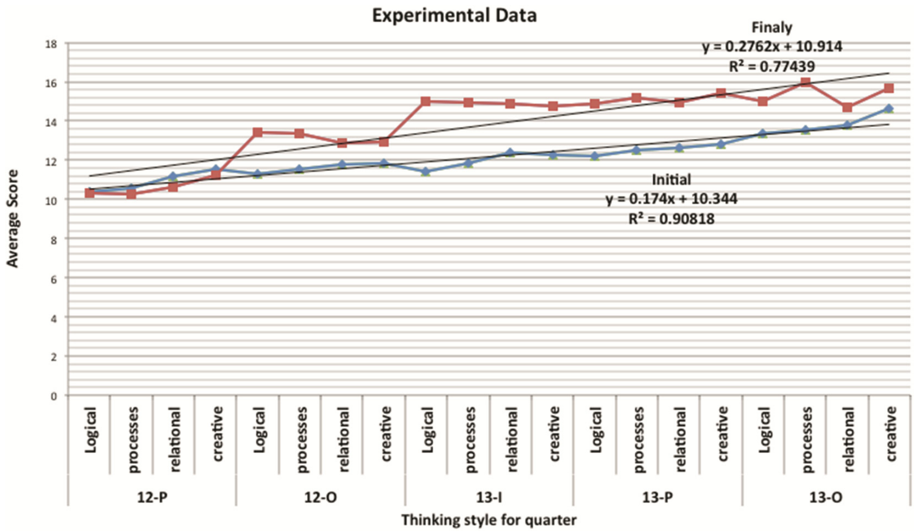


**Fig. 6.** Curve fitting for experimental data of online courser with SLM.

The RM considers two types of feedback: the first is *user-centered* (motivational) and the second is *activity-centered* (the process, the analysis and the creativity). The *user-centered* feedback is attended with the interaction between the facilitator E and the student, throughout the assessment of the activities of the student. Whereas the *activity-centered feedback* take place when the information is transmitted from the teacher to the student, and when the assessment is followed by the facilitator P (see Fig. 5).

## 6 Results

In the test cases, the results show an increment in the scoring that measure the cognitive abilities of the learner. In the Experiment 1, there is no a considerable improvement. In the Experiments 2 and 3 we are able to appreciate an improvement in all the cognitive abilities, in fact we can be appreciate the highest score for the logical and processes abilities. In Experiments 4 and 5 the scoring present an improvement in all the cognitive abilities of the learner. In this case the highest scoring is related with processes and creative abilities, as is shown in Table 2.

**Table 2.** Experimental Results for 5 test cases.

| Period | 12-P Experiment 1 | | 12-O Experiment 2 | | 13-I Experiment 3 | | 13-P Experiment 4 | | 13-O Experiment 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Thinking Style** | Initial | Final | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| **Logic** | 10.356 | 10.315 | 11.290 | 13.418 | 11.399 | 14.987 | 12.222 | 14.865 | 13.353 | 14.988 |
| **Processes** | 10.548 | 10.230 | 11.542 | 13.372 | 11.859 | 14.948 | 12.481 | 15.173 | 13.517 | 15.965 |
| **Relational** | 11.200 | 10.635 | 11.771 | 12.898 | 12.371 | 14.902 | 12.602 | 14.913 | 13.788 | 14.701 |
| **Creative** | 11.560 | 11.219 | 11.824 | 12.949 | 12.247 | 14.732 | 12.833 | 15.394 | 14.658 | 15.690 |

In Fig. 6 we show the curve fitting for the experimental data of the 5 experiments which were realized with language programming courses.

## 7 Conclusions

We have successfully implemented the Regulation Model in 5 experiments involving teachers, undergraduate students as facilitators, and the learning contents have been developed as learning objects, and learning activities were customized according to the thinking and learning styles of the students. Experimental results support the fact of the improvement on the creative, process and logic abilities.

We can conclude that the RM impact positively in the development of the cognitive abilities of the students. Hence, our contribution is the incorporation of the RM that provides the monitoring and feedback necessary to provide a motivation for the students. The RM is the top layer in the Strategic Learning Model, which constitute a learning solution based on cloud computing.

As future work we consider to automatize a reactive layer for the Strategic Learning Metamodel in order to give an adaptive monitoring to the customization of the learning activities.

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