SCAFFOLDING SYSTEM FOR SOLVING PROBLEMS IN ENGINEERING EDUCATION*

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ABSTRACT
The demands of today's world have induced necessary changes in education curricula, teaching methods, modernization of learning scenarios, pedagogies, didactics, among others. Students now require learning scenarios where they can interact with knowledge directly, turning themselves into active agents within their training process and being capable of solving problems. The main purpose of this research is to evaluate a system of contextual awareness as learning scaffolding in problem solving activities in first semester students of systems engineering in order to analyze the effect on academic performance and students' participation in solving problems. Results show that students who had access to the context awareness system as scaffolding for learning had better scores.

Keywords: context awareness, learning scaffolding, ubiquitous computing, problem solving, active learning, engineering teaching, mobile learning, context modeling, ontologies, semantic web.

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SISTEMA DE ANDAMIAJE PARA LA SOLUCIÓN DE PROBLEMAS EN EDUCACIÓN EN INGENIERÍAS

RESUMEN

Las exigencias del mundo actual han llevado a la educación a realizar transformaciones a nivel de currículos, métodos de enseñanza, modernización de los escenarios de aprendizaje, pedagogías y didácticas, entre otros. De acuerdo con las mismas transformaciones de la educación, los estudiantes requieren de escenarios de aprendizaje en donde puedan interactuar con el conocimiento de forma directa, convirtiéndose en agentes activos dentro de su proceso de formación con la capacidad de resolver problemas. El principal propósito de este trabajo de investigación es evaluar un sistema de conciencia contextual como andamiaje de aprendizaje en actividades de resolución de problemas en estudiantes de primer semestre de ingeniería de sistemas con el objeto de analizar el efecto en el rendimiento académico y la participación de los estudiantes en la solución de problemas. Al final de la evaluación se logra evidenciar que los estudiantes que tuvieron acceso al sistema de conciencia contextual como andamiaje de aprendizaje lograron tener un mejor desempeño en sus calificaciones.

Palabras clave: conciencia contextual, andamiaje de aprendizaje, computación ubicua, solución de problemas, aprendizaje activo, enseñanza en la ingeniería, aprendizaje móvil, modelado del contexto, ontologías, web semántica

INTRODUCTION

Ubiquitous computing technologies can be effectively applied to generate automatic solutions by offering the service of detection and treatment of user context data [1]. Ubiquitous computing in education not only allows the learning system to adapt to the learner's individual needs, but also allows the student to participate actively in their learning. The idea of using ubiquitous computing technology for learning coincides with the pedagogical theory of constructivism. In the framework of constructivism, educators need to provide learning environments centered on the student to facilitate the active construction of each individual student [2]. It also highlights a student's prior knowledge and cognitive learning [3]. It is evident that well-developed learning systems that employ ubiquitous computing technologies can be highly adaptive, student-based, with prior knowledge and existing performance to provide appropriate guidance or learning for each student [4]. Systems of contextual awareness applied in education in recent years have become instruments that facilitate student learning, making them more active in their training process [5-6]. Thanks to the interaction with the context, they can understand and analyze the information provided to them in order to learn in an improved manner. In [7], the researchers propose a learning environment based on augmented reality using scaffolding mechanisms to teach the basic principles of electricity to 9th grade students. The authors used two levels of scaffolding support, which were evaluated according to the students' behavior and learning results. In [8], the researchers design a mobile augmented reality system to learn historical research strategies in a real-life context, providing cognitive scaffolding strategies. In [9-10], the authors propose a ubiquitous context-sensitive learning environment based on scaffolding strategies that improve students' problem-solving skills. In [3], the authors develop a context-sensitive mobile learning application based on augmented reality, as a scaffolding platform for learning history and geography in outdoor environments.

Context modeling has been extensively studied in numerous investigations, such as [11-15], in order to identify the entities and contextual relationships. Context-aware systems that are more dynamic and capable of responding to different types of interactions can be developed.

Gagne defines problem solving as a complex combination of hierarchically ordered intellectual abilities [16]. According to [17], the goal is that, through practice, students can corroborate the concepts derived from the theory. The solutions are the outcome of deliberate efforts, oriented towards the search of divergent solutions to authentic problems, through multiple interactions among students, and supported by tools and other resources. Other definitions are provided, as in [18], where it is stated that problem solving arises when someone is faced with an issue but does not know which actions must be taken to achieve a resolution. According to [19], a problem is, in general terms, any expected or spontaneous situation that produces a certain degree of uncertainty and a search behavior for its solution. Ultimately, it can be said that the solution of problems is the ability of an individual to face a situation, analyze it and use their previous knowledge to find the answer.

Scaffolding is used to solve problems, as a support to students in the understanding of problems and related knowledge. The teacher's assistance is required as an expert guide to coordinate the beginning of activities. Bruner and Vygotsky defined scaffolding as a person with more knowledge helping others fulfill a task that exceeds their abilities [20-21]. The idea is for scaffolds to be gradually reduced as students become more capable, by integrating appropriate resources including experts, classmates, the learning context, and technology. Studies reveal that using scaffolds improves independent learning, understanding, and knowledge transfer [20]. Technological scaffolds become mechanisms that reduce students' difficulties by individually accessing learning contents [22]. Within the purposes of the scaffolding are the procedures, which are responsible for guiding the students in the operational aspects of the learning environment. In the same way, the conceptual scaffolds that guide students in the identification of essential knowledge between what they already master and what they need to know are intrinsic. Scaffolds fade gradually as students acquire the necessary skills to solve problems [17].

The main purpose of this research is the implementation of a learning scaffolding system based on the techniques of contextual awareness, as a teaching method in problem solving. The method was applied to first semester students of Systems Engineering to assess its efficiency, considering student participation in solving problems, and determining if it improves academic performance. The purpose for this research arose from situations with first semester students of the Systems Engineering program of the University of Córdoba, in the subjects of Calculus, Mathematical Logic, and Introduction to Engineering. In these subjects, it was noted that some students had a better command of certain topics than others, given that the students who entered the Program came from diverse schools of the department of Córdoba (public, private, urban, and rural). However, all students, with or without previous knowledge or memories, must maintain the same pace. Scaffolding would allow advanced students to help their peers in solving problems in such a way that the students with better abilities, along with the teacher, can counsel others regarding their difficulties, and accompany them until their assistance is no longer necessary. This method allows less advanced students to work hand in hand with those who have better problem-solving skills. This research reviews problem solving, ubiquitous learning, and contextual awareness; the methodology, results, discussion and conclusions are reported.

1. THEORETICAL FRAMEWORK

1.1 Problem-Solving

Problem solving is a cognitive process aimed at achieving a goal when the method of solution is not obvious. It is considered cognitive since it takes place within the system of each person and can directly influence behavior changes. It is considered a process because it involves representation and manipulation of knowledge [23]. The individual who solves the problem is goal-oriented. Problem solving is personal, since the knowledge and individual skills of the problem solver help determine the difficulty or ease with which obstacles can be overcome. The cognitive structure plays a fundamental role, because if the previous knowledge in the mental structure is stable, clear and understandable, they help solve problems [24]; whereas if there is no prior knowledge, it is unlikely that a person will be capable of even understanding the nature of the problem.

In the solution of problems, studies as [25] show that there is a relationship between cognitive load and teaching methods. This relationship consists of four components: a) the tasks of learning and solving problems of the context, b) the support information and tests for the solution of the problem, c) the timely information, which must contain procedural guides to the apprentices in the resolution of problems, d) the practical tasks, which must allow the apprentice the automation of exercises to acquire complex abilities from the solution of problems. Regarding problem solving in [17], they propose five activities: problem identification, exploration, reconstruction, reflection and negotiation, presentation and communication.

1.2 Ubiquitous Learning and Contextual Awareness

Bomsdorf states that ubiquitous learning is the next step in the performance of E-learning and is expected to lead to a change in educational paradigm. The potential for ubiquitous learning is reflected in the increased access to learning content and collaborative learning environments supported by computers at the right time, place and form [26]. In addition, it allows the perfect combination of virtual environments and physical spaces. The purpose of ubiquitous computing technology is basically to improve learning processes, to try to adapt the learning resources to the different contexts of use of the apprentices. According to [4], ubiquitous learning is that which employs mobile devices, wireless communications and sensor technologies, in learning activities called "Ubiquitous Learning and Context awareness". Where mobile devices, wireless communications and sensor technologies, and a wide variety of products and techniques, are part of what is known as ubiquitous computing.

2. CONTEXT MODELLING

The context was modeled to provide the information that result in learning contents developing the system and responding to the needs of student interaction with the objects that surround them. Context modeling, in a static or dynamic way, is not something new, as can be seen in [27-30]. There are several ways of modeling such as schemes with coding tag, graphics, object, logic, and ontology based. Ontologies were used in this study, since there is reasoning support. The reasoning is a method to understand the available context and infer about it, that is, according to the interaction the student has with its context, the system can offer learning content based on its location, profile, time, and date. The device allows machine-machine communication, i.e. sensor-smartphone, tablet, and user and smartphone. The system is able to adjust the contents and interfaces according to the changing environment. For instance, a student who enters a medical laboratory will immediately be able to access the learning contents that they must develop in the event they have to perform any class activity, or reinforcement activities. Dey's proposals were considered in relation to context ontology to intelligently deliver the learning contents: any information can be used to characterize the situation of an entity, understood as a person, place or object that is considered relevant for the interaction between a user and an application, including the user, and the applications themselves [31].

Although the literature shows that there are multiple studies that address context modeling, activities, collaborative or individual, as an element in educational environments have not been considered. The teacher is not usually included as part of the model. It is clear that the active learning methodology involves placing the student at the center of the process. It is necessary to include the educator, because he is responsible for orchestrating the strategies to make everything work properly. The teacher was included in this study within the context model, as part of the domains of ontology. Figure 1 shows the ontology, modeled in the Protegé 4.0 Software.

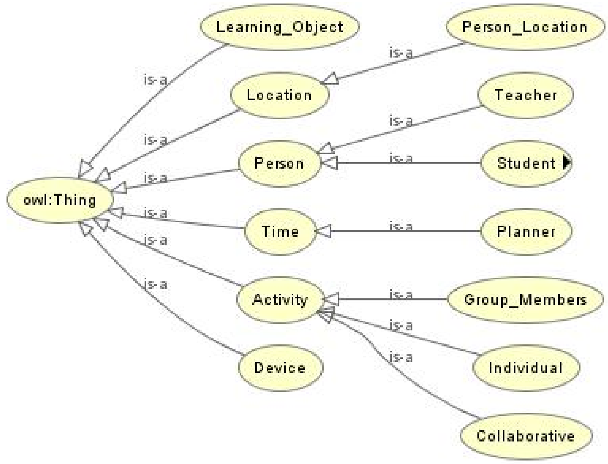

Figure 1. Context model ontology

Source: own elaboration.

- Student: The profile is selected as a reference and the information associated with their academic level, knowledge, skills, abilities, interests, subjects, academic program to which they belong, academic network to which they belong within the university institution, class schedules and study. Similarly, there is control over the activities that correspond to the type of actions executed by a student, which may be collaborative or individual. The execution of learning activities depends on the teacher's planning. According to the planning, the student must perform group or individual tasks. The system is adjusted so that the learning activities are developed. When the activities are collaborative, the students interact with the objects around them and their partners, achieving the objectives of the subject as planned.

- Teacher: mediates between students and the learning contents and can monitor student progress and intervene as many times as necessary when there are difficulties.

- Time: refers to the time and date in which a student interacts with the system, either when there is a learning activity assigned by a teacher or if the system has suggested one. It may be a particular time, date, or a certain period such as final exams.

- Devices: mobile devices used for the interaction between students and the learning environment. Among the information provided by the devices, there is GPS support and BLE (Bluetooth Low Energy) —the first for location in outdoor environments, and the second for indoor location. There is also information about computational aspects (mobile device memory capacities, bandwidth, screen resolution, and processing capacity).

- Learning objects: It refers to all the learning content that the student receives through his mobile device and the interaction it has with the environment. Learning contents are based on physical objects and virtual objects.

- Location: corresponds to the student's location, inside and outside the university campus. The system can adjust the contents based on the location. The GPS coordinates and the signal intensity of the BLE sensors associated with the tagged objects are taken. This type of interaction is implicit and is achieved from machine to machine. Classrooms, laboratories, cafeterias, computer rooms, and others are among labeled objects. These are the possible places where students access. The location can be specific as the latitude and longitude, the intensity of the signal of the BLE sensors that allow knowing the proximity of the environment or the content of learning; it can also be abstract if it is the name of a laboratory, a department, or a classroom.

3. SYSTEM ARCHITECTURE

The system is framed within the server client architecture. Both the client and the server have a series of components that will be described below:

Server: It is constituted by three main components, which have a function according to their location in the respective layer:

- Context management: its purpose is to read and interpret the requests that arrive from the client, based on the parameters according to the model of the context described.

- Context reasoner: is responsible for making inferences based on the information that comes from the model, which can be location, time, bandwidth, screen device resolution, learning object data, among other parameters. After this contextual information, according to the inference rules, it returns the contents that are subsequently displayed on the student's mobile device. The inference engine used is the Hermit 1.3.8 open source tool, and the language used to make the inferences is SWRL (Semantic Web Rule Language). Below is an example of rules in figures 2a and 2b:

Rule 1.

```
Students(?s), Profile(?pr,?s), Preference(?pref,?s),
hasActivity(?s,?a), hasExecute(?a,?e),
Learning_Object:hasCourse(?l, ?c) →
Delivere_learning_Object (?l, ?s )
```

Figure 2a. Rule using location

Source: Own elaboration.

Students perform activities in particular physical environments, where the location and physical objects of the environment are taken to deliver relevant learning objects.

Rule 2.

Students(?s), Preference(?pref,?s), ability(?ab,?s), hasActivity(?s,?a), hasExecute(?a,?e), Learning_Object:hasCourse(?l, ?c) → Delivere_learning_Object (?c, ?s)

Figure 2b. Rule using preferences

Source: Own elaboration.

Learning objects are presented to the student to carry out the activities, based on preferences and abilities.

- Learning object management: is responsible for delivering the appropriate learning objects according to the requests that come from the underlying layers, in such a way that it searches in students' databases and learning objects, and the contents are adjusted to the requests made by the client. It delivers the content based on the student's interaction with the context.

Client: The components of the client's architecture are constituted as follows:

- Mobile interface: is responsible for establishing the interaction between the student, the mobile device and context detection, which can be the location, NFC (Near Field Communication) reading, QRCode or BLE (Bluetooth Low Energy) labels that identify an object, process and send it to the server, and deliver the appropriate learning content to the student.

- Discovery context: is responsible for listening to the NFC, QRCode and BLE tags, according to the readings a student is doing at a certain time, in front of a set of learning activities. This layer contains the algorithms that are responsible for processing the information that comes from each of the sensors and then send them to the mobile interface layer, and this in turn transfers it via HTTP to the server.

Architecture distribution can be seen in figure 3.

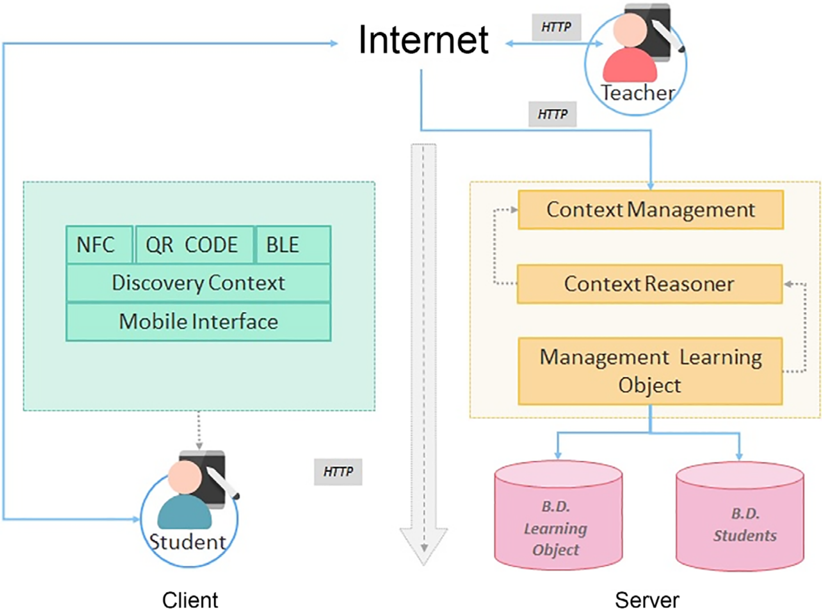

Figure 3. System architecture

Source: Own elaboration.

4. METHODOLOGY

The main purpose of this research is to evaluate a contextual awareness system as scaffolding in problem solving activities in first semester Systems Engineering students. The chosen course was 'Introduction to Engineering'. Course contents were taken from the program syllabus assigned to the Faculty of Engineering of the University of Córdoba. The activities were housed in the platform of the context awareness system. The idea was for the students to interact with the system, receive the learning content and solve problems. Scaffolding would fade once participants had a better understanding of the problems. To determine the effectiveness of the system, a comparative study with a control and experimental group was carried out, during the first and second semester of 2015. The hypothesis proposed was: students who interacted with the context awareness system as scaffolding for learning achieve better results in the course. At the end of each semester, questionnaires were carried out to analyze the degree of student satisfaction.

4.1 Participants

There were four groups (control and experimental) in Introduction to Systems Engineering with 25 participants each. The experiments were conducted in the first semester and second semester of 2015, with a total participation of 100 students. The control groups received the classes in a traditional way. Those of the experimental group used the system of context awareness. At the end of each experience, a questionnaire was applied to analyze students' attitudes and their satisfaction with planned activities in the contextual awareness system, and the tools used to support them as scaffolding.

4.2 Implementation of the contextual awareness system as scaffolding

To determine the effect that the context awareness system had as scaffolding in the resolution of problems on academic performance, "prior knowledge" was controlled, which refers to the level of knowledge related to the subject that each individual has when starting the experimental treatment. It is assumed that students have no knowledge about the selected learning unit. Initially, it was inquired if the knowledge that the students had before starting the subject was similar, in order to assure that none of the groups started from a situation of advantage or disadvantage. To answer this question, a hypothesis test was carried out on the data collected by applying a pre-test. The data corresponding to academic performance was obtained after post-test application, with which a hypothesis test was carried out to verify if there were significant differences between them.

In each of the experimental groups of the different academic periods, the use of the context awareness system as scaffolding was implemented.

4.3 Data Collection and Analysis

Pre-Test

The analysis of descriptive statistics indicates that control groups' means were 2.36 for the first academic period, and 1.99 for the second academic period. Meanwhile, the experimental groups had averages of 2.28 and 2.02 in each academic period. Means are very similar, as can be seen in table 2.

Table 2. Analysis of system engineering students' performance in pre-test

Pre-test I SEMESTER 2015			
	Control	**Experimental**	**P-Value**
Min	1.10	1.00	
Max	3.50	4.50	
Medium	2.40	2.10	0.58
Mean	2.36	2.28	
SD	0.72	0.84	

Pre-test I SEMESTER 2015			
	Control	Experimental	P-Value
Pre-test II SEMESTER 2015			
Min	1.00	1.00	
Max	3.00	3.50	
Medium	1.90	2.00	
Mean	1.99	2.02	0.98
SD	0.61	0.76	

Source: own elaboration.

Table 3. Analysis of system engineering students' performance in post-test

Post-test I SEMESTER 2015			
	Control	Experimental	P-Valor
Min	3.00	3.80	
Max	4.10	4.80	
Medium	3.30	4.50	0.0
Mean	3.30	4.36	
SD	0.29	0.31	
Post-test II SEMESTER 2015			
Min	1.30	3.00	
Max	4.00	5.00	
Medium	3.40	4.20	
Mean	3.19	4.22	0.0
SD	0.81	0.50	

Source: own elaboration.

Post-Test

Control groups' means during the first and second period (3.30, 3.19) are lower than those of the experimental groups (4.36, 4.22), as can be seen in table 4.

5. RESULTS AND DISCUSSION

The results in the pre-test P value of the control and experimental group is 0.58 for the first period and 0.98 for the second period, which indicates no significant difference between the averages of the experimental group and control, in none of the academic periods; that means that there is initial equivalence.

In most of the post-test cases the data show no evidence to come from a normal population (0.00125087, 0.045298, 0.00293916, 0.377821); except for the experimental group data from the second period of 2015, with a P-Value> = 0.05, that indicate a lack of a normal distribution. Therefore, comparisons are made using the nonparametric Mann-Whitney test for independent samples. Figures 4a, 4b, 4c and 4d show the normality tests of the control and experimental groups of the first and second period of the year 2015.

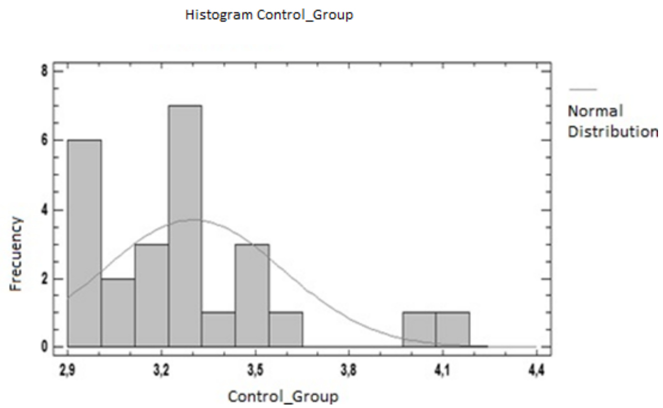

Figure 4a. Normality test for post-test 2015-I, control group

Source: own elaboration.

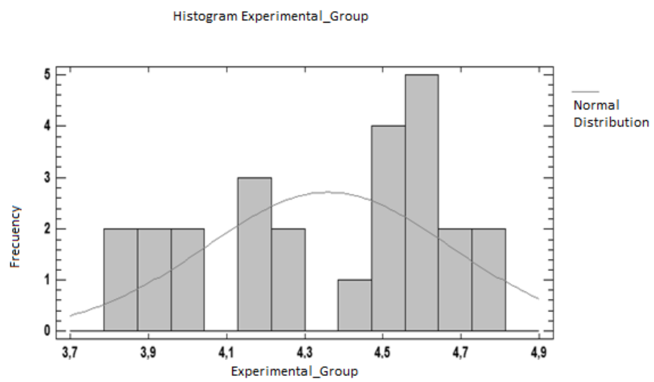

Figure 4b.Normality test for post-test 2015-I, experimental group

Source: own elaboration.

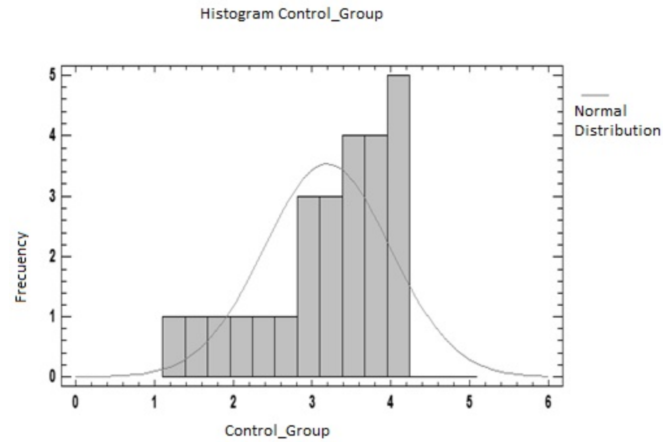

Figure 4c. Normality test for post-test 2015-II, control group

Source: own elaboration.

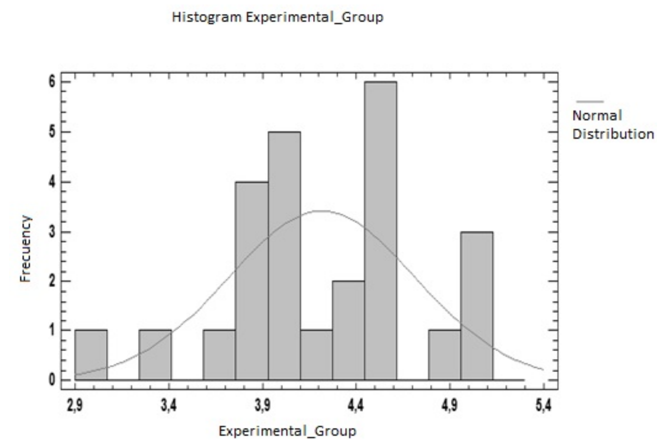

Figure 4d. Normality test for post-test 2015-II, experimental group

Source: own elaboration.

This is done with the purpose of verifying if the mean score of the control group differs significantly from that of the experimental group. Results show that, for all periods, there is a highly significant difference between the means of the experimental group and control with a P value close to 0 (table 4). That is, students in the experimental groups had better results than those of the control groups. Figures 5a and 5b show the results obtained in the two academic periods. In the X-axis the number of students that participated in the experimental test is recorded, and the Y-axis shows the grade obtained in a range of 0 to 5.

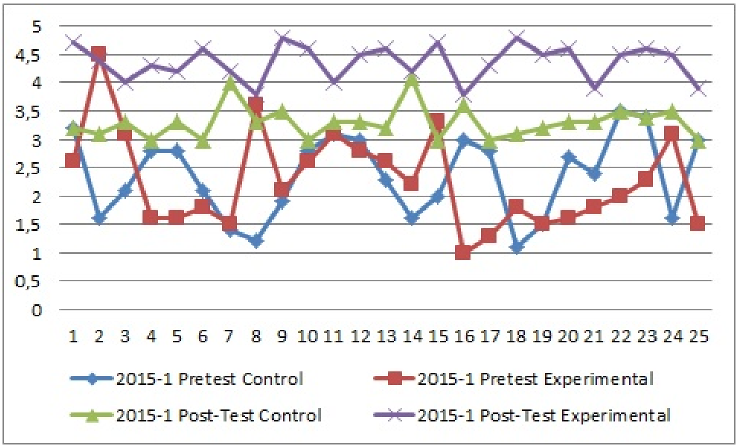

Figure 5a. Pre-test and post-test results 2015-I

Source: own elaboration.

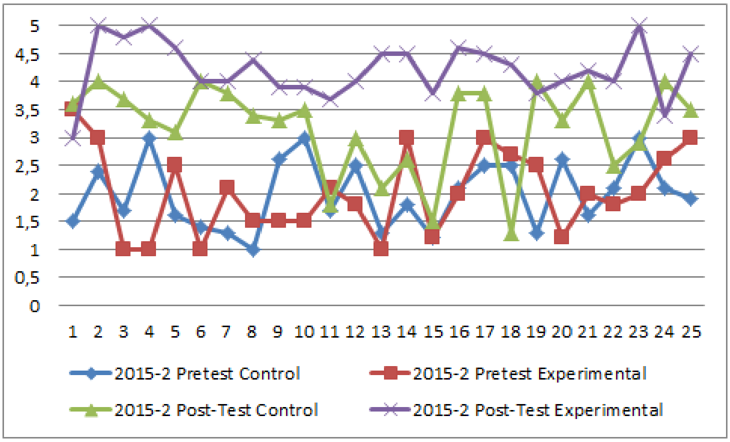

Figure 5b. Pre-test and post-test results 2015-II

Source: own elaboration.

To complete the analysis, covariance was included to determine whether the initial knowledge (pre-test) affects the academic performance (post-test) as a dependent variable. In the first academic period of 2015, 3.3403 is the intercept for the control group (it is interpreted as the average of the final grade when the initial grade is zero). 1.0586 is the difference estimated. The increase that the average undergoes when going from the control group to the experimental group, in other words, the intercept for the experimental group, is 3.3403 + 1.0586 = 4.3989 confirms the latter. Therefore, for the experimental group, the final average grade when the initial grade is zero is estimated at 4.3989. The p value associated with the experimental group (0) <0.05 indicates that the difference between the intercepts is statistically different from zero, that is, the regression lines have different intercepts. Finally, the value -0.0171 is the estimate of the slope, and its interpretation is: if the initial grade is increased by one unit, then it is estimated that the average of the final grade is increased by -0.0171 units. The adjusted model assumes that this increase is the same for both groups. The associated p value (0.7622> 0.05) indicates that this increase is not statistically different from zero (the increase is not significant), another way of reading that value p is: initial grade does not contribute to explain final grades. The results of the second academic period of 2015 were similar where the intercept for the control group was 3.2904 and for the experimental group it was 3.2904 + 1.0256 = 4.316. The p value associated with the experimental group (0) <0.05 indicates that the difference between the intercepts are statistically different from zero. The associated p value (0.7298> 0.05) indicates that this increase is not statistically different from zero (the increase is not significant), therefore that p value is: initial grades do not contribute to explain the final grades, meaning that in both academic periods initial knowledge (pre-test) did not affect the academic performance (post-test).

These results statistically confirm that students who use this learning system had a better academic performance than those who follow the traditional method. The contextual awareness system is very useful for students when solving problems. It is important to clarify that the problems posed to these students had a high degree of difficulty, which required the scaffolding infrastructure to solve them.

6. CONCLUSIONS

The evaluation conducted in this study allowed us to verify the research's hypothesis: "students who interact with the context awareness system as scaffolding for learning achieve better outcomes." The results support this hypothesis given that students who participated in the experimental groups had a better academic performance in comparison to those in traditional teaching settings (control group). It was possible to demonstrate that the learning scaffolds supported by technology have positive effects on the skills students acquire for problem solving.

In order to implement systems of contextual awareness as support for learning, the synergy of different areas of knowledge is required to support the teaching-learning processes. Furthermore, a technological infrastructure that allows the interaction between students, teachers, and learning contents is necessary.

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