Implementation of Just in Time Teaching methodology in mathematics and natural sciences study in high school institutions of Colombia northeast

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Abstract. The notably undergraduate student desertion in higher education is considered one of the main difficulties in worldwide education systems. The main factors associated with this phenomenon in Colombia are related to low academic entrance skills, economic problems of students and aspects related to socio-occupational orientation and adaptation to the university environment. At Universidad Industrial de Santander an initiative has emerged since the beginning of 2017 that seeks to strengthen the entrance skills to higher education of high school students in Colombia northeast, through “Spachovsky project” that intervenes in the teaching and learning processes of three subjects: mathematics, physics and chemistry of tenth and eleventh grade, through an active learning strategy implementation: Just-in-Time Teaching whose essence is the students’ previous class preparation, through questionnaires and didactic material in a web platform, which has a positive effect on what happens during the time subsequent to it with an appropriate teacher’s mediation. The contents are managed through virtual tools such as: links to digital books and teaching videos through Moodle platform, which together with session preparation questionnaires, and appropriate mediation by the teacher will favor study habits and the autonomous learning of students.

1. Introduction

The World Development Report 2018: "Learning to make reality the promise of education" from the World Bank argues that without learning, education cannot be the determining factor in ending extreme poverty, generating opportunities and promoting shared prosperity. Even after attending school for several years, millions of children cannot read, write or do basic math [1].

In Colombia, MEN (Ministerio de Educación Nacional) makes efforts to provide guidelines for teaching practices at basic and secondary education that ensure that all students receive a high-quality education, which contributes to the development of basic skills for entry into higher education. It was found that the average scores are significantly lower than the average of the Organization for Economic Cooperation and Development (OECD) in PISA test, which assesses mathematics, reading and natural sciences skills. In mathematics, Colombia score (376) is lower than obtained by 61 countries and very similar to those found in the countries with the three lowest scores. In science and reading as well as in mathematics, results are also discouraging; less than 57 and 53 countries, respectively [2]. The current situation of Colombian education reveals a problem and need for improvement in the teaching and learning processes that students receive before higher education. In the light of contributing to the level of education that precedes the university, "Spachovsky" project
aims to answer the research question: how can the disciplinary skills of secondary students be strengthened with the information and communication technologies (ICT) mediation and implementation of active teaching and learning strategies? Therefore, Universidad Industrial de Santander (UIS) teaching and research experiences will be used for the implementation and standardization of strategies and technologies using ICT as support [3, 4], following the MEN guidelines for student permanence and graduation management model (2005) to work in conjunction with media education institutions (IEM), with the objective of teaching and learning practices transformation and strengthening the appropriation and development of knowledge, skills and necessary attitudes for students and teachers to perform productive activities associated with scientific research.

This initiative involves a training program for teachers of mathematics, physics and chemistry about pedagogical strategies used in this intervention. This is a transcendental stage, because some different investigations call attention to the need for teacher training to respond learners needs; the continuous training for teachers is presented as a priority strategy to raise the education quality and essential axis in view of global education system improvement [5].

2. Antecedents

In order to contribute to strengthen basic competences of high school students, from the pedagogical practices transformation, it is necessary to innovate in the teaching strategies that allow to overcome and complement traditional activities characterized by the professor's exposition of knowledge that translates into students who copy from the blackboard or, from books to their notebooks without questioning [6,7]. "Spachovsky" project adopts and articulates two important components to achieve its objective as described below.

2.1. Just in Time Teaching (JiTT)

This pedagogical strategy allows to establish a teaching organization focused on eliminate the student’s passivity, the transmitted knowledge memorization, using a didactic response, and orienting the classes according to learners needs. JiTT concentrates on the student while the teacher performs a facilitation process (mediated learning) not only in the processes of knowledge incorporation but also in the evaluation processes. Due to its flexibility, JiTT can be applied to a variety of tasks, courses and disciplines, and can be easily combined with other pedagogies, it is an excellent way for students to prepare the class, it can also be used by teachers to discover students’ misconceptions or to provide classroom activities examples and develop disciplinary skills [8]. This strategy pursues three main objectives [9]: (i) Structure time out of class for maximum learning benefit. (ii) Maximize class session effectiveness by allowing teacher to work on specific needs detected before class. (iii) Create and maintain team spirit. In practice, to ensure the study different contents of a subject, this strategy allows teacher to know the level of understanding of a topic through questions that motivate the student to explore and be interested before taking the class, this through session preparation questionnaires (SPQ) that are intended to obtain a broad set of responses that illustrate the thinking processes of the students, while informing them of the class activities before it [3,10].

2.2. Incorporation of ICT in teaching and learning processes

"Spachovsky" project integrates technological resources such as Moodle to generate learning environments that encourage active, reflective and meaningful learning, as well as analysis and synthesis, decision making, problem solving, among others. Moodle will be the virtual environment in support of teaching and learning, in which digital teaching resources will be made available for each subject and each academic period, these resources include SPQ, readings and videos that will be carried out as part of pedagogical support that want to provide the students before entering their classes. This new environment will modify "way in which students approach learning and that varies their knowledge acquisition strategies since they initiate students in the development of new ways of working and organizing with others in which underlying a new methodological approach,
collaborative work” [11]. In the same way, its online and automatic using generates improvements in communication between teacher-teacher, teacher-student and student-student [12,13].

3. Methods and materials
For implementation of teaching and learning strategies mediated by ICT, a feasibility study will be previously carried out to know if the high school institutions have the characteristics to achieve the project objective. The main requirement is the provision of computer equipment with internet for teachers and each student. On the other hand, a user is required in the Moodle educational platform to access the digital resources that will be created at the start of the pilot test.

The project initially contemplates a teacher training stage in teaching and learning theories that define the methodology to be implemented. Moodle offers a set of tools that help the teacher in the monitoring and evaluation. In this way, IEM teachers will use the tools at different moments of the process, either through workshops or questionnaires that will be designed incrementally. This will allow using the evaluation from the formative perspective since its purpose is to make adjustments during the march. Different measurement and evaluation technologies for learning will also be integrated, as well as different types of questions and measurement instruments to contemplate and strengthen various learning styles, as well as Bloom’s taxonomy to categorize the measurement instruments and their results to facilitate design and information analysis [14].

For project execution, four (4) phases are proposed with nine (9) stages in total that will allow the project maturation and consolidation, as shown in Figure 1. First activity consists in the material development required by the project (material for teacher training in teaching and learning strategies, ICT, Moodle and learning modules development for tenth and eleventh grade).

![Spachovsky project](image)

**Figure 1.** Phases of Spachovsky project.

Three high school institutions will be selected through non-participant observation, a characterization will be made with information that accounts for following variables: (1) pedagogical strategies used by IEM science teachers in their pedagogical practices, (2) teaching and learning resources used by teachers, (3) academic results in each discipline for two previous school years, (4) prior knowledge of the students who will participate in phase 2, (5) curriculum of each subject that will be intervened in the tenth grade, (6) science teachers profile, (7) current conditions of classroom environments and their installed capacity, (8) socio-economic stratum of students, (9) technological
resources and connectivity availability outside of their institution. Teachers will be previously trained in the use of the methodological strategies that support the project.

In second phase (piloting), necessary actions will be deployed to organize material in the educational platform. Didactic material developed, and the measuring instruments will be incorporated into the virtual learning tool (Moodle) to initially intervene in the tenth grades. Following the regular academic IEM’s calendar, some visits "in situ" for the accompaniment and follow-up necessary to solve possible pedagogical or technological difficulties will be necessaries.

Taking as reference the characterization carried out in phase 1 and the information gathered in the monitoring and follow-up during the project execution in different components of phase 2, in phase 3 the project impact will be determined, identifying strengths and possible aspects improvement taking into account administrators, teachers and students satisfaction in relation to the proposed mediation strategies. Subsequently, with results obtained in the previous stage, necessary adjustments will be made for the new staging and reference documents will be made on the use of the elaborated material and teaching - learning - evaluation strategies.

Finally, closure phase involves analyzing results of the implementation with tenth grade and making the assess consolidation. “Spachovsky” project covers a series of actions that are framed as a strategy of contribution to teacher training that is understood as a decisive factor for practice transformation of educators.

4. Results and discussion
This work will show results obtained in the first phase of the project (preparation), in which mediation strategies that will be used in the next phase. Virtual digital resources were created (links to books in the UIS’s digital library, educational videos related to the topics of interest and SPQ development).

4.1. Mediation strategies used in strengthening of skills for autonomous learning in high school students
Based on excellent results obtained in the research carried out in 2015 by Miranda and collaborators with basic engineering cycle students, using JiTT strategy, together with "School of trainers", a designated space to training of laboratory professors (Physics 1, 2 and 3) on how to implement the strategy and organize the work before and during the class [3, 14]. It was decided that for Spachovsky project a similar methodology.

4.2. Supporting didactic resources and bimedia material
Initially a bibliographic search, collection and processing contents that should be treated in grades 10 and 11 grade was carried out. Selected books were chosen from the content distribution platform for primary, secondary and higher education institutions known as Ebooks 7-24. Bibliography used for mathematics, chemistry and physics are summarized in Table 1.

| Table 1. Bibliography used to study the contents of mathematics, chemistry and physics. |
|------------------------------------------|---------------------------------|
| Subject | Support bibliography |
| Mathematics | Mathematics I, II, III y IV, Patricia Ibáñez Carrasco, Gerardo García Torres. Ed. 1, 2011. Pre-calculus, Mathematics for calculus. James Stewart, Lothar Redlin. Ed. 7, 2016. Introductory university mathematics, Franklin D. Demana, Bert K. Waits, Daniel Kennedy, Gregory D. Foley, Robert Blitzer. Pearson Education. Ed. 1 2009. |
| Chemistry | Chemistry, Raymond Chang. Ed. 11, 2013. Chemistry I and II, Skills approach, García Becerril María de Lourdes. Ed. 2, 2010. Physics fundamentals Volume I, Raymond A. Serway, Chris Vuille. Ed. 9, 2012. Tippens, Paul E. Physics, Concepts and applications. México, 6ª.Ed., McGraw Hill, 2001. |
| Physics | Physics fundamentals, Wolfgang Bauer. Ed. 1, 2014. Gómez Gutiérrez, Héctor Manuel y Ortega Reyes, Rafael. Physics I. Editorial CENGAGE Learning. México, 2010. |
The links of guide texts are linked in Moodle platform along with explanatory videos of each topic. Videos were selected carefully, from YouTube, thanks to professors’ contribution from different parts around the world (especially from Colombia and Spain) who carry very concrete and useful explanations in their academic channels. Subsequently, SPQ were structured taking into account key concepts of each topic, this formulation work began with minor complexity questions and was increasing its level from 1 (for the simplest question) to 4 for the highest level of complexity. Below are shown some physics and chemistry questions for tenth and eleventh grade, respectively.

4.3. Basic question in Physics 10\textsuperscript{th} (level 1)
A box moves to the left in the negative direction of x-axis while applying a force $\mathbf{F}$ in four different situations. As shown in Figure 2. Which of the following is the correct order of the amount of work done by $\mathbf{F}$ from the most negative to the most positive?

a) 2, 1, 3, 4. ✔

b) 3, 2, 1, 4.

c) 1, 2, 3, 4.

d) 2, 3, 1, 4.

In previous example, a first level of knowledge can be evidenced, where the student is asked to remember or know the basic “work” meaning, which is related to the action of an external force that disturbs an object and produces a displacement in some direction. In this case, the option of comparing work magnitudes performed by different forces is generated.

For Chemistry, in eleventh grade students, following four questions are shown as an example of the different degrees of complexity, taking into account the four proposed levels.

4.3.1. Question 1 (level 1). Is each of the following statements true or false?

a) The mutual attraction exerted by the atom's nucleus on shared electrons constitutes a covalent bond. (True).

b) Elements such as beryllium and boron, with only six and four electrons respectively, are chemically stable. (False).

c) Liquid or molten covalent compounds do not conduct electricity because there are no ions present. (True).

4.3.2. Question 2 (level 2). Which of the following equations best represents the reaction shown in Figure 3?

a) $6A + 4B = 2C + D$

b) $A + 2B = 4C + 2D$
c) $3A + 2B = C + 2D$ ✔
d) $6A + 4B = 4C + 2D$

4.3.3. Question 3 (level 3). What is the bond type and stoichiometry, if A and B elements whose atomic structures are represented in Figure 4 are combined? (Electrons in red color).

a) Ionic bond and $A_2B$ stoichiometry.
b) Covalent bond and $A_2B$ stoichiometry.
c) Ionic bond and $AB$ stoichiometry. ✔
d) Covalent bond and $AB$ stoichiometry.

![Figure 3](image1.png)  ![Figure 4](image2.png)

**Figure 3.** Chemical reaction between reagents A and B, and products C and D generated.  **Figure 4.** Graphic representation of A and B atoms.

4.3.4. Question 4 (level 4). From the gaseous reagents in $A$, the most adequate representation of the product generated taking into account the limiting reagent, within the options shown in B, C and D (see Figure 5) corresponds to:

![Figure 5](image3.png)

**Figure 5.** Graphical representation of reaction between $NO$ and $O_2$ ($A$) and their possible combinations ($B$, $C$, $D$) of the products generated.

a) Option B represents the minimum amount of $NO_2$ that can be formed with the initial reagents.
b) Option C because the compound doesn’t require more $O_2$ molecules to react.
c) Option D because the limit reagent is NO and it is totally transformed, leaving $O_2$ excess. ✔
d) None of the options, because the excess reagent is NO and not $O_2$.

The first question (false/true) seeks that through statements that generate doubt, students understand a fundamental concept in chemistry: the bond types. This question generates in the student the need to remember the main characteristics of bond types and the chemical nature of the elements that are grouped in the periodic table. The student must be clear about the term “chemical stability” associated with the electronic configuration of the different elements.

Questions 2, 3 and 4 show a higher level of complexity, which starts with the representation of a chemical reaction that involves four visually distinguishable elements (different color and size), two (A and B) that come together to form two new elements or substances (C and D). In this case, the
student must know the law of defined or constant proportions. "When two or more elements are combined to give a certain compound, they always do so in a constant mass ratio." On the other hand, question 3 has a slightly higher level because from a basic representation of the electronic structure of two different atoms, the student is asked about the type of link that would be formed by joining the two elements and what would be the stoichiometry of the resulting compound. A student must know how the different bond types (ionic, covalent and metallic) are formed and what the stoichiometry of the resulting compound would be like. Finally, question 4 is the most complex, although it assumes control of chemical reactions and stoichiometry concepts, adds another important factor to consider in a reaction, the limit reagent and three different options that the student should analyze and compare with 4 response options.

5. Conclusions
With this project, it is expected to generate a great impact on the following educational aspects in the basic and secondary students: (i) Greater satisfaction on the part of teachers to see their expectations and learning objectives achievable. (ii) Greater satisfaction on the part of students when achieving their objectives, obtaining good grades, using their time better and improving their study habits, which can influence good results also in other subjects they are studying and even in the future subjects. And (iii) strengthening education quality in what corresponds to pedagogical training of those who teach science in secondary education.

Acknowledgments
Spachovsky project has been carried out thanks to the management of several dependencies of the UIS. La Facultad de Ciencias (2017) with the initiative of this project, Rectoría and iPred with its financial support and Escuela de Física for training and meetings provision with IEM linked to the project: Institución Educativa Llanadas-Lebría, Colegio Integrado Mesa de Jéridas-Los Santos and Colegio Técnico Agrícola de Cachira-Norte de Santander.

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