A compilation of more often used teaching strategies in Physics at University level

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(Received March 8, 2017, accepted May 3, 2017)

Abstract

This paper presents a compilation of the most frequently used teaching strategies for teaching physics at university level; looking for an overview of educational innovations implemented to support the development of knowledge in students of physics. To accomplish this, we chose to use the Google search engine, and through specific commands we search in a set of popular Physics indexed journals that focus on teaching. With the information extracted from experiences reported, relevant data is selected and classified for further data discovery and analysis, searching for relationships, between these experiences and application of those teaching strategies. The tool for data analysis is "R". The time frame selected is between the years 2010 to 2015. The results, allow us to describe the strategies most often used, cases of successful educative innovations as well as training requirements for teachers, among others which support the development of knowledge in students of Physics.

Keywords: Teaching Physics, Teaching and learning methods and strategies, didactic strategies.

Resumen

Este trabajo presenta una compilación de las estrategias de enseñanza más frecuentes que se utilizan la enseñanza de la Física a nivel universitario. Con ello se obtiene una visión del estado de la innovación educativa utilizada para apoyar el desarrollo de conocimientos en estudiantes de Física. Para lograr este estudio, se utiliza el buscador Google y sus operadores para realizar búsquedas en revistas indexadas de Física especializadas en enseñanza. Con la información extraída de las experiencias compartidas, se construye un conjunto de datos para su análisis posterior, buscando relaciones entre estas experiencias y la aplicación de las estrategias de enseñanza. Para el análisis de datos, se utiliza la herramienta de software "R". Se analizan artículos publicados en el periodo de 2010 al 2015. Los resultados indican qué estrategias son las más utilizadas, los casos exitosos de innovación educativa, así como también los antecedentes de formación de los profesores y con qué apoyan el desarrollo de conocimiento en los estudiantes de Física.

Palabras clave: Enseñanza de la física, Métodos y estrategias de enseñanza-aprendizaje, estrategias didácticas

PACS: 01.40.Fk, *01.40.gb,* 01.40.Ha

ISSN 1870-9095

I. INTRODUCTION

In frequent daily discussions at our Physics Department, there is always a common topic that arises among the Faculty, and it is related with the difficulties that students face in their general Physics courses., like types of teaching that do not match with their way of learning, misconceptions, failing, among others. We hear and read different experiences about how Physics can be taught more effectively with more positive outcomes, so that students learn their basic concepts and general knowledge required to advance in their curricula. This is very important to guide the students in their learning process with teaching strategies that promote to reach the curricula goals and get proper knowledge.

The goal of this paper is to overview how Physics is currently being taught at University level. It is of our interest to find, which learning paradigms are mainly present in classroom, what kind of cognitive processes are working in synergy with those paradigms, what type of teaching strategies and teaching tools are used to support formal Physics courses.

II. PREVIOUS STUDIES IN TEACHING AND LEARNING PHYSICS STRATEGIES

Looking for another papers, where a compilation of teaching and learning strategies in any discipline was made, we found

that Knight [56] in his book, dedicated a chapter to collect 25 years of *paradigms, strategies and results in physics teaching* under PER (physics education research); at the end, the author provides of strategies and tools to support physics teaching.

Another study that we found, is referred about using big data in education data mining for learning analytics, Sin and Muthu [57]. In this study authors focus in the analysis about students using mobile devices to access online contents, so they made a compilation of studies that lead to a huge table with categories like student performance, pedagogy, data mining, development, learning theory and design, assessments, MOOCs, discourse analytics, teaching styles, among others and their corresponding paper title, authors and year of publication.

Despite both studies are the result of educational research processes, and our work presents only a simple compilation of most used teaching and learning strategies for physics teaching, we find interesting coincidences such as the need to provide more information to teachers regarding the importance of using theories of learning in combination with proper educational planning that leads students to achieve learning objectives, all of those supported by proper didactic strategies, interactions between teachers and students, assessment and tools.

III. MAIN LEARNING THEORIES

Current trends in the educational process emphasize the importance that is now attached to learning and the student, in contrast to the traditional emphasis on teacher and teaching, characteristic of the model of university education prevalent in much of Europe And Latin America which resembles essentially the Napoleonic model, and was conceived to respond to the needs of a society and a market that are disappearing; where well-defined and stable professions are required with clear competence and in many cases even legally established, which barely changed during the professional life. In this model, based on the hypothesis that everything that was not learned in the university would not be learned later; the teachers, key players in the educational process, should ensure that students learn the maximum amount of specific knowledge that would be needed in working life, but, above all, those teachers should ensure that every student achieve academic qualifications without lack of that knowledge, which was essential for the practice of the profession, Ginés [52]. In contrast to this model, the role of the teacher has now changed to become a guide, a tutor and a mentor for the student and their learning, Casas [53]. But in our dynamic society, educational models had changed, and then it is required for teachers to know about learning theories which lead the planning of educative goals as well as the didactic strategies, interactions, evaluation, using of ICT's among other elements that support the achieve of knowledge in students. In Appendix A, there is a table where the main learning theories [54] [55] are described as an exercise to explain briefly some aspects and characteristics of each one, as well as how teacher participation should be and how students must be involved in the development of their learning. Due it is an extensive table, we decided to send it as an appendix to try not to lose much valuable information about the theories of learning.

IV. A BRIEF REVIEW OF PHYSICS TEACHING

There is a collection of known journals specialized in publications related with Physics Education. Only online journals which are open access or which our university has online subscriptions were queried, returning a set of papers which were explored and later classified. Access to the full text was required.

TABLE I. List of reviewed indexed journals specialized in Physics Education.

Journals
American Journal of Physics (AAPT)
Computing in Science and Engineering (AIP)
Journal of the Acoustic Society of America
Latin American Journal of Physics Education
Medical Physics
Physics Teacher
Revista de Enseñanza de la Física (Argentina)
Revista Brasileira de Ensino de Física - RBEF
Revista Mexicana de Física E

These journals, publish articles describing teaching and learning experiences in Physics topics and the science of Physics teaching in general.

In everyday physics teaching, two learning paradigms, cognitivism and constructivism are always present in all classrooms. Depending on the learning design of a course or topic within specific curricula, a cognitive process is selected according to the required knowledge acquisition and skills development needed. This leads to a selection of a cognitive process to support the student learning activities.

TABLE II. List of common models of cognitive processes.

Cognitive Processes
Active Learning
Autonomous Learning
Collaborative Learning
Critical Meaningful Learning
Learning by Inquiry
Meaningful Learning
Situated Learning

After these cognitive processes are selected for the learning activities, then there are a large number of possible teaching and learning strategies that could help and lead to the proper learning outcomes needed in the students.

Once these scenarios had been laid out, then is possible to classify most of the publications that explicitly mention a specific cognitive process and teaching/learning strategy.

TABLE II. List of common learning strategies.

Learning Strategies
Blended Learning
Computer Aided Learning
Critical Thinking
Collaborative Learning
Didactic Sequences
Discussion & Analysis
Experimentation & Observation
Flipped Classroom
Learn by Doing
Online activities
Problem Solving
Reading comprehension
Reflection
Representation
Reverse Engineering
Scale-Up

V. METHOD

In order to have a glimpse of the corresponding learning environments, this type of information can be extracted from recent publications that appear on a collection of known indexed Physics education journals, and which can be accessed on line. Only papers in which the authors explicitly acknowledge and mention some specific didactic strategy, learning paradigm or cognitive process are considered. These cases can give us an insight and indicator of the pedagogical background knowledge of the authors, their intent to address and pedagogically support a determined learning process Papers focused only on a disciplinary topic without any explicit mention of a teaching method or strategy are ignored. Google search engine was used to query directly a specific journal, publisher or online electronic libraries (e.g. scielo.org), with the appropriate boolean operators.

TABLE III. List of common models of cognitive processes.

Search keywords	*Sites*
Physics teaching	scholar.google.com
Problem Based	scitation.aip.org
Learning	revistas.unc.edu.ar
Flipped Classroom	rmf.smf.mx
Meaningful Learning	www.lajpe.org
Active Learning	www.scielo.br
Situated Learning	
Learning by discovery	

The queries, although not exhaustive, were directed to find a set of published papers between 2010 and 2015 years, of teaching and learning experiences that mentioned explicitly pedagogical terms and the course or experience were in some University, see Fig. 1. The query filtered only articles in English, Spanish and Portuguese.

A collection of 51 articles was selected [1]-[51], see Fig. 1. For each of these publications, from the analysis a set of variables were extracted: Title, Journal, First Author, Country of Author, Volume, Year of publication, Learning Paradigm, Cognitive Process, Pedagogical Strategy, Tools, Topic, Keywords, PACS, URL, Language.

With the help of the R software package, a data analysis of these extracted variables is carried out, in order to show explore the current state of Physics teaching at the University level.

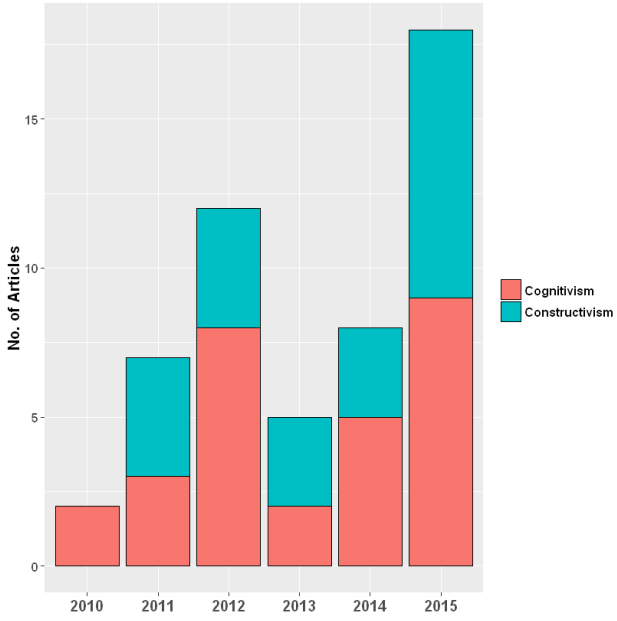

FIGURE 1. Number of articles found per year per learning paradigm that satisfied the selection criteria.

VI. RESULTS AND DISCUSSION

From the analysis, it is found that the learning paradigm cognitivism is being used slightly more (55.8%) than constructivism (44.2%), see Fig.2. Also, more variety of cognitive processes are carried out under cognitivism than constructivism.

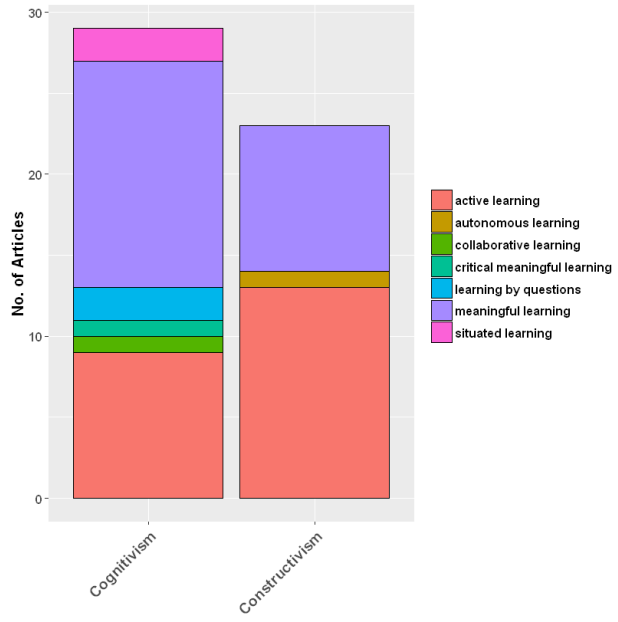

FIGURE 2. Number of articles per learning paradigm per cognitive process.

When the cognitive processes are combined with didactic strategies (see Fig. 3), it is can be noticed that active learning is being used slightly less (42.3%) than meaningful learning (44.2%). The rest of the cognitive processes group, are not used in a significant manner. Also it can be observed that, in the case of meaningful leaning processes, a slightly larger variety of options in didactic strategies are being used in physics classrooms, compared to those in active learning.

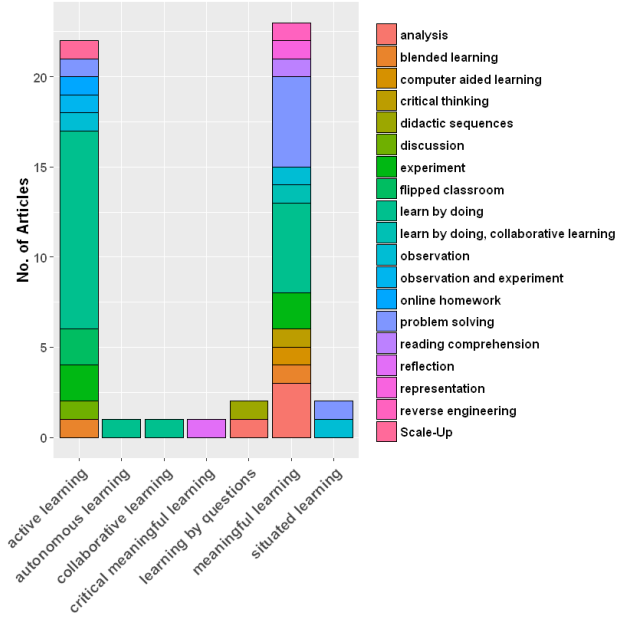

FIGURE 3. Number of articles found per cognitive process per didactic strategy.

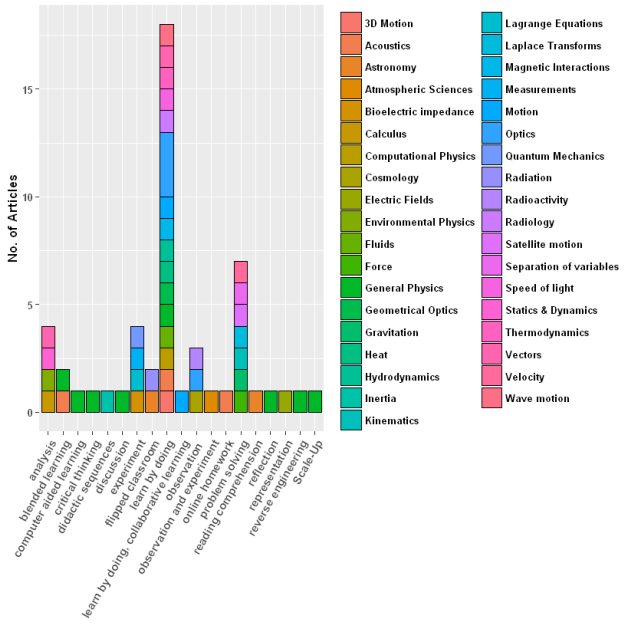

FIGURE 4. Number of articles found per strategy per topic.

Fig. 4, shows a combination of didactic strategies used for teaching a wide variety of Physics topics. It can be seen that the most popular didactic strategy is learn by doing (34.6%), followed in decreasing order by problem solving (13.5%), analysis (7.7%), experiment (7.7%) and observation (5.8%).

From the extracted data, there is a large list of tools that were used for teaching a specific topic. The list of tools by topic are presented in Table IV for completeness.

TABLE IV. List of Tools used in teaching a specific Topic.

Topic	*Tools*
3D Motion	General ICT
Atmospheric Sciences	Computer simulations
Acoustics	Clickers Quizzes
Astronomy	Educational technology Texts
Bioelectric impedance	Spectroscope
Calculus	Multiple choice quizzes
Computational Physics	e-textbook
Cosmology	Plotting
Electric Fields	Simulation
Environmental Physics	Modeling
Fluids	Lab guides
Force	4MAT
General Physics	Cramster website Demonstrating Educational technology Interactive videos Laboratories Simulation Modeling Texts
Geometrical Optics	Simulation
Gravitation	Tests

Heat	Laboratories
Hydrodynamics	Lab Guides
Inertia	Text analysis
Kinematics	Scientific method
Lagrange equations	Computer simulations
Laplace Transforms	Rethinking method
Magnetic Interactions	Tutorials
Measurements	Computer simulations
Motion	Educational technology Previous organizers
Optics	Computer simulations Images Interactive demo classes Multimedia
Quantum Mechanics	Interactive animations
Radiation	Gamification
Radioactivity	Observation
Radiology	MrSCAL
Satellite motion	Diagrams
Separation of variables	Reasoning
Speed of Light	Experiment
Statics & Dynamics	Images
Thermodynamics	4MAT
Vectors	Mobile phones Multiple choice texts
Velocity	Reasoning
Wave motion	Video

VII. CONCLUSIONS

Cognitivism predominates the publications, and is a clear sign, that there is concern by the teacher, that students understand a specific problem before trying to solve it. Students appropriate knowledge or ideas, so that there is an internal change by the acquired knowledge and therefore can establish an approach to find a possible solution to a specific problem. Thus, the meaningful learning cognitive process appears more frequently than active learning that follows the Constructivism learning paradigm. Although both learning paradigms, Cognitivism and Constructivism coexist in the teaching and learning processes as well with other paradigms. They do not exclude each other, they may supplement and enrich a learning activity.

It can be inferred that, the authors have the knowledge to design the learning activities following a methodology of the used teaching strategy. And also show that they have the knowledge to validate if the implemented strategies do work or not.

In some articles that were reviewed and not included in this compilation, the authors do follow a teaching strategy, but do not mention which strategy they use and how they validate them. It can be inferred that, either they do not know what is their strategy and unintentionally apply it or simply they do not want to disclose it, focusing on the disciplinary aspects of Physics topic, putting aside the pedagogical aspects of the learning activity.

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APPENDIX A

	BEHAVIORISM	COGNOSCITIVISM	CONSTRUCTIVISM
Authors	Skinner Watson Pavlov Bandura Desollador Thorndike	Gagné Bruner Anderson Gardner Novak Rummelhart Norman	Vygotsky Piaget Lave y Wenger Bransford Hasselbring Grabinger Spiro y cols.
Characteristics	It studies observable behavior (human behavior, which is analyzed scientifically), considering the environment as a set of stimuli and responses.	It is based on the premise that learning is derived from the experience in the generation of ideas and concepts by the student.	Its main characteristics is the promotion of reflection based on the student's experience, allowing the context and content to be dependent on the structuring of knowledge.
Educative goals	Learning is gradual and continuous, when it is achieved that the student's appropriate	Achieve meaningful learning as well as develop general and specific learning	Learning through the construction of knowledge, which is based on student experiences, through the

	response as a function of the stimulus, a change in the form of behavior is observed.	skills.	performance of activities that are useful in real world.
Teachers rol	It directs the entire teaching-learning process by designing the stimulus-response process and reinforcements, punishments or appropriate stimuli.	The teacher is not the center of the learning process, but his rol is to plan and organize relevant didactic experiences that lead student´s learning.	The role of the teacher must be as a moderator, coordinator, facilitator, mediator and at the same time participant, contextualizing the different activities of the learning process.
Students rol	It has a passive role, is a "blank board" empty of content. To learn depends on the stimuli received from the outside. Learn through memorization and repetition, even if he do not assimilate the concepts, do not understand them and forget them quickly.	The student is an active fellow who process information with the ability of using it to support his learning.	Its role as constructor of both schemes and operational structures, being the last responsible for his own learning process and the active processor of information, constructing the knowledge by himself and no one can replace him in this task
Interaction between students	It is based on a relationship of good behavior, not knowledge creation.	The interaction between the students is based on the linguistic part, through which it is presumed that evidences the process of thought and learning.	It is active and collaborative through work in learning communities, which ideas and concepts are shared with the final goal of knowledge construction.
Relation between teacher and student	The teacher is the active subject who designs activities and stimuli, while the student is a passive subject that does not contribute to his learning.	Relation based on feedback and requires student high level of participation as well as the creation of a positive learning environment by the teacher.	The key is the communicative function of teachers during the whole evaluation process of the educational activity, which is the process through the personality of the student is configured
Cognitive process approach	• Educational objetives • Mastery learning • Multiple intelligences • Meaningful learning • Discovery learning • Expansive learning	• Situated Learning • Experiential education • Learning styles • Organisational learning • De-schooling society • Homeschooling • Critical pedagogy	• Active learning • Collaborative learning • Critical meaningful learning • Experiential learning • Social networking learning • Collaborative inquiry learning
Assessment	The assessment is determined by defined objectives, observable and measurable quantitatively through tests and exams. Not interested in the process, only the achievement of the objectives or behaviors evaluated in the student.	It is focused on the student learning process, using qualitative data and giving greater importance to the strategies used to achieve the objectives, more than the grade that student achieves	It focuses on the evaluation of learning processes, considering the cognitive and affective aspects that students use during the process of constructing their learning.
Use of ICT	Digitized proposal of the programmed teaching, which present a syllabus and a series of exercises and questions and answers aimed at verifying their understanding and acquisition by the student, thanks to a heavy	ICT's are useful resources in promoting learning because they encourage participation among students and allows the creation of programs and systems where the students develop their cognitive abilities.	In constructivist theories, ICT's applications and their tools enhance the active engagement of the student, as well as participation, interaction, feedback and connection with the real context, in such a way as to lead the student to control and be aware of his own

	repetitive load.		learning process.