Five-step guide to flip the classroom and to improve physics teaching at university level



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Abstract

The present paper, describes an educational experience with the goal of developing a proposal for the didactic planning of Computational Physics course (CP), using the Flipped Classroom (FC) method, supported by active learning to promote meaningful learning in physics students of Physics bachelor program at University of Sonora. FC is an innovative educational strategy that emerges in 2007 and within its principles establishes that, mainly, learning is centered on the student and that there are activities that they do outside the classroom and others within it, to the teacher, it is not clear how to carry them out. Due to the above, the question arises as whether if this method facilitates the learning of physics in students who study the subject of computational physics, seeking to carry out the teaching-learning process in a non-traditional way. Then, a 5-step guide has been developed, which involves the proposal for the flipped classroom Method and was implemented in a physics course during two semesters 2016-2 and 2017-1. The students, who passed this subject in both periods, evaluated this experience and the result shows the achievement course learning objective as well as that FC method facilitates the learning of physics.

Keywords: Physics teaching, flipped classroom method, Active learning.

Resumen

El presente trabajo describe una experiencia educativa con el objetivo de desarrollar una propuesta para la planeación didáctica para un curso de Física Computacional, utilizando el Método de Aula Invertida (en inglés Flipped Classroom Method), apoyado en el aprendizaje activo para promover el aprendizaje significativo en los estudiantes de la Licenciatura en Física de la Universidad de Sonora. El Aula Invertida es una estrategia educativa innovadora que surge en el año 2007 y entre sus principios, establece que, principalmente centra el aprendizaje en el estudiante y para ello, el profesor planea y diseña actividades que se llevan a cabo en el aula al igual que otras que se realizan fuera de ella; sin embargo, para el docente no queda claro cómo llevar a cabo dicho diseño y planeación. Por lo anterior, surge la pregunta de si este método facilita el aprendizaje en los estudiantes de este curso, ya que implica llevar a cabo el proceso enseñanza-aprendizaje en forma no tradicional. Se ha desarrollado entonces una guía de 5 pasos para orientar al profesor en implementar el método de aula invertida para este curso durante los semestres 2016-2 y 2017-1. Los alumnos que aprobaron esta asignatura en ambos períodos evaluaron la experiencia y los resultados muestran el logro del objetivo del curso de Física Computacional y corroboran que el Método Aula Invertida les facilitó el aprendizaje de la física.

Palabras clave: enseñanza de la física, método aula invertida, aprendizaje activo.

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I. INTRODUCTION

Education is defined, from a psychological analysis, as a process in which the student modifies his behavior regarding to his environment, "he learns by the mediating action, direct or indirect, from the teacher; this process occurs in a context that may or may not be the school "and is determined by circumstantial and historical factors that can hinder or facilitate its realization. Ibáñez [1].

But, the education process needs to reformulate its practices, starting from the premise that the scenarios and the conditions of this professional practice are dynamic and diverse in their composition and relationships; despite the relevance of the student-teacher dyad (which links the pedagogical tendencies with the theoretical systems on the *Lat. Am. J. Phys. Educ. Vol. 12, No.4, Dec. 2018*

origin of knowledge), it is necessary to explore beyond these two elements to have a more complete picture of the processes that define the educational phenomenon. Hernández [2].

II. CONTEXT

A few texts in-deep describe this process with clarity: how learning activities are designed to achieve the competences proposed in the plans and programs of study; how students are guided on the achievement of the criteria that must be met; they remain empty about the levels of complexity in which the interactions established between agents and factors of educational processes are designed during an instructional http://www.lajpe.org

episode (Ibáñez [1]) and how students acquire and integrate, extend, deepen and use knowledge significantly, up to the development of thought patterns (Marzano [3]). Regarding the teaching of physics, Díaz, Lombaerts and Lizárraga [4] mention that in the teachers there is a concern for the problems that students face in learning this natural science, however, teachers continue to replicate the traditional teaching method adopted from the beginning in front of the classroom, focused mainly on the resolution of disciplinary problems, without stopping to consider the pedagogical aspects of the learners such as the way of learning, context analysis, if they have false ideas, if they drag with misconceptions, if they know how to address a problem before seeking to resolve it, among other aspects. This situation, generates a gap between discipline and pedagogy and, during the academic life of the teachers, in several times the institutions of higher education have given them didactic-pedagogical training, in order to make the teaching-learning process more efficient, but since the teachers are not clear how to implement this training to teach their classes, the didactic planning of the activities of its courses, is determined by a teacher's beliefs system instead of a formal educative planning. For this reason, Tourón [5] states that "it is not possible to achieve the objectives that require deep learning, such as: mastery of the subjects, ability to solve problems, creative and critical thinking, collaborative work, and others, with a model based just on the transmission of knowledge by the teacher".

The above, motivates the development of this work with a proposed method called Flipped Classroom in order to provide a guide to the teacher to carry out a didactic planning that focuses on student's learning and that incorporates aspects such as: promoting student's participation in his own learning development, analyzing the curricular moment of the course to establish the dimension of learning in which they will be working on, diagnosing both the preferred teaching style and the learning styles of the student; looking for students to have a harmonious work in their learning process in the classroom and outside class, determination of the activities that will be carried out in class as well as those that will be carried out outside of class and finally, implement an evaluation that support the development of learning; all this oriented for the students to achieve both the training objective and the discipline knowledge as well as the teacher can have a thoughtful process about their practice.

III. DESCRIPTION OF THE FLIPPED CLASS-ROOM METHOD

In the traditional educational paradigm, the role of the teacher has been framed in such a way that during many decades he or she has been seen as the transmiter of knowledge, that is, someone who reads, interprets and reproduces the corresponding information of a given subject for the student.

The duties of such an educator are to explain in detail the aspects within the curriculum, to clear doubts, to provide bibliography for consultation and evaluation, among others. Díaz and González [6]. As is stated before, this is a model that

has been in existence for a long time in which the educators formation is based practically in his or her professional experience. However, and as García-Valcárcel [7] points out, the formation of educators is a controversial subject that faces continuous changes and innovations that attempt to overcome the deficiencies and problems that are observed through time about the teachers formation. These innovations are focused on promoting a change of paradigm in the classroom: to change from being centered on the teachers to being centered on the students and their developments in their learning; which implies that the time spent in the classroom must be used to work hard on the assimilatin of knowledge through strategies such as problem solving, debates, collective development of proposals, group discussions, while outisde of class the students might access a website to carry out activities previous to or following class, such as: revision of materials, watching videos, reading, answering questionnaires, preparing for upcoming activities, using social media to exchange ideas, etc. Brame [8]. Then, the teaching/learning processes are not just about developing knowledge but also enabling the students to think critically at a high level. The Flipped Classroom strategy promotes lower level thoughtprocess activities to be carried out outside of the classroom while in site classroom time is devoted to attention to analyses, evaluation and creation. Peppino[9].

To achieve the goals of Flipped Classroom Method, we developed the next 5 steps to guide the teachers to implement this strategy in their courses:

Step 1 Diagnosis of teaching and learning methods:

Location of the course goal regarding Marzano's Dimension of Learning, plus Diagnosis of teaching style and Diagnosis of the student's learning style (Figure 1, *see Appendix A for best image view*).



FIGURE 2. Teaching style questionnaire (Appendix F).



FIGURE 1. Step 1 to flip the classroom (Appendix A).

We begin with the diagnosis of the professor's teaching style, as well as the learning style of the students. In this stage, we use two different data collection tools:

Teaching style diagnosis McCarthy [11] (Figure 2, see Appendix F for best image view): this questionnaire contains 6 categories among which are classroom environment, favorite teaching activities, focus of the classes, primary role of the teacher, evaluation method, curriculum approach that in turn intersect each with 4 teaching styles. Teachers must select in each category a preferred style of teaching in the classroom.

Once the above is done, the incidences are summarized vertically and the teaching style with the highest value, denotes they preferred style.

FIGURE 2. Teaching style questionnaire (Appendix F).

Learning style diagnosis (Figure 3, McCarthy and McCarthy [10], see Appendix G for best image view): a questionnairetype instrument with 26 items that the students answer is used, through a series of statements that are presented to the student and that are designed to detect preferences related to their learning style, for example: "when learning, which option Would it describe you better? "Use the scale 4, 3, 2, 1 in the following way: assign a 4 in the option that best describes you, then assign a 1 in the option that least describes you, then

Five-step guide to flip the classroom and to improve physics teaching at university level assign 2 and 3 in the remaining spaces. In each statement, you must place the 4 numbers without repeating them and / or equaling them in it. The idea of the diagnosis is not to have students and teachers remain in the resulting style for the duration of the course, but rather to have the teacher using a didactic planning that guides students to work on all the quadrants of the 4MAT system, so they can develop the corresponding abilities as well as their learning through a variety of strategies.

Diagn	óstico sobre estilos de aprendizaje
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nstruc referen escala un 1 e cada a	ciones de llenado: las siguientes afirmaciones están diseñadas para detectar preferencias ites a tu estilo de aprendizaje al aprender, ¿cuál opción te describiría mejor? utiliza la 4, 3, 2, 1 de la siguiente forma: asigna un 4 en la opción que <i>mejor</i> . te describa, luego asigna n la opción que <u>menos</u> te describa, posteriormente asigna 2 y 3 en los espacios restantes. En firmación debes colocar los 4 números sin repetirlos y/o igualarlos en la misma.
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	entiendo los sentimientos de las personas
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	the haga pensar
	🗢 sea colaborativo
	esté orientado hacia la tarea

FIGURE 3. Learning Styles Questionnaire (Appendix G).

The 4MAT system framework (Figure 4) provides support for the teacher by examining the scope and ampleness of the teaching and learning as well as the different styles of teaching/learning interact under different activities. The roles of the teacher, the students and the activities are adjusted when everyone moves from one quadrant to another within the learning process of 4MAT. When the professors design their teaching activities based on this system, they move the students from experimentation to reflection and conceptualization, and from these to observation and analysis which eventually leads to execution or performance, as we can see in Figure 4, where:

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FIGURE 4. 4MAT System quadrants.

- In **Quadrant 1**, the objective is to engage the students to discuss related experiences to the topic, which is known as *Discussion Method*.

- In Quadrant 2, the objective is to clarify and give key information or key concepts. This is known as the *Information Method.*

- In **Quadrant 3**, the objective is that while students work with some course resources, they experiment and solve problems as soon as they are working with the course material. This method is called *Training/Guidance/Advising Method*.

- In **Quadrant 4**, the objective is to have students adapt their learning to new and original styles. This is called *Self-Discovery Method*.

Once the instrument is answered, those responses must be processed and get individual and group results. This allows guiding the selection of strategies to carry out a balance in the didactic planning of the course.

Step 2: Incorporation of the course context to lead to a structured topics sequence (Figure 5, see Appendix B for best image view).

Relying on Marzano's Learning Dimensions, in this step it is determined in which dimension the objective of the course is located and, starting from this in conjunction with the results of the teaching and learning styles diagnosis, is that we are able to carry out both the structure of the course, the main didactic strategy and the logical sequence of topics (which begin with basic knowledge until reaching the topics with higher complexity), sub-topics and specific activities to be developed.

Step 3 Instructional design of the course (Figure 6, *see Appendix C for best image view*) carries out to the teacher, the selection of activities to be done in-class and out-class, according to what is established in Bloom's Taxonomy for flipped classroom (Figure 7) based on the objective of the course to be achieved and, supported by the principles of Fink's Holistic Active Learning (Figure 8), the results of the diagnoses with the 4MAT System and using the strategy like Problem Based Learning.



FIGURE 5. Step 2 to flip the classroom (Appendix B).



FIGURE 8. Fink's [15] holistic view for active learning.

Flipping the classroom implies that students must do different but rich activities at class and out class, but all of them must lead to achieve learning. To reach this, teachers design those activities using Bloom's taxonomy for flipped classroom where higher thinking skills are done in-class (group mode), like analizing/discussing situations and doubts, evaluating possible solutions and/or creating proposals; at same time teachers also design the out-class activities where lower thinking skills are developed by students (individual mode) through acquisition of information and concepts from primary and secondary sources at course website, using methods like



FIGURE 6. Step 3 to flip the classroom (Appendix C).





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interact with simple simulations, among others. At the same time, teacher supports this activities design using the active learning principles, where according to Felder and Brent[13], active learning is all that, within a course, is related to the students and is far from anything that implies a passive attitude on their part. It is necessary, therefore, that the students become involved in the activities in a dynamic and proactive manner, where they perform tasks and are able to reflect about them. Bonwell and Elson[14]. However, active learning cannot be achieved through the sole lecturing abilities from the professor nor the sole reading abilities of the students, but depends entirely on a method that planifies class and incoporates some or all of the following aspects or endeavors: activities, interactive elements (professorstudents-course contents, students-students), students. promoting the search of information as well as activating learning through specific strategies such as problem solving, group discussions or collaborative work, among others. Some of the characteristics of active learning, according to Web del maestro [16], are:

a) *It is an adventure*, since it involves the student in an active manner for his learning, and allows for discoveries to be made, activities, actions and participating oportunities that enrich the classroom activities and the learning process.

b) *It is captivating,* since it allows the students to explore many different ways to offer different solutions to one problem.

c) *It involves everyone,* both the professor and the students remain active and involved in the construction of learnings.

d) *It is based on the student, not the professor,* since it is the student who creates, debates, asks, proposes, and participates while the professor guides the group.

e) It is a guided process, in which the students experience learning.

f) *It implies participation*, both from the professor and the students, since being part of the experience helps articulate it and provide it with more meaning.

g) *It is relational*, since active learning also implies a social process where the sharing of knowledge enlarges learning, which is why it is important and necessary for students to develop relationships among themselves so they can learn from each other.

Those activities would be like brainstorming, sharing texts, observation of phenomena and take notes, use of simulations to make contrast with real life similar situations, as well as working on collaborative projects.

Step 4 Feedback and Formative-Educative Evaluation (**Figure 9**, see Appendix D for best image view)

Regarding the evaluation, it is important that assessment become an activity where students reinforce their learning instead of make them feel notice that they are part of this phase in the educative process. It is necessary that teacher designs an educative system to grade homework in order to reduce the stress that evaluation could cause in the students. On the other hand, each product is evaluated weekly and a timely and individualized feedback of the delivered work is provided, as well as the performance and participation of the student inside and outside the classroom, giving him the opportunity to

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improve his work and with the possibility of delivering them again without any penalty; therefore, it is important to carry out evaluation procedures that the teacher develops and that allow him to provide students with feedback that is:

Frequent: on class days in the classroom, the teacher takes note of the students' participation; weekly evaluates the work delivered.

Immediate: in class it is important that the teacher stimulate daily participation by involving everyone in thematic discussions and give them feedback in a positive way.

Discriminatory, (based on clear criteria and standards): it is important to make clear the instrument that will be used to carry out the evaluation of the works; for this inverted classroom method, it is proposed to use rubrics for the valuation of delivered products.

Loyally exposed: mainly being kind and respecting the privacy of the student.



FIGURE 9. Step 4 to flip the classroom (Appendix D).

Step 5 Integration of all the elements and creation of the Proposal for the Flipped Classroom Method (Figure 10, *see Appendix E for best image view*).

In this final step, with the whole integration of the Marzano's Learning Dimensions, the 4MAT system, the structure and logical sequence of the course, the instructional strategy, the Guide for the Integrated Design of Courses, the Taxonomies of Bloom, the Holistic Model for Active Learning and the Educative Evaluation, we have as a result our Proposal for the Flipped Classroom Method:



FIGURE 10. Step 5 to flip the classroom (Appendix E).

These are the principles of the Flipped Classroom Method, which guide professors and students in their search for efficiency in the classroom, as well as promoting off site tasks for students. During class, instead, the plan is to dedicate that time to discussion, clarification of doubts and more creative activities that require the presence and guidance of the teacher. This can be carried out in groups or individually, allowing for different rhythms to be established for every student according to their skills and to improve the overall environment of classroom work because every student is an active member. Techniques and didactic strategies can be introduced such a differentiated instruction, learning based on projects, problem solving, situated and meaningful learning.

IV. IMPLEMENTATION OF THE FLIPPED CLASSROOM METHOD IN A PHYSICS COURSE

To provide an example of how the didactic planning would be for a Flipped Classroom Model, a general description is now to be explained for a topic of a Computational Physics course (Bachelor in Physics program at University of Sonora, Mexico) and is developed over the first five weeks (the rest of the weeks are designed in a similar manner, just changing the contexts and the level of complexity of the learning activities):

Teaching and learning styles (4MAT System):

- The results for the professor selected for this study place him mainly within type 2 of the teaching methods.
- the students are mostly defined within the 2nd style of learning.

As we can see, both the professor and the students coincide with Style 2 (Analytical) within the teaching/learning styles. While the students seek to reflect about new ideas and connect them to their previous knowledge through the creation of models and developing new theories, the professor must guide them and get them to focus on the course material by using a logical and structured organization of the topics, themes, lectures and support tools, as well as promoting note-taking activities. However, the idea of the diagnosis is not to have students and teachers remain in the resulting style for the duration of the course, but rather to have the teacher develop a didactic planning that guides students to work on all the quadrants of the 4MAT system, so they can develop the corresponding abilities and construct their learning through a variety of strategies.

Computational Physics Course Marzano's Dimension of learning:

If we recall the general objective for the CP course, we can see that it is to "develop abilities in the students for the use of experimental, numeric, computational and analytical techniques to solve Physics problems that involve within them algebraic, matricial, and ordinary differential equation problems." Since the students must make decisions about what techniques they must use to solve Physics problems presented during the course, we locate this course in the **4**th

Dimension: to use knowledge meaningfully, in which the most effective learning occurs, being the teacher capable of using knowledge to perform meaningful tasks, and activities that promote the meaningful use of the student's knowledge, as well as their decision making, research and problem solving activities.

Applying the Flipped Classroom Method:

Week 1: General Introduction to the CP course, presenting the support website <u>http://computacional1.pbworks.com</u> and describing the first topic of the course: The Structure of the Atmosphere.

Topic: Introduction of the Flipped Classroom Method for the CP course.

Professor's Activity in Class: The method to be utilized during the course is explained, as well as the format of activities and products to be realized and delivered, evaluation forms, etc. The students are shown how to register on the github.com website, where the students will upload all their products and will form their electronic portfolio of evidences. Also, the students will be indicated which closed social media support group (Facebook in this case) they will be using, requiring them to become a part of that group. Once these steps are completed, the students are asked to read the corresponding material before next class session, and to extract the main concepts regarding the structure of the atmosphere. (*Quadrant* 2 – *Information Method*).

Student's activities in class: Each student registers in the pbworks.com website and requests permission to edit within the course's portal, so they can register their data in the page where their progress will be measured (full name, email, URL for their electronic portfolio in Github.com). (*Quadrant 4 – Self-Discovery Method*).

Posting of the next activity in the portal: The teacher announces his or her post to the student Facebook group, so they can read about it and get to know the next activity. (Quadrant 2 - Information Method).

Student's activity outside of class: Once the previous steps have been completed, the student learns about the activities to be carried out during the first topic, and begins a glossary of concepts derived from the readings. (*Quadrant 4 – Self-Discovery Method*)

Week 2: The structure of the Atmosphere.

Topic: Properties of the Atmosphere.

Professor's Activity in Class: (Activation of learning) The professor promotes participation through a brainstorming session regarding the main physical phenomena that occur in the atmosphere, as well as what the physical properties of these are, such as: pressure, temperature, relative humidity and others. Through this participation (Ouadrant 1 -Discussion Method), it is sought to learn about the relationship between these physical phenomena and the physical properties of the atmosphere, as well as learning about which of these phenomena might have been already experienced by the students. The students have previously been acquainted with the subject through their readings and prepare a synthesis of the indicated readings. A website is now presented from the University of Wyoming that provides data from the daily atmospheric scans (or probes) performed by various governmental agencies from the USA and Mexico. (Quadrant 2- Information Method).

Student's activities in class: The professor asks each student to explore the atmospheric scans (probes) portal and choose a place in the USA and one in Mexico, so the student then will download the corresponding data of the day. (*Quadrant 3 – Guidance Method*)

Student's activity outside of class: Each student creates a synthesis about the structure and properties of the atmosphere, to which he or she will add images and graphs from the selected locations. For this activity, the student has been asked to use the online tool "LaTeX" to elaborate the activity's report. Each student reads (*Quadrant 4 – Self-Discovery Method*) manuals on how to elaborate documents on LaTeX, how to add images, write equations, etc. The experiences when using LaTeX can vary significantly, some students are able to use it easily and some are not. Interaction between students is promoted, especially between those who can use the online tool and those who are not. They are asked to share links in the discussion group on Facebook that will make everybody's assignments easier or to pose their questions there to receive support from their peers.

Posting of the next activity in the website: The teacher announces his or her post to the student Facebook group, so they can read about it and get to know the next activity. (*Quadrant* 2 - Information Method).

Week 3: New topic: Preparing atmospheric probe data for analysis.

Topic: Data filtering.

Professor's activity in class: (*Activation of learning*) The teacher introduces the filtering of atmospheric data topic for its analysis, asking the students to mention the types of atmospheric phenomena and their physical properties studied

the week before. Then, the educator shows a code (command sequence) in a BASH translator with the goal of automatically downloading one year's worth of data from the University of Wyoming website. The teacher promotes participation for the analysis of command sequences and the tasks they perform so the group can find the set of commands and the most logical and sequential organization to filter out data garbage. The tool EMACS is modeled after to filter the information automatically from a set of data (what is downloaded is a text document) and to have the set ready for its use in graphs and analysis. (*Quadrant 1 – Discussion Method*).

Student's activities in class: Each student takes a copy of the code to automatically download a year's worth of data from the probe data website. The students adapt the code for his desired location. Both professor and students generate a guided-counseling activity for everyone, mostly to help those who have problems modifying the code, as well as to suggest changes when the chosen locations have too much missing data. The student is asked to design his or her own data extraction strategy from the full data archive while recognizing patterns within them using the commands from the EMACS tool. The teacher then verifies that the data filtering process has been adequate, since otherwise corrections will have to be made and it will be necessary to begin from scratch again. (*Quadrant 3 – Guidance Method*).

Student's activities outside of class: Each student works with their data bank and the Emacs tool to later perform a graphic analysis of their years' worth of data. At the end, the students are asked to elaborate a report using the familiar tool LaTex, and to upload the finished report and work archives to his or her online file. It is encouraged that the students share results, similitudes, and differences among their locations. (*Quadrant 1 – Discussion Method*)

Posting of the next activity in the portal: The teacher announces his or her post to the student Facebook group, so they can read about it and get to know the next activity. (*Ouadrant* 2 - Information Method).

Week 4: Preparing atmospheric probe data for analysis. Topic: Exploratory Analysis of Data.

Professor's activity in class: (*Activation of learning*) The professor begins a discussion asking the students to identify – within the set of data they downloaded and filtered the previous week – the minimum, maximum, average and quartile distribution parameters in a set of data with the goal of linking them to the Exploratory Analysis of Data theme. Through this process, it is sought that the students produce distributions of certain atmospheric variables present within the sets of data being manipulated. For this purpose, the students are lead to distinguish the different forms there are to process data to generate these distributions, given the volume of said data it is necessary to use computational strategies to carry out these procedures. (*Quadrant 1 – Discussion Method*).

The educator models the use of the programming environment and data work tools with the Python programming language. The data archive reading process is described, to know the annual distribution of values of specific atmospheric variables in the atmosphere. The data analysis is supported by using the Python Pandas library (*Quadrant 3 – Guidance Method*).

Student's activity in class: Each student will work with their own data to produce the monthly distribution corresponding to their analyzed locations. For this, they have been provided a series of readings and documents regarding the analysis of data with Python and data manipulation libraries. (*Quadrant 4 – Self-Discovery Method*).

Student's activity outside of class: The student will use these tools to work on his or her data and repeat the analysis. Once that is finished, the student will proceed to elaborate an activity report in LaTeX to then upload said report and the corresponding archives to his or her online file. (*Quadrant 4 – Self-Discovery Method*) Collaboration is encouraged among the students to share their difficulties and experiences in the analysis of data. They are asked to share, within the Facebook group, some of their experiences, suggestions or doubts so that their peers can provide support. (*Quadrant 1 – Discussion Method*).

Posting of the next activity in the portal: The teacher announces his or her post to the student Facebook group, so they can read about it and get to know the next activity. (*Quadrant* 2 - Information Method).

Week 5: Preparing atmospheric probe data for analysis.

Topic: Visualization of data (Graphs).

Professor's activity in class: (Activation of learning) Once the students have read and analyzed the data of each location, the Matplotlib library of Python is introduced for the visualization and graphic display of their data. A gallery of graphs is shown that are eligible to be reproduced with Matplotlib and their corresponding codes. The activity consists in producing certain graphs of the analyzed data. For example, they are asked to create a graph that reflects how atmospheric pressure is affected by height, or the variation of temperature with respect to height. (*Quadrant 3 – Guidance Method / Quadrant 4 – Self-Discovery Method*).

Student's activity in class: The student explores the Matplotlib library, and adapts code segments to produce the requested graphs. (*Quadrant 4 – Self-Discovery Method*).

Student's activity outside of class: The student reads the additional resources presented for the current activity, to understand a set of functions that help to produce the types of graphs being requested. It is encouraged that students share their experiences or questions in the Facebook group to make their work easier and to ensure that all the students achieve the same goals. Once the activity is finished, they will elaborate a report to be uploaded along with the corresponding archives to their online file of evidences. (*Quadrant 4 – Self-Discovery Method / Quadrant 1 – Discussion Method*).

Evaluation and feedback

Rubric for the evaluation of products (tasks) turned in during the CP course. The teacher elaborates a rubric (Table 1) to evaluate and grade the products from the activities the students; they upload the files to the online learning evidence file (*e*-folio) at GitHub.com. Following to the conclusion of each activity, the professor provides feedback to each student regarding the contents of the products that were developed and submitted, guided by the criteria to evaluate each task. As has been mentioned, the student can improve what he submitted and re-submit without penalty. At the same time, the teacher reviews the suggestions from each student after answering the feedback questionnaire, then creates a compilation of these suggestions with the goal of making the necessary adjustments as the course goes along to ensure the improvement of the course for future editions.

Table I. developed	Rubric for the in the Compute	ne evaluation ar ational Physics c	nd grade of pro ourse	oducts (tasks)
	Excellent (100)	Satisfactory (80)	Can Improve (60)	Inadecuate (40)
Products	It is evident that there is complete comprehe nsion of the activity. Includes all the elements required by the activity	It is evident that there is comprehensi on of the activity. Includes two-thirds of the elements required by the activity	It is evident that there is partial comprehensi on of the activity. Includes one-third of the elements required by the activity	Evidence indicates little comprehens ion of the activity. Does not include even one- third of the elements required by the activity
Report	Cover Page Abstract Introducti on Structured and coherent document Uses various references , aside from the basic ones. Uses various figures, graphs, and tables to support the text, congruent with the code and the text. Clear writting	Cover Page Introduction Structured and coherent document Uses few references, aside from the basic ones. Uses few figures, graphs, and tables to support the text, congruent with the code and the text. Clear writting	Cover Page Coherent document Uses only basic references. Uses one or two figures, graphs, and tables to support the text, congruent with the code and the text. Clear writting	Cover Page Document is too short or incoherent Lacks references General incongruity , does not use figures, graphs or code to support the text. Unclear writting
Work blog / chronolo gy	History of developm ent with source codes mandatori ly entirely functional	History of development with source codes mandatorily partially functional	History of development with source codes mandatorily not functional	Missing
Aftertho ughts (reflectio n) about develop ment of activities	Responds entirely to posed questions	Responds partially to posed questions	Tries but does not respond to posed questions	Missing

<i>J</i> •	jup me enablis com and to improve physics reacting an anti-ensity tevel								
	Comple	Attachme	Attachments	Attachments	No				
	mentary	nts that	that partially	that do not	attachments				
	archives/	entirely	support	support					
	Docume	support	presented	presented					
	nts	presented	evidence	evidence					
		evidence							

Topic Closing

In the last five activities, the topic Structure of the Atmosphere has been used to introduce a set of tools (Emacs, LaTeX, Python, Pandas, Matplotlib), as well as the materials that appear in the course portal in PBworks, their online file of evidences in Github.com and their discussions within the closed Facebook support group.

The topic *Structure of the Atmosphere* has been used as a detonator of interest in the Physics students. The concept of the Atmosphere is familiar to the student, yet he or she has learned new things about the topic and has been granted the opportunity to work with data manipulation for its analysis, visualization and interpretation of phenomena that occurs in the Atmosphere. All of this with the help of real life tools that are used daily within the Computational Physics field.

The student is asked to answer (freely) a document with a series of questions, which require them to reflect (active learning principles) upon what he or she learned and make comments about their experience with flipped classroom method and active learning. Those comments will help to guide any adjustments that need to be made during the course as well as possibly shaping future editions of the course:

- Do you consider useful the activation of learning activities? Why?
- What was your first impression when using all the tools that were introduced?
- What things were difficult to do when using these tools? Why?
- What was your favorite thing about the activities developed?
- What changes would you suggest?
- What do you consider that was missing from these activities?

Posting of the new topic and next activity in course website: The teacher announces it through a post to the students Facebook group, so they can read about it and get to know the next activity. (*Quadrant 2 – Information Method*).

V. RESULTS

The Computational Physics course was taken by five students in the 2016-2 semester, out of which 3 success the course, 1 failed and 1 deserted. During the 2017-1 semester, a total of 19 students were registered for the class, out of which 18 success and 1 failed. The students whom success from both semesters were then kindly asked to answer (voluntarily) the questionnaire that evaluated their educational experience during the CP course. The questionnaire has 20 questions, with a Likert scale for their answers. 21 students answered the questionnaire.

The analysis of results of the survey applied to the students in this course, shows, initially, a positive effect of the strategies designed, a good reception and adaptation of the students to the proposed topics and activities. Also, they consider that the way the teacher worked contributed to their learning process, as well as the used tools, including the course website <u>http://computacional1.pbworks.com</u>. One of the most significant aspect is that they refer being able to move some acquired knowledge in CPC to other courses.

Some aspects to improve from the student's point of view are: to increase the collaborative work, to improve the flow of student's contributions to the process in the classroom or by social networks; to promote more activities that have impact beyond the course itself and to reflect in other courses.

As a synthesis, it is observed that the students received the course proposal well, they obtained a good result in carrying out each one of the assigned activities; the teacher managed to involve them in the course development and they think that it is necessary to improve the flow of ideas that they can raise, and to increase activities with collaborative work. Then consider favorably to have other courses with these strategies and to improve, in those other subjects, increasing communication both in person and through social networks.

VI. CONCLUSIONS

Analyzing the results of the student's evaluation as well as the grades they got, we can infer that the use of the Flipped Classroom Method to promote and encourage active learning is effective, given that the students modified their behavior, going from a passive to an active attitude, where since the third week of classes they were practically already ahead of their expected progress with additional information or questions for the classroom activities. These results tell us that the students achieved the learning goal of the course and confirm that the Flipped Classroom Method facilitates the learning of physics in the students. Taking in consideration that this was a new way of participating in class, students adopted very fast the way of working and it facilitated the course's dynamic. We can say that students are open to new ways to approach learning, and professors would take advantage of this aspect to improve his/hers teaching style, looking for boosting student learning effectiveness.

It is important to mention that these experiences with the Flipped Classroom are possible due to the fact some infrastructure is present at university; key aspects of this infrastructure include: internet connectivity, the ability to take/impart classes in a computer lab where every student has access to a computer, a space that facilitates and enables collaborative work, the support from social media (such as Facebook) and the website designed to provide support to the CP course. This educative environment promotes learning and improves the student's performance, as well as creates a social environment and develops a constructive learning where everybody participates, collaborates, and achieves the learning goals. Therefore, this method has been applied to a course at the bachelor level, it is considered entirely possible that its implementation in higher education and graduate courses, would be just as good as rich for to those who are involved.

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FIGURE 2. Teaching style questionnaire

APPENDIX B STEP 2





Bloom's taxonomy on flipped classroom by Ian Kinchin, https://profkinchinblog.wordpress.com/tag/blooms-taxonomy/





APPENDIX E STEP 5



APPENDIX F

Questionnaire applied to the Instructor for knowing the teaching styles

Style Ramifications for Teachers and their I	avorite Strategie	S				
For each characteristic (ITEMS 1-6) please chosee the one option that seems most appropriate by placing a check in the column to the right of the descriptor.	Type One		Type Two	Type Three	Type Four	
Then add up the columns to get a sense of what teaching approach you might prefer the most.	Insightful Learners		Analytic Learners	Common Sense Leearners	Dynamic Learners	
1. Classroom Climate	Comfortable with small group interaction		Business-like and teacher-directed	Hands-on and skills-oriented	Spontaneous, diverse and flexible	
2. Favored Teaching Activities	Group dynamics, sharing and listening		Lectures, expert data	Programmed Practice	Indepen dent Projects	
3. Lesson Focus	Student perceptions		Detailed explanations	Experiments	Open-ended tasks	
4. Teacher's Primary Role	Facilitator		Scholar	Coach	Challenger	
5. Evaluation Methods	Group work. Analyses of perceptions and realities		Essay work and readings	Skills demonstration	Project portfolios	
6. Curriculum Focus	Connections to Current Students		Key Ideas	Skills Development	Creating Performance Options	
TOTALS of EACH COLUMN						

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APPENDIX G

Questionnaire applied to students for knowing their learning styles.

"El saber de mis hijos hará mi grandeza"	
Diagnóstico sobre estilos de aprendizaje	
Cuestionario sobre Estilos de Aprendizaje Núm. de expediente: Lic. en	
Instrucciones de llenado: las siguientes afirmacione referentes a tu estilo de aprendizaje al aprender, ¿ escala <u>4, 3, 2, 1</u> de la siguiente forma: asigna un 4 en un 1 en la opción que <u>menos</u> te describa, posteriorm cada afirmación debes colocar los 4 números sin rep 1. 1. Soy excelente cuando	s están diseñadas para detectar preferencias cuál opción te describiría mejor? utiliza la la opción que <u>mejor</u> te describa, luego asigna ente asigna 2 y 3 en los espacios restantes. En petirlos y/o igualarlos en la misma.
tomo decisiones realistas	
Ilego a conclusiones precisas	
descubro relaciones ocultas	
entiendo los sentimientos de las personas	
2. Es más importante que un ambiente de aprendizaje	
te haga pensar	
📰 💽 sea colaborativo	
🗄 🌲 esté orientado hacia la tarea	

	experimentar y manipular
	escuchar y compartir
	intuir y explorar
	reflexionar y pensar
I. La	ente me identifica como una persona
	support of the second s
	🗢 creativa
	sensible
	🗢 lógica
	mi experiencia al planear
	mi practicidad
	mi capacidad de escuchar
6. Al a	prender disfruto
	explorar posibilidades ocultas
	Carlos and the second s
	crear relaciones pronias

me es	fuerzo al lograr
II (… consenso
II (precisión
II (… eficiencia
∷ (… aventura
Gener	almente soy
II (… creativo
∷ (… preciso
II (decisivo
∷ (… intuitivo
III (impulsivo
∷ (… muy sensible
II (muy ansioso por concluir
∷ (… muy crítico
). Gene	eralmente soy
∷ (… cooperativo
H (ordenado
₩ (₩ (ordenado directo