Flipped classroom method as a strategy to promote active learning in physics students at university level

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(Received January 15, 2017, accepted February 20, 2017)

Abstract

This paper presents an educational experience for a computational physics course taught at university level where, flipped classroom method is used and includes a synergy between Fink's model, the 4MAT system, and formative assessment. This process of educational innovation aims to lead students to active learning; therefore, all activities during the course are designed according to: characteristics of the discipline studied, curricular requirements in students; learning styles, attitudes, previous knowledge, among others. Those aspects allow us to determine what is discussed in the classroom and which strategy to use; the research should be done by students, and how to supervise it. It is expected that students during the course: participate actively in sessions at school as well as thru social networks, reach course learning goals, develop specific skills, transfer course knowledge to others and interact with the online system where course contents are located.

Keywords: flipped classroom, 4MAT, learning physics

Resumen

Este trabajo presenta una experiencia educativa en un curso de física computacional enseñado a nivel universitario donde, se utiliza el método aula invertida. Este es utilizado en sinergia con el modelo de Fink, el Sistema 4MAT y una evaluación formativa. Este proceso de innovación educativa busca conducir al estudiante hacia el aprendizaje activo, por lo tanto, todas las actividades durante el curso, son diseñadas de acuerdo con: las características de la disciplina estudiada, estilos de aprendizaje, actitudes, conocimientos previos, entre otros. Estos aspectos nos permiten determinar lo que se discute en el aula y bajo cuál estrategia, la investigación que deben realizar los estudiantes y cómo supervisarlo. Se espera entonces que durante el curso, los alumnos participen activamente en las sesiones escolares así como a través de las redes sociales, alcancen los objetivos del curso, desarrollen las habilidades, transfieran los conocimientos adquiridos de este curso a otros e interactúen con el sistema en línea donde se encuentran alojados los contenidos del curso

Palabras clave: aula invertida, 4MAT, aprendizaje de la física

PACS:01.40.Di, 01.40.gb, 01.40.Fk **ISSN 1870-9095**

I. INTRODUCTION

The educational system faces a great challenge: to train students with the capacities that allow them to perform effectively. In order for educational institutions to face this challenge (with conditions, subjects, and objects) in a changing nature; it is required that the educational practices may vary according to the condition that is required to obtain an expected product. Education needs to reformulate its educational practices, starting from the premise that the scenarios and the conditions of the exercise of a professional practice are dynamic and variant.

Current tendencies in educational processes, requires shifting from the traditional emphasis placed on teaching to a centered learning model. Thus, the role of the teacher changes to become a guide, a tutor and a mentor for the student and their learning. Casas[1]. García-Valcárcel[7] emphasize the teachers training and their teaching style are a controversial subject, with continuous changes and innovations that try to overcome the deficiencies and problems that are observed in classroom.

But these changes are not automatic, professors need to be trained for the most important aspect in a course: planning the class and to achieve this, is required that teacher acquires:

- knowledge in didactics, psychology of learning, technological resources and mastery of the subject that is taught,
- planning skills (organization of teaching), intervention (communication techniques, group management), and assessment,
- adopting positive attitudes such as responsibility, understanding, reflection, self-criticism, research on teaching.

These requirements in teachers are very valuable and may be more willing to incorporate new ways of teaching a science. This is the pretension of this work, which refers to a course in computational physics, which belongs to the bachelor program in physics of the University of Sonora.

II. NATURE OF COMPUTATIONAL PHYSICS COURSE (CPC)

The course is planned for the fourth semester of the Bachelor in Physics program; it has as prerequisite having approved and passed three courses: Ordinary Differential Equations, Linear Algebra, and FORTRAN Language Programming. It is part of the mandatory professional courses of the program, which has the goal to train the student in the use of experimental techniques, giving him/her the analytic methods, numerical and computational techniques needed for his/her professional development. Bachelor in Physics program[1]. The CPC course focuses on developing students' capability to solve physics problems (Table I) that involve algebraic or matrix problems, as well as those which involve the use of ordinary differential equations.

Table I. Student´s specific and transversal skills at CPC

Specific Skills	Transversal Skills
Install and configure software applications and tools	Scientific and technical document composition
Work in diverse operating systems and configure program development environments	Reading in a second language different to their native language
Use of an ASCII text editor, for working in programming environments	Use of Information and Communication Technologies (ICT).
Construct function and collected data graphics for their analysis	Time management
Scientific document preparation that include mathematical equations, tables and graphics	Complex thinking
Use of scientific programming languages and specialized software libraries	Self-learning
Select appropriate algorithms for the numeric solution of ordinary differential equations	Problem solving in holistic form
Use of general computational algebra systems for symbolic manipulation, numerical solutions and visualization	Collaborative work

III. OFFICIAL PROGRAM ASPECTS OF CPC

1. Suggested didactic strategies for CPC

a. *Main strategies:*
Learner centered, promoting active participation as well as skills development in the involved computational tools and methods.

b. *Course development*:
The course is carried out in a workshop format, under project and problem based learning cognitive process.

c. *Educational technology:*
A Linux based computer lab, with free and open source software composed of symbolic, numerical and visualization systems; online content management system hosting contents, digital resources and activities descriptions for the students; access to computer systems with the appropriate computational tools like high-level programming languages, computer algebra systems, electronic typographic systems and visualization tools.

2. Assessment

a. Students must attend to class as it is established in the scholar calendar
b. Each week students must develop and deliver a product
c. Students must take and pass all course exams
d. At the end of the semester, students must have attended at least 75% of face to face class in order to access ordinary grades; on the opposite they only have access to extraordinary grades.

Course development

The course is carried out as a workshop that includes individual as well as collaborative work. Traditionally environments to develop this class are classroom (3 hours a week), and computing laboratory (2 hours a week). Face to face group sessions are organized at the beginning of each project, where the problem to be solved is discussed. Each following problem has a greater complexity level, therefore the structured sequence for course contents by Fink[6] (Figure 1) was used to define projects, its duration and their order by complexity level of learning.

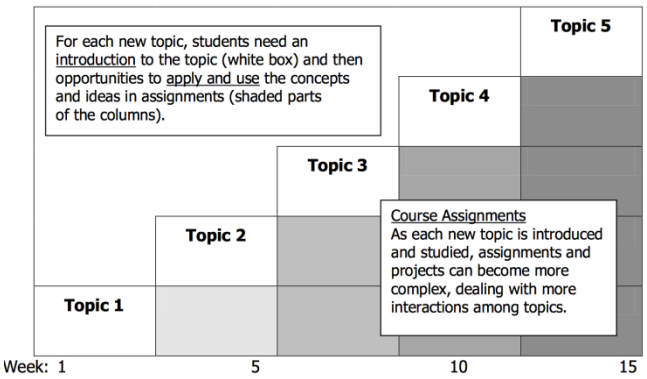

Figure1. Structured sequence for course contents, Fink [6]

Students are motivated to activate their previous knowledge in order to start analyzing possible solution scenarios. Also group sessions are carried out when all the students (individually or in group) cannot overcome a specific problem, and then a discussion is guided by the instructor to explore different strategies in order to advance in the problem solution. Also, there are periodic face to face individual sessions or thru a social network group, in order to follow up on students, to clarify doubts about the complexity of the problem or answer specific questions. This will depend on each student's individual learning curve, previous academic background and computational skills. The rest of the time, the student works autonomously and at some points in collaboration with fellow classmates. The activities are done using a variety of platforms as well as free and open source software, which are mentioned in Table II. The essential characteristic of these tools is, that they can be freely downloaded from the Internet and there are versions available for almost all operating systems (Windows, MacOS, Linux and others), or they are online tools that can be used thru any Internet web browser (Firefox, Safari, Google Chrome, Opera, Internet Explorer). These features allow versatility and portability for the user in any working environment. On the other hand, it helps the students develop the necessary skills to download, install and configure software tools on their personal computers or in the ones in the computer lab. In any case, the student has the choice of working in an environment that makes him feel comfortable or try a new one that more experienced classmates use.

Table II. List of software tools used on CPC 2016-2

Purpose	Tool
Document preparation	Latex
Data editor	Emacs
High level Programming Language – Plotting tools	Python - Matplotlib
Exploratory Data Analysis	Pandas
Interactive data science and scientific computing	Jupyter Notebooks
Personal Electronic Portfolio (*e*-folio)	Github

IV. ASPECTS TO CONSIDER IN THE COURSE DESIGN

To develop the course design, it was necessary to keep in mind the nature of CPC, its learning goals and also the official course aspects, because centering the learning in students strategy and workshop carry out method implicate, for teaching, going far away from just lecturing. It is required to involve students to be active in developing their knowledge and skills, and at the same time, it needs from the professor to come out from his comfort zone of teaching and explore playing different roles to promote learning in students. In conclusion, *teach in a different way*.

1. FLIPPED CLASSROOM DELIVERY METHOD

However to get students involved into their own learning construction, it is important that the class becomes dynamic in its delivery method, which requires focusing in using the time in classroom to do a harder work on assimilating knowledge through strategies like problem solving, debates, developing proposals, and discussion among others; while outside of class, students may gain first exposure to new material like watch videos, read text, answer quizzes (printed or online), review activities, use social networks to exchange ideas, etc. Brame[3]. Those are flipped classroom principles and are supposed to lead professors and students, to find efficiency in activities at classroom; at the same time, students have the responsibility of accomplishing activities before going back to school (outclass).

2. ACTIVE LEARNING

In accordance with Felder and Brent [5], active learning is all what is related to students in a course, and is far away of just a passive attitude, so it is required to involve pupils into dynamic and proactive activities where they *do* things and may have *reflection* about it. Bonwell and Eison[2].
But active learning is not possible just with lecturing and reading texts. It becomes important to plan the class using a model and/or method which integrates activities, elements of interaction (between professor and students, students and course contents, students and students), go for/receiving information and move forward to activation of learning by means of problem solving, group discussion, analysis, among other strategies.

3. TEACHING AND LEARNING STYLES

This is a big challenge for professors because most of them are used to teach the way they were taught, and often this is mainly based on the form their teachers used to, but this does not always work for all students. Professors should necessarily diagnose the student's learning style, but also recognize his/hers own teaching style, and with this information look for a strategy to make them compatible in class McCarthy[8]; simultaneously, teachers also require to use a model for course design which integrates prior styles+course learning goals+course planning+proper assesment in order to look for the students learning success.

At this point, essentials questions emerge in teachers (whom finally decide and design course planning and activities): how to activate learning in students? How to flip the classroom and decide which activities will be developed in class and which ones will go outclass? Which model should be used to lead course design to respond properly to those questions? *Is there a model/method which integrates flipped classroom, active learning and teaching and learning styles?*

MODEL FOR INTEGRATED COURSE DESIGN

In our search we had the objective to find a model or method that allow the integration of the aspects mentioned as well as the permanent interaction between them instead of one in a linear mode. We find those requirements of Integrated Course Design from Fink[6] (Figure 2).

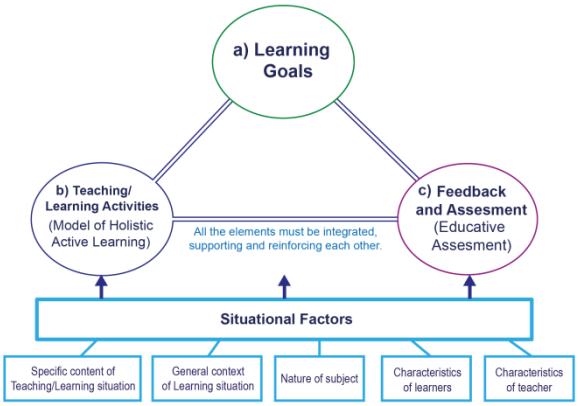

Figure 2. Model for Integrated Course Design

This model is composed by 4 aspects, and all of them are always interacting with each other in order to reach learning in students:

a) *Learning goals*; it is important for both teachers and pupils, to be clear about what is going to be learnt and how it is possible to use this knowledge not only to solve problems, but to change their way of thinking about others and themselves.

b) *Teaching and Learning activities*; here Professors must plan course activities which lead to achieve learning goals, using the Model for Holistic Active Learning (MHAL) (Figure 3).

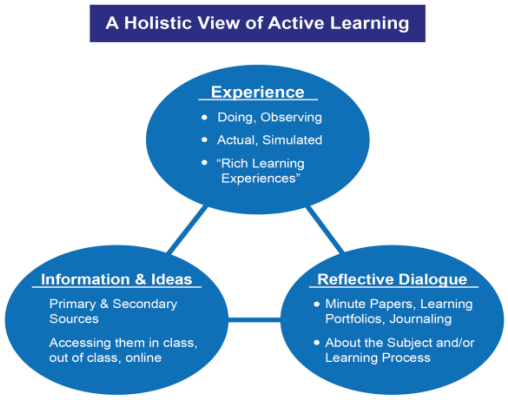

Figure 3. Model for Holistic Active Learning. Fink [6]

c) *Feedback and Assessment*; through proper activities related to this step it is possible to know if learning goals are being accomplished ("FIDeLity" Feedback).

d) *Situational Factor*; in this step is important to specify:

a. *Specific content of teaching and learning situation*: how will the course be delivered? How many students will be at class?

b. *General context of learning situation*: what is expected from this course to contribute to next courses as well as student knowledge acquire?

c. *Nature of subject*: is this course theoretical, practical or a combination? What is the prior knowledge of students for this course?

d. *Characteristic of learners*: which is their life situation, learning goals, expectations and preferred learning styles of students (Figure 4)?

e. *Characteristic of teacher*: what beliefs and values does the teacher have about teaching and learning? What is his/hers teaching style (Figure 4)? What is the level of knowledge that the teacher has about this subject?

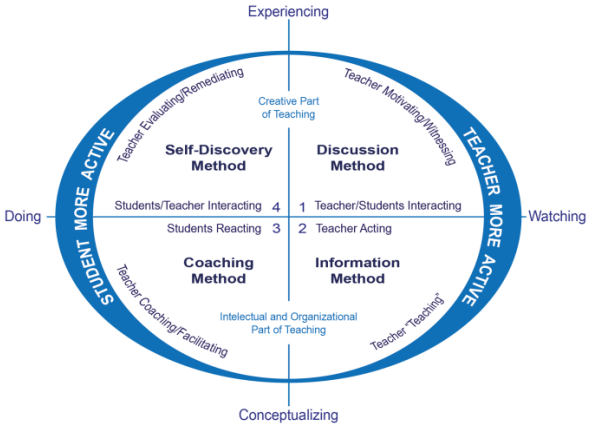

Figure 4. Teacher and Students Learning Style (4MAT System) by McCarthy [9]

V. COURSE DEVELOPMENT

In this section we describe, in a brief mode, most of the course design activities for CPC, these begin with the diagnose of teacher and students learning styles, and conclude with the proper assessment; for reasons of space, we made an effort be very as clear as possible in each case.

4MAT System

As we said before, an important aspect to design pertinent learning activities is to know what is the student´s preferred learning styles, so we supported this diagnose with 4MAT test by McCarthy[8] which consider 4 styles for learning:

a) *Style 1. Imaginative learners*; they look for opportunities to find meaning in what they learn, and find interesting to share and learn from opinions, beliefs and feelings of others. The challenge for teachers in these learning styles is to lead students to get a connection with course contents through in class debates, group discussion and individual participation.

b) *Style 2. Analytic Learners*; they look to reflect with new ideas and connect this new knowledge with previous, through creation of models and developing new theories. Teacher's challenge with these students is to focus in course contents through logical organization of topics, proper readings, and promote taking notes.

c) *Style 3. Common Sense Learners*; they learn by doing and look for practical applications, and prefer to work at classroom. The challenge for teachers with this learning style is to plan activities where students do tasks which leads to reinforce their skills and develop new ones.

d) *Style 4. Dynamic Learners*; they learn by discovering things by themselves, have a strong need to experience freedom in their learning, and they tend to transform anything. For teachers, the challenge with these students is to plan activities based on real life and situated learning.

The results of the diagnosis in our students were a majority in the style 2 as it can be seen in Figure 5:

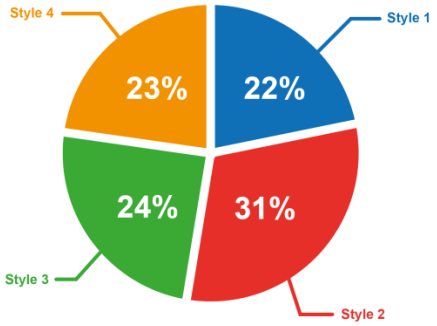

Figure 5. Student´s Learning Styles results at CPC semester 2016-2

In the case of the teacher, he also answered a test by McCarthy [8] Nicoll-Senft[10] to know his teaching style which, as result, is mainly located at quadrant 2.
Both results addressed about how teacher and students should be working on CPC in order to promote active learning and flip the classroom.

FLIPPING THE CLASSROOM WITH AN INTEGRATED COURSE DESIGN

It was established 14 weeks of work with 2 central topics. To define which things should be taken in class and what must be done outclass, we used the "castle top" template by Fink [6] Figure 6:

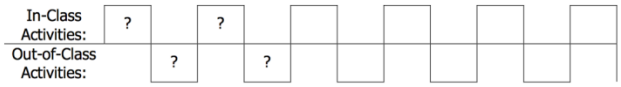

Figure 6. castle top template

To show an approach of the course instructional design, we are describing in general how CPC was developed during the first 5 weeks (the others weeks were design and developed following the same model but considering the new topic and higher level of complexity on learning and activities):

- Week 1: General introduction to CPC including course website (cw) http://computacional1.pbworks.com and introduction to first topic: Structure of Atmosphere
  First subtopic: Physics of the Atmosphere in troposphere
  Professor at class**:** explains course method, assessment, etc., and coaches the students to sign in at GitHub.com where they will be delivering all of the products; open a group on Facebook and let students add themselves.

Students outclass: must visit cw and read about this subtopic to bring a synthesis to the next class.

- Week 2:
  Subtopic: Physics of the Atmosphere in troposphere
  Professor at class: promotes sharing ideas about the synthesis students did and leads them to explain the elements that are present in the atmosphere.
  The last day of class in this week, he introduces new subtopic and encourages students to go to cw for reading, watching videos or simulations to get first exposure in this subject.
  Students in class: they participate actively in group, sharing information about all the elements and discussing about how they interact and affect each other.
  During the week, professor coaches them to make a file in Latex with a synthesis of the subtopic.
  Students outclass: may read more about the subtopic and continue to writing the synthesis that must be delivered by the end of labor week; if any doubts rise, they can use a Facebook group to ask for support from others students and/or teacher.
  By their own, must go to cw and attend about texts, videos, etc. for information about the new subtopic and tool to be used: emacs.
- Week 3:
  Second Subtopic: Cleaning data
  Professor at class: ask students to share their ideas about the elements that are present in atmosphere like, barometric pressure, humidity, temperature, etc. and make a brief group representation in order to get clarity about how they interact and influence our climate variation. Once this is accomplished, students must choose one of those aspects to be analyzed, and begin the extraction of the specific part of data they are interested.
  On the final day of week 3, teacher introduces the next subtopic.
  Students in class: each of them selected one of these elements to be studied and analyzed because in this week, they will choose one region and obtain a group of data to be processed. Due to the fact those data comes in a file which brings another information, then it is needed to "clean" them and leave only what is going to be processed and analyzed; to do this emacs tool is used. But this is not as direct as it seems, so they have to begin using some commands in this tool. After this, they must develop a file made in Latex describing the process to obtain the data, to clean it and also the final file in emacs.
  Students outclass: Professor encourages to use cw as well as social network to share more information, applets, images, look for help or help other students to solve doubts.
  Before the final day of week 3, students must approach to the new subtopic through cw.
- Week 4:
  Subtopic: Atmosphere Exploratory Data Analysis
  Professor in class: each student already has a collection of data, now is time to work with computational statistics looking to "play" with Extreme values (minimum, maximum), median and quartiles, which are defined for all empirical distributions. Python with Pandas Lib are the tools that are used to process the data collection.
  At this point, the professor coaches the group of students by presenting models of the computing programming to do so; next students make it by their own with the criteria of the data. Teacher becomes a facilitator, leading discussion and encouraging students to share with others the problems that are facing to solve with Python programming as well as how to solve them.
  Before the final day of week 4, Professor introduces new and last subtopic**.**

  Students at class: they used to work in individual way because each one picked up a different group of data, but they return to the group to share information or look for guide and for this, Professor keeps motivating group discussion in addition for individual coaching.
  Students outclass: Professor encourage to use cw as well as social network to share more information, applets, images, look for help or help other students to solve doubts.
  Before the final day of week 4, students must approach to the new subtopic through cw.
- Week 5.
  Subtopic: Data visualization (Graph)
  Professor in class: In the previous Activity, students learned to perform the Exploratory Data Analysis with the help of Pandas. In this activity they get into the process of visually representing the data to obtain relevant information, using Python-Matplotlib tool. The professor coaches each student with the programming in Python to graph the group of data and, when the images appear, he brings students to analyze them and explain what is happening.
  When students had finished this part, they must develop a file in the terms and form described at cw.
  To close this topic, Professor asks students to answer a list of questions through a file written in Latex and also develop it at GitHub.com; those questions try to lead to a reflection process and they are:
  - *What is your first impression of using all those tools?*
  - *What aspects did you like the most?*
  - *What things were not possible for you to do with those tools? Why?*
  - *What did you like the most in the development of those activities?*
  - *What would you change?*
  - *What do you consider is missing in these activities?*
  - *Can you share some new references that you consider useful and was not considered?*
  - *Any additional comments you would like to share*?

Talking about assessment, the professor decided to eliminate exams in order to avoid the stress it might produce in students. Instead, each week he evaluated the products developed by them and gave feedback individually, giving chance to students to improve their products without penalty or leave it that way. This was considered as formative assessment.
Also, each week the professor made a brief report where he described his experience with topic, tools, activities, and strategies in order to analyze if adjustments were required to some aspects mentioned before.

VI. RESULTS

The CPC was taken by 7 students in the 2016-2 semester: 2 were new at this course, 3 dropped off without failing in previous occasions and 2 had failed before.

At the end of this CPC, 5 students passed the course and 2 dropped off since the second week because they had another course at same hour than CPC (this is very common in our bachelor program) so they decided to go for the other.
We asked to the 5 students whom success on CPC, to answer a survey where they evaluate their experience in this course. It had 20 items (original in Spanish language) with a Likert Scale. In order to show the results in expanded mode, we encourage the reader to go to Appendix A.

The analysis of results of the survey applied to the students in CPC, 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 http://computacional1.pbworks.com . One of the most significant aspect is that they refer being able to move some acquired knowledge in CPC to others 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 others subjects, increasing communication both in person and through social networks.

VII. CONCLUSIONS

Analyzing the results of the student´s evaluation as well as the grades they got, we can infer that using the Flipped Classroom method to promote active learning was effective, since the students went from a passive attitude to an active attitude, where practically from the third week of classes, they were already ahead of classes with additional information or questions to raise in the classroom activities.
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 dynamic.

It may seem that students are open to new ways to approach learning, and if professors take advantage of this aspect to improve his/hers teaching style, this synergy may lead to boost student learning effectiveness.

For next the semester, we look forward to apply this method to a bigger group of students whose will take CPC for a very first time.

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APPENDIX A

Item	Always	Often	I don't know	Some times	Never
1. Professor keeps my attention during the session	75%	25%	---	---	---
2. Professor explains clearly the contents of the session	100%	---	---	---	---
3. Problems solved in course, are useful	75%	25%	---	---	---
4. Professor promotes individual work along the course	50%	50%	---	---	---
5. Professor promotes collaborative work along the course	---	50%	25%	25%	---
6. Professor promotes discussion, sharing ideas and questioning on face to face sessions or via social media	25%	50%	25%	---	---
7. Professor seems receptive and respectful to the students	100%	---	---	---	---
8. My involvement in analyzed subjects has increased after this course	50%	50%	---	---	---
9.The number of activities for each week is adequate	25%	75%	---	---	---
10. The fact that this course is only taught in computer lab is better for my learning	100%	---	---	---	---
11. I have enough time to understand and assimilate what we discussed in class	---	100%	---	---	---
12.The teaching method used in this course is adequate for the characteristics of the group and of the subject	100%	---	---	---	---
13. What I have learned in this course, Is useful in my in other courses	---	75%	---	25%	---
14. The tasks that I've done in this course, reinforce my learning	75%	25%	---	---	---
15. To support my learning and the development of my tasks in this course, I use the recommended books,	25%	50%	---	25%	---

e-books, websites, manuals and webliography					
16. The website http://computacional1.pbworks.com has been useful to follow the sequence of the course, to review activities, to resolve doubts regarding the tasks (contents, dates of deliveries, formats) to consult support material and to download files	100%	---	---	---	---
17. Software applications (Latex, Python, Github, emacs, among others) have proved being useful and interesting to do my tasks	100%	---	---	---	---
18. I would like other courses to use this method of teaching	25%	50%	25%	---	---
19. I consider that the way of working in this course is different from other courses I have taken in my bachelor program	25%	75%	---	---	---
20. I think I learn better with this type of class method	100%	---	---	---	---