Electronic Notes Via *Jupyter Notebook*s

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Abstract: Nowadays there are many tools to teach, both analogical and electronic. In our classes we use either tools: slides (and their xerox copies), computer driven presentations, videos, exercise bundles, calendar of the subject, syllabus, blackboard, detailed program of the subject... In the teaching/studying process there are to reference systems: the teacher's and the students'. In the former, it is the teacher who knows the subject and has designed it, whereas in the latter the students should acquire the competences relative to the module, grade... To that end, the students should follow the teacher's indications and use the materials we give them directly or indirectly. Unfortunately, the students, in their reference system, and due to the way teachers do our job, do not have any linear narrative threat facilitating the acquisition of the knowledge and competences. In this communication we present a tool, the electronic notes via ***Jupyter notebook***s, which provides the students with a linear narrative threat based on a static initial schema but adaptable to each student, and modifiable and extensible by each student, being executable as well.

1 INTRODUCTION

As far as we know, in the current Grades offered in the Science and Technology Faculty of the Basque Country University (UPV/EHU), the syllabus are quite rigid; That is, it is specified very precisely what is to be taught. Of course, the same thing happens with competences. The first reason for classroom teaching sessions of the subjects as it is actually done has to do with how the syllabus, programs, have been designed. One of the authors (JM Igartua) knows from his own experience how those syllabus have been designed: it has always been taken into account, at least in the degree commissions in which he participated, what are the learning outcomes to be achieved and with what level is expected to address the students a specific subject, which will determine number of ECTS assigned to the subject and its relative position with respect to the rest of the subjects in the Degree. All of which also determines what is the essential part of the subject, in what order it should be taught, both, relative order in the subject and absolute with respect to the rest of the contents of other subjects of the degree. We do not know how curricula and, more specifically, subject syllabus, are regulated in other university education systems, in Europe, for example. But it is actually a known fact that Subjects, despite being called in the same way, for example, and being ”surrounded” of the same type of subjects in the same courses of equal Physics Degrees (with the same name), are not equal; In many cases it is almost impossible to find even a single equal or moderately similar theme between programs, and we do not know how to solve ”the problem” generated by this dispersion of programs either. If we know how it should be resolved in our environment in most cases.

This fact of prioritizing some aspects, some concepts, against others or certain orders in which to deliver the subjects, causes, among many other consequences, that there is not *a priori* a text related to that subject that completely covers any of the programs proposed. Unless, of course, the program has been proposed on the basis of an existing text. This last case also occurs in our environment, but it is not very common. The most common case is the general situation in which for most subjects their contents are scattered in a small series, at best, good textbooks. This implies that the preparation of the subject by the teaching team requires the use of those good books, which is not bad, in itself. The bad point is that it is all the parts used of those books that have to be recommended to the students. Unless an *ad hoc* text is created for that specific subject. This has its advantages and disadvantages. The essential advantage of

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that approach is that the entire program of the subject is self-contained in a single text, which will have to be prepared with greater or less success. However, it does not seem an easy task to prepare a *patch-work* text, with elements from good reference textbooks and get, as a result, a good reference book; In spite of the possible great experience of who prepares the *patch-work*. With which the first drawback has arisen.

Another drawback is that using a single text, adhering to an existing one or creating an *ad hoc* one, causes the diversity of criteria to be lost and diversity of ways of explaining, showing results, posing and resolving exercises etc. Books are written thinking to whom they are addressed. In the case in hand, they will be students of Physics, for example, or undergraduate or master or doctoral students or *junior* or *senior* researchers. This fact establishes the approach of the book, the means that are used to publish it, the level etc. In fact, we must take into account that diversity is not only important to find that part of that book that best describes or explains something, according to the criteria of teaching team: we do not all understand in the same way, and it may require a broad range of ”ways of explaining” (type of exercises, basic examples, etc.), extension and precision in explanations, ..., so it is important for those who must understand, students, to have the opportunity to do it as close as possible to the actual way they do it; And this will be more likely to be achieved the larger the spectrum of explaining modes, for instance. Thus, this (scattering) inconvenience, in fact, could have its possible advantages: diversity is good.

All this makes the students ”have to” face a series of texts scattered, almost always, in the aspects to which we referred above and also, in most cases, are not correctly referenced, in the sense that they are simply listed in the syllabus, without indicating which part of which book is used as the basis for this or that part of this topic or this other topic of the program. (In our experience, from the critical observation of teaching guides, it follows that whoever does not provide his/her students with a bibliography with three lists full of books, basic bibliography, recommended, deepening ... *is not a good teacher*: everyone tries to make those lists as *complete* as possible, pointing to be the good teacher, but, as a result making them actually intractable.) Another aspect that is usual when making the recommended bibliographies, is the impossibility to have access to all the books: because it would be impossible to physically read them (nor study them) and because it would be difficult to buy them, even if we want to, due to their usual high price. All these reasons, and some others, make the students, in most cases, ignore the bibliography (in our experience this is what happens) and study directly only from their own notes, that in some cases can be modifications of the notes created by the teaching team. The same, and almost in the same terms, could be said about supplementary materials, for which there are different sources, formats etc: video channels, web pages etc. Or even, regarding programming languages in which someone feels confortable. (This sentence makes sense when discussing one of the characteristics of some subjects, below.)

We would like to mention, as well, the source of the information that the students are given: written notes, physical copies of the slides used in the class, copies of the electronic files of the used presentations, links to web pages where additional information can be found, copies of specific figures, references to chapters of books written on the blackboard, photocopies of some pages of a book, a journal, some research article ... an endless means, which in many cases are transmitted to students on the fly. A dispersion impossible to maintain under control by students, so that it can be used in an efficient way.

Finally, there are the students' hand-taken-notes, in the event students take them at all. In recent years, the observed trend is to see students attending a class as if they where watching the Discovery Channel: 30% of the students in our respective classes sit twiddling their thumbs, there are those who drink a coffee waiting to understand and to study the subject just by pretending to attend the lesson curiously. Those notes, in the best of cases, are taken in a notebook by subject, but normally they are taken in single sheets that put together make the *base camp* to study the subject. A *base camp* that is normally an empty lot, which students try to fill, successfully in some cases, but in the majority of cases unsuccessfully.

2 HOW IS THE FACE-TO-FACE CLASS OF A TYPICAL SUBJECT OF THE PHYSICS DEGREE TAUGHT: A CASE STUDY

We will use as a guideline of this section the subject *Termodinamika eta Fisika Estatistikoa*, full academic year, with 12 ECTS, taught in the third year of the Degree in Physics. We have chosen it since it is a subject we know very well, on the one hand; And on the other hand, because it is a subject that brings together, from our point of view, all the characteristics suitable to associate it the electronic notes we are proposing. Among others, these are the characteristics we would like to stress: It is a ”long” course, extending to the whole academic year (2 semesters, actually of 4 months instead of 6, 15 weeks per ”semester”) and 4 hours a week of classroom teaching (including all teaching modalities: lectures, classroom practices, seminars ...); With a great amount of new contents for the students, both in the first and in the second semester; With a lot of technical aspects (advanced mathematics), in which appear functions that depend on many parameters, multivariate, that are used to represent complex behaviors of systems. These which can be understood much more easily by adequate graphs (adequate in the sense that in addition to being those that should, the values of the parameters on which they depend could be modified to see how they are altered and understand better the behaviors they represent), and functions that have a great applicability and use in all parts of physics and science; To solve any problem in this subject there are many ways and there are many ways that same point come to the same point, or not . . . What matters to us in this paper is that it is the result of the fusion of two fundamental and classic subjects in the plans of Physics: Thermodynamics and Statistical Physics. *Thermodynamics* is a *fundamental* subject, introduces concepts and provides techniques, tools, which are used in many other subjects. It is a *classic* subject, present in all grades of science, for its wide applicability, except eventually in the Mathematics Degree, even if there is a lot of mathematical effort in it. Thus, *Thermodynamics* is placed in the initial courses of the degrees (not the current case of the Physics Degree, we will analyze the reason for that). *Statistical Physics* is also a fundamental subject in the degrees in Physics, but it is very specialized and very technical: It requires much more specialized knowledge and, hence, traditionally, has been located in the high courses of the curricula. The current subject comes from those two undergraduate subjects of the previous Physics plan (started in 2011) in which *Thermodynamics* was in second year and *Statistical Physics* in fourth year: one has risen to the first semester of third year and the other has fallen to the second semester of the third year. In addition, in the first case, credits have been lost, a weekly hour of class, which has lightened the content. In the second case, lowering course, but not number of credits, has lightened the level. Finally, another important aspect to keep in mind is that both subjects are devoted to the study and solve the same fundamental problem. Very succinctly: the initial equilibrium state of a system is known, we induce a process and we want to know in what final state of equilibrium the system will be found. However, each of them addresses the problem using different criteria: Thermodynamics uses a macroscopic criterion, on the contrary, Statistical Physics uses a microscopic criterion. That is, for the former the system has no structure but, for the latter, it has. This seemingly simple fact, causes the approach of the fundamental problem to be radically different and the tools, the techniques and the mathematical machinery, as well. In short, two subjects, basic and fundamental, that study the same in a radically different way and with a different mathematical machinery, in essence and in complexity, merged in one. The main consequence: absolute dispersion of textbooks and non-adaptation to the program/syllabus of the subject. In fact, most books are devoted to one or to the other.

So far, in our case, two basic books are used for the first part of the subject, each of which in turn uses a radically opposite approach: the first (Zemansky and Dittman, 1991), is inductive, so to speak, it goes to the laboratory, performs experiments, takes data, draws conclusions, deduces general behaviors and, finally, raises several principles. The second book (Callen, 1987), on the other hand, uses a deductive method: it accepts some principles and it deduces from those the behaviors in the systems. The first is an experimental approach; The second is an axiomatic, more technical approach, although in both cases the concepts are the same and the approach is macroscopic. For the second part, in which the approximation is microscopic, three books are used: the first (Pathria, 1996) is the one that provides the outline of the themes to be developed. The second (Kittel and Kroemer, 1996) is used because it brings a lot of concepts and examples that are treated differently than they are done in the first: in a very qualitative and much less technical, more intuitive (if possible) way. In almost all the chapters of the latter the figures are very good and show very appropriately the theoretical concepts, something that does not happen in the first, which is used as a base since its content is precisely the one that is in the program of the curriculum. In addition, in this second text the macroscopic and microscopic criterion are intercalated, and in this way, it serves to remember things of the first semester. Finally, the third book (Blundell and Blundell, 2006) is used because it brings a lot of technical aspects that are overlooked in the other two. Of course, not all the subject of the three books are developed.

3 PROPOSAL

Before stating the proposal, we would like to clarify what we mean by *electronic notes*, in the hope the it is not yet too late in the actual text. The reader needs a clue: *electronic handout-notes*, should it be, perhaps. In our environment, *notes* refers to written material teachers provide to students, not to the actual hand-taken notes by students. The *handout-notes*, thus, points to the material provided by the teacher. We would like to leave out the very interesting (more classical (Bretzing, 1979; Bretzing and Kulhavy, 1981; Brown, 1988) and more modern (Hembrooke and Gay, 2003; Bohay et al., 2011; Mueller and Oppenheimer, 2014)) discussions related to the pulse between the hand-taken or typed notes. We think, as many of the performed studies have shown(Stacy and Cain, 2015; Bui et al., 2013), that the blind verbatim typed notes give less comprehension of concepts than the hand-taken notes, for which a selective process for the written sentences facilitates the medium and long term comprehension of concepts and recalling of data. In fact, we encourage or students to type their notes in the hand-taken fashion, selecting, as if they were writing, to ensure the mentioned benefits, but, at the same time, to acquire an electronic personally enriched version, so personally suited, of the standard teacher's linear threat notes. This is the innovation aspect of our proposal, in our view: *With these notes, the disadvantage of the sole verbatim typing is discarded and the advantage of the selective writing is retained, so that the positive of the two worlds meet.* The linear standard threat of the subject is *personally decorated* by the student *in-situ*, where she/he decides it is worth, so that there is no break of the threat; *in-vivo*, while attending the class, or *ex-vivo*, while studying, preparing the exercises etc. The NB sharing capability gives the possibility for further enrichments, so that grupal contributions from students in a one step or in successive refining steps, can be added.

The tool we are proposing is not a mere document management tool Moodle, as we understand it. In a sense, it could be thought also as that, but, then, the concept of document should be considered in a broader sense, because in the linear threat of the subject, both the standard provided by the teacher or the personalized by the students, nearly any kind of object can be included, as mentioned before: videos, links, executable programs, text, figures, visualizations, interactive visualizations etc.

We would like to mention that the proposal is in its initial stage: we do not have yet results of the improvements generated by the use; for the moment, we have restricted ourselves to the proposal/implementation stage. The aim of the present paper is to share with the community the idea and its implementation via the Jupyter Notebooks, so that the remarks, observations and criticisms shape both the concept and its actual implementation, so a better tool arises. We are convinced of the benefits of the proposal, but, of course, it needs a deep evaluation of the achieved results, which we postpone for a next stage.

In the classroom teaching sessions (which includes all teaching modalities), and in our reference-system, the teaching reference-system, a lot of resources are used: *slides* (handmade, on the computer, with links to web pages. ..); *Blackboard*, for plotting reasons, for instance: Schemes of devices, systems etc, graphical representations of functions (qualitative, of course), conceptual schemes, reminder tables; *Demonstrations*, *developments*...; *Complete exercises*, *exercises approaches*; *Distributed photocopies*, with concepts to deepen, with exercises; *Examinations*, five for each part (statement sheets and answer sheets); *Computer*, to show complicated behavior of some functions; etc. All these resources constitute a set of ordered elements (in the order we have decided, as said), but which of course do not have a common support. ***Our proposal is to place the complete list of elements on the same medium, an electronic medium: The http://jupyter.org/Jupyter notebook version of the Notes, which we have developed and given to the students*** at the beginning of the subject, let's say. There could be a lot of approximations, since the electronic resource could be made public, when the previous topic has finished, so that the students have the possibility to start downloading it and have a look at it before starting with the topic. All them could be published at the beginning of the academic year; Could be published by modules, taking into account the examinations that will be proposed during the semester, so that it is structured in a natural way in its sub-blocks.

This electronic medium in which a block of the subject is made public, has an essential advantage: it is dynamic, it is editable. It is not a mere list of elements, of pedagogical resources offered, but a list of pedagogical resources that can be altered both *in-situ* and *in-vivo*, by ourselves, the teachers, and by the students themselves. The point that the students can edit it, is as remarkable as that we can edit it on the fly, while we are explaining. Mind the point: As important as the above is that it can be saved and, in addition, versions also can be saved.

The fact that it is an editable electronic notes makes it dynamic. We alter it, while giving class, *in-vivo*, at the point where we need to do it, *in-situ*: because we really have to do at that moment or, because it has been prepared it to do it that way. But in the same way students can do: while we explain, we show the figures, we connect to the internet, we show a video ... students can be taking their own notes on the same medium, just where it is needed, notes that we have proposed as a basis, and turning them into students' own notes.

The next advantage of these electronic notes is that they constitute a study element, a work element, that provides a linear argument thread: It is not a linear list of resources (Moodle, for example, or any other platform of this type), in which to work you need to jump from one element of the list to the next, you go and return, or you go and from there you go to another element and you go and go, and you return...it is a linear sequence (we have proposed the order of the elements), but that can also be traversed in any order, since the real electronic support is a window that opens in any browser.

One possible disadvantage is that anyone who wants to use these notes in the way they have been thought of, should always have the computer with them (or a tablet, of course, it can also be done on the mobile). It could happen that someone did not have access to a laptop or that carrying it every day would entail excessive loading; But it would also mean that you would not have to carry daily the physical notes (paper), nor the books. We are aware of having not mentioned the very important case of disabilities. We apologize for this, and we want to stress that this proposal is just a first approach, a first step, that has to be sustained by some evaluation and metrics we are also planning. Being the results good, as we expect, some approach to the disability case should be done.

It is very interesting that these electronic notes are independent of the operating systems (OS). We prepare them on MacOS, but they can be used on Linux or on Windows, in any of their versions. This is a very important advantage since we avoid the theoretically non-existent incompatibilities between OS that effectively always appear. The electronic notes do not know of OS, since in essence they are pure text files, in JSON format, that are shown in the window of an Internet browser. Of course, the browser can be anyone, each one can work with its favorite one and exactly as well in one as in another, nothing is going to be lost. It is also independent of the browser version. Incidentally, once downloaded, no internet connection is required: it works locally on each computer, changes made locally in the text file are reflected immediately locally. But, they can be shared (there are public servers in which to upload the files so that they are not only publicly displayed, but they can be downloaded), can be sent by e-mail (without weight, regardless of what is contained in the file, because you can always make videos, for example, that could be very heavy, were not embedded, without being loaded dynamically, need connection, or loaded the first time and be embedded, so only the new local version would have weight, not the one that has been shared). Of course, to make all this fully work, the students must have installed in their computer a software, *open source* and *free*, that exists for all operating systems and that is installed automatically.

4 JUPYTER NOTEBOOK

The following lines are adapted from (Jupyter, 2017). The ***Jupyter notebook*** is an interactive computing environment that allows users to create NBs that include: Live code, Interactive widgets, Cells, Narrative text, Equations, Images and Video. These documents provide a complete, self-contained record of a calculation that can be converted to various formats and shared with other users via email, Dropbox, version control systems (such as git / GitHub) or nbviewer.jupyter.org.

Components

The ***Jupyter notebook*** combines three components:

- **The NB's Web Application**: an interactive web application to write and execute code interactively and create NB documents. It allows users to perform the following actions:
  - Editing the code in the browser, with automatic syntax highlighting, indentation, automatic completion and introspection.
  - Run the code from the browser, so that the results of the calculations are attached to the code that generates them.
  - View the results of the calculations through a large number of representations such as HTML, LaTeX, PNG, SVG, PDF, etc.
  - Create and use interactive JavaScript widgets, which link interactive UI controls and displays to second-level computations of reactive cores.
  - Create Narrative text using Markdown language, markup type.
  - Construct hierarchical documents that are organized into sections with different levels of headings.
  - Include mathematical equations using the LaTeXsyntax, Markdown, which are rendered in the browser by mathjax.
- **Kernels**: Separate processes initiated by the web application of the NB that runs the users' code in a certain language and returns the output back to

the portable web application. Each core is able to execute code in a single programming language and there are kernels available in the following languages, among others: Python, Julia, R, Ruby, Haskell, Scala, Node.js, Go... The default *kernel* runs the Python code. The NB provides a simple way to choose which of these *kernels* is used for a given NB.

- **Notebook Documents**: Separate documents that contain a representation of all the content visible in the Web application of NBs, including input and output calculations, narrative text, equations, images and representations of objects in multiple formats. Notebooks contain the inputs and outputs of an interactive session, as well as the narrative text accompanying the code. The result of code execution (some program created in the session, or that has been imported, even in some compiled programming language) is part of the output, in any type of format such as HTML, images, video and plots (figures that have been created with code), and this output, is embedded in the NB, which makes it a complete and self-contained record of a calculation, for example.

  Notebooks consist of a linear sequence of cells. There are four basic types of cells: **Code cells**: live code input and output cells that run in the kernel, **Markdown cells**: Narrative text with embedded LaTeX equations, **Heading cells**: 6 levels of hierarchical organization and format, **Raw Cells**: Plain text that is included, unmodified, when NBs are converted to different formats using nbconvert.

5 CONCLUSIONS

Our proposal is to place the complete list of elements on the same medium, an electronic medium: The ***Jupyter notebook*** version of the Notes, which we have developed and given to the students at the beginning of the subject.

1. The electronic medium is dynamic: not a mere list of pedagogical resources offered, but a list of pedagogical resources that can be altered both *in-situ*, *in-vivo*, *ex-vivo*; Students can edit the electronic notes on the fly, turning them into students' own notes; The electronic notes constitute a study element that provides a linear argument thread personally suited to study
2. These electronic notes are independent of the operating system; The browser can be anyone, and its version; Incidentally, once the electronic notes are downloaded, no internet connection is required: it works locally on each computer
3. The electronic notes can be shared (in public servers) and by e-mail (without weight); run on *open source* and *free* software compatible with all the operating systems

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