Another Learning Sequence for a Course of Logic.

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Abstract

We present the experience of teaching a course of logic of one semester. The sequence is linear. For each subtopic we teach a theoretical class followed by a practical class, and the topics are teached in sequence following the curriculum. The theoretical classes present definitions, theorems and examples. The practical classes consist in solving the exercises in groups, the practices have solutions and there are additional exercises for which we don´t give the solutions. Students ask questions when they have some doubts about exercises, some questions are answered in person, some in group, some exercises are solved in the boad by the professor, other by students.

Keywords: *Logic, didactics, didactic sequence, problem based learning, competencies.*

1. Introduction

In 2012 and 2013 I have written the articles: A Didactic Sequence for a Course of Logic (2012) and Didactic Sequences applied in the Teaching of Logic (2013). These papers were written when the course was virtual and annual. In them I have narrated my experience with the course teached in 2011. At this time the course was teached along the year.

Here I narrate the experience of the course teached the actual year, after a change in the curriculum, being the course semiannual. The course again follows one sequence, but is a different sequence.

2. What and how I have teached

The students acquire knowledge imagining, understanding, reflecting, creating, taking decisions., thinking. Thinking is the basic unity of our mind. We live thinking. We expect our students to get emphaty with ourselves. Is to be the teacher of themselves. We are a magnet that attracts what we talk, think and feel, and the same happens to them.

Students talk in class, between themselves or with me. Ask questions when there is something that they does not understand or when they want to give an opinion or when they doubt about the meaning of a propositional or first order construction. The course has consisted in a sequence of

pairs of classes, two classes for each subtopic, one theoretical and another practical followed of two partials, one after teaching propositional logic and another after finishing with the units (after

first order logic). Previously to the partials, the students and myself had solved partials of previous years. The students solve the exercises, in front of their partners, explaining how they do it.

Our didactic sequence, is defined in the following way: theoretical class (opening), practical class and questions (development), and partials (closing). The pair theoretical and practical class is repeated until we finish with each didactical subunit.

The sequence corresponding to the first unit of the course is: formal systems and formal languages. We introduce systems formed by rules with premisses and conclutions. The idea is that the students think in this kind of system before seeying natural deduction. After this we teach induction. We study the inductive definition of sets, the principles of primitive induction and recursive primitive functions. This finishes the teaching of the first unit. The next unit is propositional logic syntax and propositional logic semantics. In the classes of propositional logic syntax we see the syntax of the set of propositions (inductive set), the corresponding principle of primitive induction, subformulas, formation sequences and substitution.

In the classes of propositional logic semantics was seen tables of truth, valuations and semantic consequence. Afterwards the solution of partials (closure) and the first formative evaluation (the midterm exam). The resolution of practicals and partials are aplications of the method of learning based on problems (Diaz-Barriga, 2005). Each exercise in the practices are problems to solve. Are solved by the students with our guide and our help. We know which students work by the questions they make. We see what didn´t be clear after our theoretical class and we explain to the students what we see they need to understand.

The second part of the course studies natural deduction of propositional logic and predicate logic, syntax and semantics. We teach quantifiers and how to use them to represent mathematics. Afterwards we introduce the inductive languages with which we will work. The language of terms (constants, variables and functions applied to terms), the language of formulas (False, Predicates applied to terms, both kind of atomic formulas), the formulas constructed applying binary connectives, negation, forall and exists (not atomic formulas). We show to the students in which way they can define both languages from an alphabet (syntax), the principles of primitive induction (syntax), how to construct the sets of free variables (syntax), and substitution (syntax). In what respect to semantics, we teach the correspondence from the alphabeth to an structure (model), how to interpret closed terms and closed formulas (sentences), how to interpret open formulas by means of its closure, semantical consequence and a lemma that explains the intuitive meaning of the connectives.

We see when a variable is free for a term in a formula, this is a condition for making a substitution. We finish this, applying the same method that in the first part, with the students solving exercises between them and afterwards in the board.

To experiment with formative evaluation we define a checklist, saying to the students what they have to show in the middterm exam that have understood. This is a guide for the students and makes more easy the task of evaluating the exams. Our check list has five columns. The first for the issue that will be evaluated, another for the concept inside the issue and the other three for the result of the evaluation. This can be True (knows the subtopic), Intermediate (knows approximately one half of the topic), or False (does not know the topic).

We have used checklist for the second middterm exam. We propose for the next course to apply checklist in both partial exams or a rubric in one of the two or in the two (Leymonie Sáenz, J. 2008).

We show below the checklist and the way in which we translate from formative evaluation to sumative evaluation. In the score, T means true, I means intermediate and F means False.

In the issue, Pr. means propositional logic and PL. predicate logic.

Issue	Concept	Points	T	I	F
Pr. Natural Deduction	Understand how to use the rules	4			
PL. Structures	Knows how to define a structure	2			
PL. Similarity type	Knows how to define and interpret when something is a correct similarity type	2			
PL. Term	Knows what is a term, if is open or closed.	2			
L. Form	Knows what is a fórmula, if is atomic or not atomic.	2			
PL. Form	Knows if a form is open or closed.	2			
PL. Interpretation	Knows how to define an interpretation	2			
PL. Term	Knows how to interpret terms	2			
PL. Formulas	Knows how to interpret formulas	2			
PL. Quantifiers	Understand quantifiers	4			

There is a correspondence between the points to True, Intermediate and False. We assign 0 to False, 2 or 1 to Intermediate and 4 or 2 to True. Intermediate is always one half of the points in the corresponding column. To get a sumative evaluation we sum the scores and divide between 24.

In previous versions of the course, when the course was annual the possible results were: exonerates, gives regulated exams or has to give free exam. We define a correspondence between the formative evaluation of the actual curriculum and the sumative evaluation we have obtained before in the following way: if the result of the division is between 0 and 8 the result is free exam, if is between 9 and 16 the result es regulated exam and if is betweeen 17 and 24 the result is exonerated.

The final score that figures in the scholarship can be obtained as the numerical result indicated before divided 2.

In the present curricular unit the score was defined as follows:

1. not achieved (1 or 2)
2. poor achievement (3 or 4)
3. acceptable achievement (5 or 6)
4. satisfactory achievemenet (7 or 8)
5. advanced achievement (9 or 10)
6. outstanding achievement (11 or12)

From 1 to 4 corresponds to free exam, from 5 to 6 correspond to regulated exam and from 9 to 12 corresponds to exonerated.

3. Cognition

Cognition can be classified in conceptual, procedimental and actitudinal. A conceptual cognition is the cognition of something through a mental image of the object we see. The object can be a sustantive, a word, being seen in our mind or a physical object whose image we remember in the same way than if the object is in front of ourselves. In the conceptual cognition, the object that appears belongs to a mental category that is a metaphysics entity. A mental image is something that arises only in the conceptual

cognition. The object with whom is related the conceptual cognition is the object conceptually implied (SB).

The conceptual thinking is not only the voice that sounds in our head, includes the conceptions and preconceptions of the things to which refer the words, that we need to give meaning, to what we are experimenting and comunicating with the others. In other way we couldn´t understand language. There are different mental categories. The characteristic definitorial of the category "food" is: something that develops the function of making the disgusting sensation of angry dissapear when is eaten (SB).

The procedimental cognition or "know how" is one of the two ways in which we store the information in the memory to long term. The procedimental knowledge is the knowledge related with things that we know how to do but we are not conscious of why is in this way, as by example to breath, to eat, to talk. The procedimental cognition is adquired gradually through the practice and is related with the learning of abilities.

The actitudinal cognition allows to create a tendency and develop some behavior in front to different situations or events. Is related to the kind of behavior that assumes an individual in a particular context.

After, in 4.7.6, we define this cognitions for the case of the curricular unit of logic.

4. Adding competencies for the next course. A change in the curriculum.

4.1. Competencies in Uruguay

To learn by competencies implies to develop in the students a set of capacities and actitudes in a way that allows them to solve the complex situations of life and work. The principle of pertinency consist in a superior education that answers the expectative and needs of society, by means of a national planification, a development regime, a scientific humanistic, tecnologic development and the cultural diversity.

The learning process consists of diverse characteristics such as interaction, problem-solving and experience. Learning serves many purposes in human life and adopts group thinking by matching behaviors, beliefs and attitudes.

The competency approach, is useful for the training of teachers. Poses the neccesity of ranking and selecting contents. The currriculum explains the competencies to develop and evaluate in each curricular unit.

The scientific method was applied before the development of competencies. According to (Bunge, M.), science can be characterized as rational, systematic, exact, verifiable, fallible, factual knowledge. Through scientific investigation, men has reached a conceptual reconstruction of the planet each time more wide, deep and exact. With competencies students learn to research.

Formative evaluation is a type of evaluation that assesses the development or progress of a project, program, or product to improve its effectiveness. It is done during the development process to provide feedback and make necessary changes before the final product is released.

Summative evaluation is a type of evaluation that occurs at some stage of a learning period or program. It assesses students's learning and whether they have meet the established learning goals.

It evaluates the effectiveness of a learning program and provides a final grade for a student's peformance.

Men creates a world of artifacts and culture. Science as activity belongs to social life. As well, is applied to better our natural and artificial media. The invention and creation of goods converts to technology. Nevertheless science appears as the more dazzling and amazing activity when is considered as a producer of new ideas.

The graduation profile by competencies represents the final step in the advance of the student in their studies. Beside this are defined intermediate steps that guide the student, their family and the profesor along the studies (Marco Curricular Nacional, MCN, 2002). Plans and programs explain clearly the competences to develop and evaluate the different curricular units.

In Uruguay, the curriculum has established 10 general competences and the knowledge that all the disciplines contribute to their development (MCN, 2002). These competences are organized into two domains: a domain that referes to competences linked to the ways of developing the *thinking and comunication* and competences linked to the ways of developing *relationships and action*, existing between them a necessary interaction.

The concept of "learning situations" demands to the profesorship the design of experiences and educative proposals oriented to the adquisition and development of competencies important and specific for the studentship.

4.2. Situations applying contents
A situation is the set of things that are happening and the conditions that exist at a particular time and place. To apply contents is to base oneself in a curriculum, to use notes, videos, papers, books to the effect of learning, solve exercises, present a issue.

Didactics involves strategies of teaching and learning together in time. In this sense, the strategies of learning refer to the design, programming, elaboration and formulation of contents of learning in verbal or written form.

By example were developed languages or idioms that are different in their sound, the words, the way in which are organized and used these words as well as what this words mean. The existence of diverse languages is called linguistic diversity or diverse languages.

4.3. Learning evaluation, feedback
We present the competencies to evaluate to the students. To evaluate by competencies we can apply checklist or rubrics. There is a supply chain. Is the process that is generated from when the student makes an exercise until when the correction of the solution is returned.

4.4. Organization capability
The organizational capability refers to the capacity to use effectively our resources, human or material with the end of reaching our objectives and goals in an efficient and effective way.

Is related to the actitudinal cognition. This is to develop a behavior in front to a situation or event in a particular context. In (SG), that is related to metaphysics, is defined to know what is to be true and to know how to act. Identifies complex situations and phenomena that can be formulated as scientific or technical problems.

4.5. Teaching, learning and science
Men creates a world of artifacts and culture. Science as activity

belongs to social life. As well, is applied to better our natural and artificial media. The invention and creation of goods converts to technology.

Demostrability and verifiability: our methods can be demonstrated empirically by means of direct experience (experiments) or by an explanation that can not be refuted by means of logical and demostrable arguments. Examples of scientific thinking: rational knowledge, empirical knowledge, demonstrable knowledge, comunicable knowledge.

4.6. Logical Thinking

Logical thinking is abstract. Relate different forms of reasoning, relational thinking with a determinated set of premises. Is precise, justified and evident, ideal for argumentation. Argumentation is clue for any form of debate, deduction or verification of thinking.

We understand by logical thinking those forms of reasoning purely relational, that involve real or abstract objects and a series of relations between them. Is a kind of thinking that comes from the own individual elaboration, that requires an abstract and hypotetical elaboration.

In this kind of reasoning, is fundamental to extract valid conclusions from a set of premises as in propositional logic. This kind of reasoning is, extremely ancient since was cultivated widely by ancient greek philosophers, who see in deduction and formal correlation the better method to get the truth. Nowadays we know that certain conclutions can't be reached in this way, but anyway, logic forms part of contemporary scientific thinking, over all in what concerns to the rules of the formal process of research. Logical thinking can be combined with others thinking, allowing in this way logico-mathematical, logical-abstract and logico-spatial thinking, between others (CPL).

Logical thinking is precise, justified and evident, represents the ideal for argumentation and this is the key for any form of debate, deduction or comprobation of thinking. Deductive logic is part of the most employed reasonings in academic scopes, being essential for mathematics. By this reason is teached from early stage of cognitive development (CPL). We call logico-mathematical thinking to the application of logical thinking to the formal rules of mathematical language that consist fundamentally of a set of signs that represent quantities or variables and the relationships between them. Is a kind of reasoning, key in numeric or matemathical intelligence, that allows to manage operations, constants, variables, logical relations, quantifiers and models.

Some examples of logical thinking are: the rubric cube, the puzzles, riddles, any mathematical exercise.

4.7. Competencies

Below we ennumerate and explain the different competences of the MCN following the document MCN 2002. After that we present the competences corresponding to the curricular unit of Logic for Computations and the corresponding Graduation Profile.

4.7.1. Domain thinking and comunication

Group competencies are related to comprehension, expression and interaction by means of different languages (**competencies in comunication**), being the original language a privilege. It is central for the development of the person both to comunicate and to structure thinking and construct knowledge. There is no learning process without thinking.

There are four ways to exercise the reason, each of which as a result of the attitude in front of the world, a series of activities and a posible final result. The different ways of thinking are called:

- Creative thinking
- Critic thinking
- Scientific thinking
- Computational thinking

Are complemented with a metacognitive competency: to think about our own thinking. These contributes to potentiate learning.

Learning Process: is established a competence called computational thinking that guides ourselves saying what, how and when we will work along a certain determinated time.

Competency in Communication
Interacts with other interlocutors in different modalities: employs elements of the languages applying knowledge, habilities, actitudes to understand, elaborate, interpret, evaluate and reflect in communicative events as teach, submit a presentation, publish an article.

Creative thinking
The person demonstrate interest and curiosity for those aspects that does not know being capable of being involved. Allows to act in the generation of ideas to give answer or propose innovated and alternative ideas. Develops science and technology.

Critic thinking
Allows a person to be involved in favor or against a point of view. Considers in particular:

a) dialogs with others, interaction and mediation.

b) use of texts, interpretation and signification.

c) dialog with himself, instrospection and reflexion.

Scientific thinking
Anticipate, interpret, describe and discover problems in different contexts. Development of the capacity of methodical research, with the individual formulating hypothesis and obtaining evidences and information by means of the observation, inquity, analysis, comparison and experimentation.

Computational thinking
Identifies which aspects of the real world can be modelated or systematized by means of algorithms, and which problems can be solved with the use of computational logic and technology.

Comprehends and takes into account the practice and the impacts of the use of algorithms and the advances of the technology.

Elaborates models to the effect of analizing, designing, and evaluate algorithmic solutions, using logics for computing (provers, logical frameworks, proof assistants, constructive logic).

Metacognitive Competency
Learn to learn. Reflects about the internal processes of thinking to: know, process, and find the better cognitive habilities in each circunstance and context. Constructs strategies for a permanent learning.

4.7.2. Domain Action and Relationship
Intrapersonal competency
To develop this competency the person reflects to know about herself applying scientific and philosophical tools in a critic way. In the actuality, in view of environments each time more complex,

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becomes important the identification and comprehension of personal emotions, asociated to the capacity of using them as complement for the decision making and problem resolution.

This allows to preserve the optimism in front to unfavorable conditions.

The mistakes are not frustrations anymore and are transformed in oportunities of perseverance and of replanning. By this reason es trascendental the search of solutions in oneself and in the recognition of factors about problems resolution. Is an input to personal satisfaction giving as result a healthy life from all the points of view that define human beings.

Competency in initiative and orientation to the action
To develop the competency, the person transforms ideas in creative and innovating actions from proyects that generate individual or grupal undertakes. Implies the estrategic planification of proyects, analizing preliminarly the factibility of its realization and anticipating risks.

Is understood that, promotes the formulation of objectives, mantaining the motivation to reach them. The objetives are reached when are established stages for its concretion fulfilling a calendarization and a permanent evaluation for its reformulation. By this reason the monitoring and the correction during all the stages of the action try the responsability of the proper actions, valorating its impact in the personal and social actions.

Competency in the relationships with the others
When the competency is developed, the person construct interpersonal links and cooperate with the others constructively, to make, think, execute collaboratively understanding the importance of the integration of the individual contributions in the interchange to get better solutions. In this way is developed and expressed the emphaty when is comprehended the reality, the thinkings and feeling of the other persons to interact proactively taking them into account.

The actual society imposses the management of the dissent and the neccesity to act in front of the conflicts in diverse contexts of performance searching the better forms of negotiation. To this end we have to equilibrate and comprehend the diferences, the coincidences and the complementarity that are produced in educative environment multi and interdisciplinary.

Competency in local, global and digital citizenship
When developing this competency, the person is integrated to public life knowing and respecting their rights, duties and obligations (in participation spaces, in familiar life, in estudiantil, comunitary, laboral scopes).

The personal identity and citizenship is developed in diferent scales. Education must recognize them to the development and compliance of Human Rights. Individual and collective participation are necessary for the convivence and respect of Human Rights.

The respect to diversity, the valoration of culture and nature in all the country support this competency, promoting responsible attitudes. Allows to act consciously, with rational use of goods for the protection and promotion of personal health, individual and collective, preventing ambiental problems.

Besides, incorporate the comprehension and use of financieral concepts, the meaning of money, the value of saving, basic notions of micro and macro economy and its impact in daily life as well as the development of habilities for the decision making.

Definitely, tends to promote and visualize digital media in an ethic way, to analize and question the information and the contents. From this positioning, is possible to transit for the digital process, personal or colectively with responsability, knowing benefits and associated risks.

Formative Evaluation
We see how is done the formative evaluation in the processes of teaching and learning: is established a programming competencies-computational thinking, that indicates when and how we will work along a determinated period of time. Can be assess if the planification is being done in agreement with what was planified, if are being reached the expected results and in case of not to made a modification.

Purpose: possible maximal learning of students through the design of strategies that give answers to detected needs. Search how to better the educative process repeatedly. Has to be counselor, regulating and motivating; allows to act in case of possible detected errors; has to have procedural and continuous character reorienting the activities in permanent form; offers the possibility to know the evaluation from the beginning with respect to the established goals; allows to perfection the process and result of learning (Leymonié Sáenz, 2008).

Sumative Evaluation
Is focused in the final results after an instruction period. Is a type of evaluation that assesses students'learning and whether they have meet the established learning goals. It evaluates the effectiveness of a learning program that provides a final grade to student's performance.

Its purpose is to measure the overall achievement of a student or group of students at some point of a course, usually at their end. Provides valuable information to teachers, schools and educational institution about the success of their teaching methods and curriculum design (TF, 2024)

Constructive Evaluation
Constructive evaluation (Reilly & Denny, 2010) is an innovative pedagogical approach which shifts students from being consumers of knowledge to participants in a community of peers engaged in actually producing and sharing knowledge. Students are focused on the construction and evaluation of assessment items. Students are required to author a question that assesses learning outcomes of a course along with a sample solution. These are stored and become available for other students to use as a learning resource.

Once a student answers a question can see the answers of other students and reflect on their own response. Students must review their own answers and engage in discussion of questions and answers.

Besides improve content knowledge, students develop important meta-skills as organizing and communicating knowledge, judging the quality of information, giving and receiving feedback and improving self-assessment skills.

Constructive evaluation is aligned with both reflective profesional practice and social theories of learning.

4.7.3.   Specific Competences for Logic
Define and analyses formales languages aplying them to informatic concepts as is the example of type theories (M. Löf, 84).

Comprehends the scientific and formal dimension of informátics and relates it with formal education. Represents, infers and evaluates systems and realities using formal languages (Plan, 2023)

4.7.4. Graduation Profile Competences.

Is comunicated by means of different languages that make viable teaching and learning in diverse environments. Appropriates, manages and articulates knowledge related to a field of knowledge, to the fields about education and of didactics. Acts in agreement with ethical principles that govern their profesion, recognizing its identity of educator and its commitment with the improvement of educative system in its totality. Contributes to the development of its personal and professional being from the generation of knowledge in the frame of permanent learning (Plan, 2023).

4.7.5. Suggested methodology for the development of the curricular unity

The course will follow a theorethic-practical methodology for what is suggested to follow methodologies of learning with a strong practical component where the emphasis of the course is in the students learning. The development of the curricular unity will be done in an interdisciplinary approach, searching the interrelationship with other curricular units with the intention that the students comprehend the world in a holistic view (Plan, 2023).

As examples of the application of logic we have: databases, software engineering (Dijkstra & Feijen, 1988), proof checkers (Coq, Agda), systems architecture, temporal logics (Lamport, 80). The bibliography of the course were notes defined by the professor, together with practices and their solutions and complementaries practices without solution and the book of (Van Dalen, 97).

Will be promoted, always that is possible, that the tasks and works for the students be realized in teams, developing gradually the colaborative work as a production tool and personal development. Today, the world needs trained persons that can work in teams because this kind of work generates synergy, commitment and development in employes, flexivility in front of change and enhanced creativity (Plan, 2023).

4.7.6. Conceptual, Procedimental and Actitudinal Contents of Logic

Conceptual contents

1. Formal languages
2. Propositional logic
3. Predicate logic
4. Induction
5. Recursion
6. Use of Logic for the modeling of problems
7. Case Study
8. Introduction to proof assistants.

Procedimental Contents

Identify and recognize the syntax of a formal language.

Apply fundamental laws of propositional and predicate logic.

Apply rules of inference.

Actitudinal Contents

Development of Intelectual curiosity by means of the search of new knowledge in logics and informatics.

Promote work in teams and colaboration in the development of logical problems. Promote an actitud of questioning and analysis in case of conceptual and logical problems.

5. About government and education

(C. Hilb, 97) says in it article: yeas ago was said that "all is politics" in oposition with the idea of a possible neutrality of sciences, of decisions, of disciplines. We have to depoliticize the debate. This is not to not have a gobernment. Is to research, to develop science, disciplines. A science of didactics, independent of the current government. A neutral development of sciences, true sciences, not completely developed yet.

Politics, must be a provision for Universities, who can return to them their knowledge, in an interchange of ideas, in an agreement. Logic can be taken as basis, our laws must be true. This means we have to respect human rights, and following this axiom, must be developed politics.

By the other side, all is politics can be interpreted as all the sciences supporting politics. But we have to accept other currents too. Not necessarilly all the politicians have to be scientists. But science has to be developed respecting human rights and serving the people. And this has to happen in all the environments in the country.

Politics has not to be, necessarily, the name of an existential oposition, of the affirmation of an hostility. Must be the mode in which a community is recognized as such. Politicians must be a true institution, without discrimination of the legitimate, of the just, of the community. Politics must be the name where persons have to recognize one another as participants of a coexistence. Governement must be the representation of the people, the constitution of a public space. Must search an agreement that is the conjunction of points of view, of opinions, of arguments, respect to a common object, public good.

Undoubtely the proper criteria of the education, the distribution of educative goods and assignation of benefits must be a fundamental concern. A university of state, primary, secondary and terciary education, supported by state. With a retroalimentation from science to politics. With logical laws that can be seen as true, that respects the equality of rights, where the study centers of the state have the necessary support, in such a way that any citizen, independently of his economical power can study, learn, progress and work. Must be recognized the autonomy of the criteria that must guide the resource assigment, the recognition of public and autonomous education, with their own gobernants and supported by the state.

6. Further Work

We can define rubrics for each of the two tests of the course. Also a checklist for the first semester test that evaluates inductive sets, principle of primitive induction, recursive functions and propositional logic: syntax, semantics and natural deduction.

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