# LOGIC AND EPISTEMOLOGY: A GRADUATE SEMINAR

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I this paper I offer a description of my experience so far, of a graduate seminar I have been teaching, for several years now. Depending on audience type and length, titles have varied as follows: "Logical Consequence and Reasoning" (10hrs), "Logics for Uncertainty" (10 to 20 hours module), "Non-Classical Logics: Selected Topics" and "Logic and Epistemology: Selected Topics" (1 semester each). In these longer versions, I have conducted the seminar together with other colleagues.

In general terms, this seminar is on logic and methodology, focusing on the relationship between logic and epistemology, with an emphasis on the dynamic aspects of logical information processing. Logic is presented as a frame and tool to organize and manipulate information. More in particular, our interest lies on the analysis of the inferential mechanisms by which knowledge is manipulated. That is, how is that knowledge is acquired and fixed; or how is that it is reproduced as other forms of knowledge[1].

This course has worked well for Philosophy, Philosophy of Science, Computer Science and Cognitive Science graduate students alike. In its shortest version, it does not presuppose any logical skills, but it nevertheless relies on analytical skills for the understanding of the philosophical and computational literature revised. In its longest version, this seminar covers philosophical, logical and computational aspects of non-classical logics, for these logics aim at modelling reasoning types in scientific contexts as well as in common sense reasoning.

As for evaluation, students either write-up written reports based on a chosen reading for each session, plus a final essay, or else prepare a critical presentation of a reading to be discussed in a class session. The main objective of the seminar is to introduce students to the study of logic in its relation to epistemology on issues concerned with non-deductive reasoning and discovery.

Next we present the course topics, to be described in the following sections. In particular, a more detailed description is given for module 1, the part that is included in all versions of this seminar. We omit the last section (conclusions), as it adjusted depending on the particular seminar version delivered.

[1] Notice that we use the terms knowledge and information interchangeably, since their putative differences are not relevant for our analysis.

OUTLINE
Introduction
1.- Logic and Knowledge
1.1 Peirce and Russell
1.2 Heuristics and Discovery

2.- Advanced Selected Topics
2.1 Epistemic Logic for Distributed Agents
Common Knowledge
Epistemic Dynamic Logic
2.2 Adaptive Logics
2.3 Non-Classical Logics
Non-Monotonic Logics
Modal Logics and Dynamics of Information Processing

INTRODUCTION

The motivation for this introductory part of the seminar is to pose the following question: What is logic? This question is tackled by describing three rather different origins and traditions in the logical enterprise, namely axiomatics, dialectics and the procedural approach, showing that in all of them logic can be understood as a frame and tool for information processing.

Under a broad view, logic concerns general forms of reasoning –be it human or automatic—to manipulate inferential reasoning. That is, forms in which, from information we already have —the premises ($P_1$, … , $P_n$) -- some more information — a conclusion (C)--is produced. Thus, knowledge is conceived as having an inferential format, in which premises and conclusion are related by some kind of logical consequence, as follows:

$$P_1, \ldots, P_n \Rightarrow C$$

Logic analyses and generates a series of methods to manipulate information given in an inferential format. The following question is then in order: is the product of an inference, knowledge? And if so, what kind of knowledge is it?

The way to tackle these questions is by making a distinction between different kinds of inference, drawing on a classification into deduction, induction and abduction[2]. The epistemological status of information that these three produce is, respectively, knowledge that is certain, probable or only plausible. The notions underlying this three types of reasoning are respectively: truth, frequency and hypothesis.

This introduction seeks then to present a panoramic and broad view of logic, regarded as the science of reasoning, and showing that it is intertwined with epistemology. The following module will address the philosophical and methodological aspects of this proposal.

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[2] This is a distinction introduced by Charles Peirce, whom we will study in more detail in the next section.

LOGIC AND KNOWLEDGE

1.2 Peirce and Russell

In the first module we examine philosophical foundations and motivations for non-deductive logics, through two philosophers who guided their reflections by epistemological questions, but that tackled them by logical means. These are Charles Sanders Peirce (1839-1914) and Bertrand Russell (1872-1970), two close and complementary thinkers, at least in this respect.

On the one hand, we analyze Peirce´s thought. This is done by first reading his "Fixation of belief" (and depending on time, his "How to make our ideas clear"). The questions raised in this essay are how is that we humans acquire knowledge and how is that beliefs are fixed. He argues for the scientific method as the best and most promising method for this aim, after revising the methods of tenacity, authority and a priori, all of which seem at first to serve the purpose of fixing a belief, but are deemed to fail sooner or later. For Peirce, knowledge is search, and any search departs from doubt, which is in turn the departure for abductive reasoning. We then study Peirce´s argument classification into deductive, inductive and abductive, through his short but excellent essay "Abduction and Induction"[3].

On the other hand, we turn to Russell´s view. For this part, we first analyze his "Human Knowledge: Its Scope and Limits", of which we cover at least "The science of mind", and "Probable inference in common sense practice". We are interested on this book by Russell, being its last big philosophical one, for it approaches the problem of non-demonstrative inference. His motivational questions are epistemological: how come it that human beings, whose contacts with the world are brief and personal and limited, are nevertheless able to know as much as they do know? Moreover, while Russell grants scepticism as an impeccable logical posture, he considers it psychologically impossible, and sets himself to investigate the canons of non-demonstrative inference, particularly for investigating whether these forms of inference do warrant knowledge. He explored Pragmatism for this purpose (most prominently Dewey and James rather than Peirce, though), something that also served him to distance himself from the positivists.

His "The science of the mind" is especially important in the type of seminar we propose, as it can be viewed nowadays as the foundation for Cognitive Science, giving to Psychology a privileged place for studying the processes by which we draw inferences. Moreover, it gives especial attention to the power of introspection.

Then we move to "Probable inference in common sense practice" and complement the study on induction with Salmon´s "Logic", in particular his chapter 3 ("induction"). That is, we provide a philosophical motivation of induction through the work of Russell, while at the same time we provide some --very basic and not technical -- introduction to inductive inference. The book of Salmon describes several types of inductive arguments, including induction by enumeration, statistical syllogism, analogy, and the hypothetico-deductive method. He also provides a good introduction to inductive fallacies, including insufficient statistics, biased statistics,

[3] All these essays are contained in Buchler (1955).

the fallacy of incomplete evidence, misuses of the argument from authority, and causal fallacies. It is full with examples and the presentation is rather simple. At this point of the seminar, it is convenient to make clear that in the literature there is often a two-way division into the deductive versus the inductive (such as Russell and Salmon do), contrasted with the three-way distinction proposed by Peirce (abduction, induction and deduction), which we advocate. The difference is largely terminological and depends on personal taste, but it tends to create ample confusion when it is not clarified.

1.2 Heuristics and Discovery

We next turn to the second parte of this module, namely heuristics and discovery, which is largely based on my own writings (Aliseda 2000, 2004, 2006). The first thing on the agenda is to talk about the "context of discovery versus content of justification" distinction drawn in the Philosophy of Science, in order to show that while it was a useful methodological distinction which gave to (deductive) logic a privileged place, it relegated the study of discovery issues in science to Psychology. Still, authors outside the accepted view, did some work on discovery issues, and we analyze the cases of Rescher, Hanson, and Lakatos. The last one is especially important, for his proposal of heuristics as the logic of discovery. Moreover, we analyze in more detail the case of discovery in mathematics, through the work of Polya. We also analyse the case of computational research, which is really what brought back the study of the context of discovery to the philosophical agenda. I am referring to the pioneering work of Simon and his team (Langley etal 1987) and that of Thagard (1988), who coined the term "computational philosophy of science". The central question here is whether there is a logic of discovery. We analyze this question through several interpretations of both "logic" and "discovery".

We then move to discuss about the place of logic in scientific methodology and revise some (depending on what is covered in next section) logics for artificial intelligence and information processing, such as statistical, preferential and dynamic inference, also mentioning by passing belief revision and epistemic change[4].

We conclude that the use of non-standard logics to model processes in scientific practice, such as confirmation, falsification, explanation building and theory improvement, is after all, a feasible project. Nevertheless, this claim requires a broad conception of what logic is.

In this module, we sometimes use as a transition to the next one, an excellent essay by Russell, namely "Mysticism and Logic". In this work, Russell departs from the reflection that metaphysics, as an attempt of conceiving the world in its totality through thought, was developed by the union and conflict of two rather different human impulses: mysticism and science. In order to explore the validity of the former, Russell asks several questions, one of which is the relevant for our seminar: Are there two modes of knowledge, reason and instinct? His answer is briefly that the opposition between instinct and reason is illusory: instinct, intuition or introspective vision is what first leads to beliefs, which reason refutes or confirms. Reason is the

[4] We analyze all these logics in detail, when the seminar includes the module on advanced topics, in particular its section on non-monotonic logics.

force that constructs harmony and tests, but it is not creative. Even in the domain of logic, it is intuition what leads to the discovery of a novelty.

The content of this part provides sufficient material for a 10 to 20 hours module. Therefore, it can be indeed one module or two, and in any case, only part of a longer seminar, lasting three to six months total, and complemented by one or two of the following advanced topics.

ADVANCED SELECTED TOPICS

2.1 Epistemic Logic for Distributed Agents

One choice to complement a seminar of the type proposed here, is by adding two more modules on "Epistemic logic for distributed agents", one of them offering an in-depth analysis of a particular type of knowledge, namely common knowledge and another one on a quite sophisticated logic, namely epistemic dynamic logic. The general idea on common knowledge is to study its philosophical motivations as well mathematical models. The suggested themes are first to approach the notion of common knowledge via convention and coordination problems, as proposed in Philosophy (Lewis 1969). Then to study three characterizations of this notion, their equivalences and problems (Barwise 1988), to end by analyzing some of the computational literature which applies this notion to problems of distributed processing (Fagin etal 1995).

As for epistemic dynamic logic, the idea is to present a framework in which it is possible to reason on information change. Dynamic logics were devised as a response to problems in formal linguistics, computer science and belief revision. Topics to be presented in this part include logic for public announcements, epistemic actions, as well as technical issues concerning expressivity and completeness. The best is to present this material as in a recent book (van Ditmarsch 2008), especially when the protagonists deliver the material[5].

2.2 Adaptive Logics

Another proposed module is to introduce a family of logics, such as adaptive logics. These provide an excellent framework to deal with defeasible reasoning in general, be it in an inconsistency setting (for which they were initially devised), an inductive or an abductive one. These are formal systems able to refute conclusions inside a proof. They are naturally presented in a proof-theoretic setting, but they do have a rigorous and clear semantics as well. This module can go into the detail of describing its metatheory as well as decidability maters. Adaptive logics are also good for combination, for example an inconsistency adaptive logic with an adaptive abductive one is a possible case. This paradigm was developed in Ghent by Diderik Batens and his team[6]. It is work still in progress (See: http://logica.UGent.be/centrum/writings), and I am glad to say that a master student of us (who took a long version of this seminar) has extended their work in her master thesis (Leonides 2011).

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[5] In 2008, we had the privilege at UNAM of having Barteld Kooi and Allard Tamminga from Groningen University giving this module as part of a one semester seminar entitled "Logic and Knowledge".

[6] In 2009, we had the privilege at UNAM of having Diderik Batens and Joke Meheus delivered this module.

2.3 Non-Classical Logics

Two more modules for this seminar were taught by two of my colleagues, in a seminar we entitled "Non-Classical Logics", in which I conducted module 1 on "Logic and Knowledge", Diderik Batens and Joke Meheus the mentioned module on "Adaptive Logics", Raymundo Morado (UNAM) conducted a module on "Non-Monotonic Logics" and Francisco Hernández Quiroz (UNAM) conducted a module on "Modal Logics and Dynamics of Information Processing". We had students from three graduate programs: Philosophy, Philosophy of Science and Computer Science. The complete description of this course may be consulted at:

http://www.filosoficas.unam.mx/~morado/Cursos/09NoClasicas/Temario.htm

## SOME FINAL REFLECTIONS

This seminar is not an introductory logic course, but rather a seminar about logic, in the context of its relationship to epistemology, something which has philosophical interest by itself, but that is also relevant for students in Computer Science and Cognitive Science. The themes in advanced topics however, presuppose basic logical skills, as they are aimed to get an in-depth analysis of a particular logical framework.

I have been using this material as I have described so far. I am planning to prepare some version that may work as a manual, for independent study or even for professionals outside the interface of logic, language, and computation. I will be happy to receive criticisms and recommendations for this project. I thank two anonymous referees, both of which made useful comments on a previous version of this text, all of which I tried to incorporate.

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