

“Up to University” EU funded Project (**Up2U**) – “University as a Hub” sub-project (**U-Hub**)

Learning Path: "**Education towards Critical Thinking**" (ECT)

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## UNIT 2 – Reasoning and language

### Statements

The statements are the basic unit of discourse. A statement is a sequence of words that expresses a meaningful thought in such a way as to make it accessible to others.

In logic, according to the classical definition, a statement is a proposition of which it makes sense to say that it is true or that it is false.

To be *meaningful*, the statements must be:

- syntactically well formed; counterexample: *The jumped cat on the table has*
- complete: including subject and predicate; counterexample: *James has*
- not contradictory; counterexample: *That circle is a square.*

The statements that express theses about real or presumed objects or events are said to be *thetic*. The thetic statements can be judged as valid or invalid by other interlocutors: they form the basis of the reasoning and they are mainly concerned with the theory of argumentation, that is to say, in simple terms, the *logic*.

In addition to thetic statements, there are other types of statements with meaning; for example:

- interrogative statements, which do not express an opinion but require it from others; example: *What time does the train leave?*
- imperative statements, which express a command; example: *Close the door!*
- conventional formulas typical of ceremonies and other events; example: *The session is open*
- exclamations, such as: *What a bore!*

Among the thetic statements (those of which it is possible to say whether they are valid or not) we can further distinguish:

- *apophantic* statements; the term was introduced by Aristotle (in Greek: *apofanein* = to manifest) to denote the statements that refer to a reality independent of us and manifest it: only they can be evaluated as true or false depending on whether they correctly manifest reality or deform it or hide it; they include all the statements of the sciences and most of those about the facts we observe.

- *prescriptive* statements; example: *We need to think before we speak*; they refer to rules to be followed when acting; rather than telling if they are true or false, we can say whether they enjoy consensus in a community or in a context; according to some, they are non-thetic statements in disguised form; the example could be reformulated as an imperative statement: *Think before you speak*
- *evaluative* statements, which more or less openly express our feelings about things and events; example: *Horse meat is disgusting*; according to some people, these are often masked exclamations, like *How disgusting horse meat!* but perhaps it is more natural to rewrite them as "compound" statements, like *Horse meat does not like me and it causes me repugnance*.

## Discourse

The Discourse is a coherent sequence of statements.

A discourse can:

- describe an object or multiple objects
- tell a fact or a succession of facts
- explain a fact or a set of related facts
- justify or motivate a choice
- make assumptions and forecasts.

However, there is a distinction between these possible forms of discourse:

- the first two, *description* and *narration*, are coherent speeches, but not internally connected
- the *explanation*, the *motivation* of a choice and the formulation of a *hypothesis*, are types of *reasoning*.

We have already seen that there are *simple* statements, corresponding to sentences with subject and predicate, and compound or *complex* statements, obtained by composing other statements by *conjunctions*: by *coordination* ("and"), by *disjunction* ("or") or by creating subordinate sentences. Complex statements are (logically) a single statement. A part of the symbolic logic deals with how to calculate the truth value of a complex statement starting from those of the component statements.

The discourse, in turn, may consist of one or more statements.

## Reasoning and inference

The basis of the correct reasoning is the inference between the statements. *Inference* is the link between different statements that causes one of them to be considered dependent on others. That is, if the latter are valid, we must admit the former as valid.

Logicians usually

- call *premises* the statements by means of which you infer
- call *conclusion* the statement reached with inference.

The reasoning is a process of thought that takes place through inferences. The best-known type of inference is *deduction*, but later we will see that there are several other types of inference.

When the reasoning is aimed at soliciting the consent of others, it is also called *argumentation* and its reasons are usually called *arguments*.

## Analysis of reasoning

The analysis of reasoning starts from the analysis of the discourse that expresses it. Since reasoning is based on inferences, it is useful to know which are, in the text of the discourse, the expressions that typically indicate which statements constitute (explicit) premises and which instead indicate conclusions.

From [2] we adapt the content of a table in which are juxtaposed typical premise indicators and the respective conclusion indicators:

| <i>premise indicators</i>  | <i>conclusion indicators</i> |
|----------------------------|------------------------------|
| if ...                     | then ...                     |
| given that ...             | ergo ...                     |
| because ...                | therefore ...                |
| since ...                  | thus ...                     |
| based on the fact that ... | it follows that ...          |

*Guy is not in the house. I rang the doorbell and he didn't come to open.* (conclusion and explicit premise)

In this example, there are no explicit indicators of premise and conclusion. It has been noted that, while the conclusion follows logically the premises, often in the text of an argument the order is reversed, especially when explicit indicators of premise and conclusion are absent.

### Explain yourself better

Sometimes our reasoning is not clear to others: in the course of discussions, it happens that the listener is not aware of the implicit premises that have been assumed. Then we must "explain ourselves better", that is, make explicit the process of thought that we have followed. The *logical analysis* of a reasoning aims precisely to make the process of inference transparent, mostly by making explicit some of the implicit premises of the reasoning.

*If Guy was in the house, he would have come to open the door.* (implicit premise)

Any reasoning concerning the concrete cases of life has many implicit premises. In our case, we would probably recognize the implicit premise that we report above, but we would not think of many other premises, useful to protect us from "unforeseen" conditions, such as

*If the doorbell works.* (additional implicit premise)

A reasoning is more convincing, therefore, when its premises are capable of excluding certain cases from the list of possible cases; that is, when the validity of the conclusion is explicitly subordinated to the non-occurrence of a whole series of exceptions.

### Reconstructing reasoning

*Peter will spend his holidays in Greece: Paul told me, who knows everything Peter does.*

From [2] we report this other example in full, precisely because, apart from the technicalities, it seems to us that taking for granted some premises is by far the main source of misunderstanding in the discussion. To analyze the soundness of the statement, we will identify all the salient premises and put them in order according to their strength (= ability to exclude alternatives) in order to progressively approach the desired conclusion.

1. Peter is always honest with Paul. (implicit premise)
2. Paul is always honest with me. (implicit premise).
3. Paul told me that Peter will spend his holidays in Greece. (premise)
4. Therefore, Peter is planning on spending his holidays in Greece.
5. Except for unforeseen events, Peter will spend his holidays in Greece.

## Types of inference

The main types of inference are: deduction, induction, analogy and abduction.

### Deduction

*Deduction* is a process of inference in which the conclusion is completely justified by its premises. The deduction is recognized by its necessity: given the premises, there is no other possible conclusion: the conclusion does not add new information but makes explicit that already contained (implicitly) in the premises. Any false premise invalidates the conclusion; vice versa, if the conclusion is false, at least one of the premises must be false.

*All men are mortal. Socrates is a man. So Socrates is mortal.*

This is the most classical example of deduction; and also the most classical example of *sylogism*, but, as we will see later, syllogism represents only a particular kind of deduction that, as we say, goes *from the general to the particular*.

*If you were a gentleman you would eat properly at the table. You don't eat properly at the table.  
So you're not a gentleman.*

In the argumentation, the deduction can be used both to support a thesis, as in the example on Socrates, and to refute it, as in this latter example.

### Induction

*All the crows I saw are black. So all the crows are black.*

*Induction* is the best-known form of inference in which the conclusion does not necessarily come from the premises. This is a process of reasoning that aims to derive a general statement from the examination of a number of particular cases, as in this example. Induction is clearly a risky process, although it can achieve a high degree of plausibility in the face of a large number of cases examined with methodological rigour. There are many cases of generalization that fail.

### Analogy

*Analogy* is another type of very common non-deductive reasoning; it consists in considering a statement P true for a case x if P is true for a case y that "looks a lot like" x. The reasoning by analogy is considered by many, starting from Aristotle, similar to induction; in a sense, it transfers a property from a case or object x to a case or object y applying a different form of generalization.

Among the most frequent uses of analogical reasoning there are:

- the argument based on a reference to a historical precedent; examples: inferring risks from the analogy between the behavior of contemporary politicians and those of Hitler or Mussolini; to predict how the world economy will evolve from the comparison between the crisis of 1907-11 to that of 1929-30

- the argument based on a proverbial case; that is, to apply to a current case the "moral" of a proverb on the basis of the similarity of the context.

## Abduction

More recent is the identification of a new type of inference that somehow recalls induction: *abduction*. Abduction goes back from one or more particular cases (observed) to a particular case (not observed) that would be able to explain them. The observed cases are considered as clues to what was stated in the conclusion.

*The crime took place on a damp ground. That evening, they saw Guy with wet shoes. Guy is the culprit.*

The abduction scheme is as follows:

- (1) there is an observed fact x (a crime that took place on damp ground, in the case of the example) of which there is no explanation
- (2) if the fact y were true (Guy is the culprit), it would explain x; indeed, it would also explain the facts (w, z, ...), also observed
- (3) therefore y is true.

## Formal logic

The word *logic* derives from logos (Greek λόγος), which means thought, word, intellect; in a broad sense, logic studies thought, word, intellect [1]. In a more specific sense, logic is the analysis of reasoning carried out with rigour, sometimes using a specific apparatus of symbols and operations.

Traditionally, logic was considered part of philosophy, but today it is an indispensable skill for anyone doing intellectual work. [2]

Moreover, it is a possible tool for the unification of culture, to counter the tendency to compartmentalize knowledge and skills in specialist disciplines - speaking of school we could call them "subjects" -, a fragmentation that is functional to the division of labour as it is implemented in an industrial and globalized society (Lucio Lombardo Radice, in [5]), and that cannot be overcome only with a generic recourse to interdisciplinarity.

### The "mathematical logic"

Nowadays, when we speak of logic, we often mean to refer to mathematical logic, that is to those parts of logic that can be expressed in a formal way, with mathematical models. In general, formalizing means explicitly defining and using in a rigorous, coherent way the terms used in a discourse. Formalisation is a method, a type of approach to the description and resolution of problems that, together with other methods, can be useful in many fields and whose use during the last century has progressively extended from the natural sciences to the human sciences.

Formal logic is often, but not necessarily, also a symbolic calculation. *Symbolic calculus*, sometimes called *algebra*, contrasts with numerical calculus; it replaces the use of numbers with that of symbols, in order to construct more general expressions, for example formulas for solving entire classes of problems, such as the calculation of the square of a binomial  $(a+b)$ , the correctness of which can be proven as well.

In recent decades mathematical logic has acquired a good deal of popularity also because, in George Boole's formulation, it models the primitive operations underlying the functioning of digital devices. Before him, Leonhard Euler and John Venn had systematically studied the analogy between logical operations and set

*operations*; these, in turn, are the basis of an approach to mathematics teaching, which makes use of *Venn's diagrams*, which proved to be effective even with small children.

### First steps in the formalization of deductive reasoning

The simplest formalization of deductive reasoning is the *propositional calculus*, which will be the main subject of the next unit. It considers as given the value of truth (*true or false*) of a statement and analyses only the mechanisms that preserve the truth in composing elementary statements in complex statements; it is based on the analysis of the properties of the *logical connectives* used in this composition, connectives that often have analogies, in natural language, with *conjunctions*, such as "and" and "or", and with other parts of the speech.

An example: from the statement *Mary can play and [Mary can] sing*, deduce that *Mary can sing*.

Remaining within the propositional calculation, a first progress is made by extending the set of connectives taken into consideration; if to the basic set, which corresponds to the words "and", "or" and "not", we add the connectives of *implication*, corresponding to the expressions "if ... then ..." and "if and only if ... then ...", we are able to carry out some form of *hypothetical reasoning*.

An example: from the statements *Paul knows how to direct if and only if [Paul] knows the music* and *Paul does not know the music*, to deduce that *Paul does not know how to direct*.

The main limitation of the propositional calculus is that it does not consider how an elementary statement is made within it, that is, it does not enter into the merit of what it states. This limit is overcome by the *predicate calculus*, to which belong most of the forms of reasoning known as *sylogisms* since the time of Aristotle.

Historically, the first step was to model each statement as a couple (*subject, predicate*), in which the subject can stand for an individual or a group of individuals and the predicate affirms some *property* of the subject (e.g.: *the snow is white*); subsequently, we moved to a more general model, in which at the center of the statement is the *predicate*, which has the subject and the various complements as *arguments* (e.g. *Fido eats the food in the bowl*). The increased expressive power of the predicate calculus is also evidenced by the fact that it is able to model statements that, in natural language, would require the use of words like "every", "all", "some", "none", "exists [at least] one"; that is, statements that include the so-called *universal* and *existential quantifiers*.

An example: from *All men are mortal* and *Socrates is a man*, to infer that *Socrates is mortal*.

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