**Expectations and challenges brought by ICT in AEC education**

Luca Caneparo  
*Politecnico di Torino, Italy*

ABSTRACT: This paper aims to present some considerations about the relationship between architectural design education, technology of architecture and the expectations that can be reasonably placed on the innovations brought about by information and communication technologies (ICT). The starting-point cannot be information technology itself, but rather the problematic nodes of architectural design, in order to explore and measure the impact and opportunities that information technology tools can have on design education. To this aim, we find the distinction between method-oriented and case-oriented architectural design made by Roberto Gabetti, who passed away recently, particularly interesting.

1 Method-Oriented Education

Two domains of the method emerge from Gabetti’s work, the design domain and the educational domain.

Gabetti investigates the possible links between architectural design and technical-scientific research, and how the method can act as a *trait d’union*, even though «the design activity may be [...] internal to a process of scientific research, without actually being such itself tout court.»⁴ Through an epistemological interpretation, he highlights the ways in which the scientific method itself has been subject to disparate interpretations and expectations.

At one time expectations were higher: design was the result of a methodical procedure, e.g. Lodoli, Rondelet, Durand and the *grille polytechnique*. This was an “algorithmic” conception of design further advanced by the availability of new, more powerful and versatile computational tools (Stiny⁵, partly Alexander³).

Expectations have also been lower: the method «corresponds to the concept of strategy, which does not necessarily give a detailed indication of the actions to be carried out, but just the attitude in which the decision must be taken and the overall plan according to which the actions must be carried out.»⁴

Whatever the expectations of the method, «Downstream from the technical operation one comes into direct contact with the individual [just as] any technical procedure that is carried through to completion leads to an art. [...] It is no longer a question of method, but of style, in the sense in which style, speaking in very general terms, is the organization and the implementation of what in the individual experience escapes the web woven by the concepts, in order to grasp the generic fact according to a method. *A posteriori a style can certainly be described as a strategy*»⁵.

The capability to narrate a style as a strategy is an establishing act of architectural design education. It is the teachers’ ability to re-elaborate her/his own experience, her/his own design practice, in a narrative form, and to offer students lectures as a tool with which to develop their own design methodology.

However there is a quantum leap between method and style. A style cannot be a strategy, because a strategy must be usefully transmittable, whereas style cannot or rather, must not be an action on which education is based: the latter must take place in the dialectic between the proposition of methodological coordinates and the presentation of exemplary cases, which concretize those methodological coordinates according to particular interpretations. The stylistic aspect of these interpretations cannot be proposed without danger of plagiarism, which is precisely the opposite of a method for developing students’ own design methodology and style code.

1.1 The Polytechnic Tradition

The transposition of the method-oriented approach to the field of education dates back to the École Polytechnique. The polytechnic educational tradition tends to provide students with propaedeutic tools during the introductory two-year course, a revision of these in the third year, and finally a design
synthesis during the fourth and fifth years. The teaching, which today refers to the technology of architecture, was part of the introductory and mandatory teaching in the various years of the course.

In the best cases, the polytechnic Schools managed to translate the multiplicity of teaching proposed in the first two years into a method, which the students then applied in the design exercise and the engineer or architect subsequently applied in the professional practice.

The method proposed by the École Polytechnique is the scientific method, but not of theoretical or pure science, rather than of applied science. Monge, one of the founders of the School, highlights the identity of the methods between algebra and descriptive geometry, which he formalized⁹.

The educative role attributed to descriptive geometry is particularly significant. At the time of its official foundation in 1795, the École Polytechnique dedicated 45% of its lesson time to descriptive geometry, alongside analysis, mechanics, and architecture. In 1801 the lesson hours dedicated to descriptive geometry were reduced to 40%, and the tendency for this proportion to decrease continued in the decades that followed.

1.2 Symbol systems

At the beginning of the nineteenth century there was a growing awareness that the technical problems have to be oriented to the modeling of the physical, managerial and productive phenomena and that the modeling process could be beyond a graphical representation. Technology progressively followed science and research along the road of arithmetisation, to the detriment of geometric and graphic methods. In return it obtained greater flexibility and precision and with the advent of the first calculators⁷, and later of computers, growing automation.

The definition of the symbol systems, more generally of the language, is a central issue for science: «the fact is that the use of a symbol system is not just an accessory, secondary aspect of the scientific knowledge. There cannot be science, in the strict meaning of the word, which is not expressed, i.e. which does not represent its objects in a symbol system»⁸.

In architectural design, the design procedure has remained tied to the graphical representation, while technological innovation since the industrial revolution has introduced systems with their own know-how and methodologies which have brought about increasing specialization. At the same time representation of the design has become the link between the various competencies, with the aim of making the design content clear and communicable. Today we are facing the co-existence of different languages, relevant respectively to the constructive, structural, managerial, lighting, heating etc. aspects of the project⁹.

Mathematics has also seen a proliferation of disciplines and symbol systems¹⁰. In the last decades scientific research in the natural and human sciences has begun to deal with problems that cannot be exhaustively dealt with by one discipline alone, that cannot be broken down and analyzed in parts or subsystems. Problems which require an emerging synthesis¹¹ which actively involves researchers from different disciplines. The Santa Fe Institute, also known as the Institute of “complexity”, and other research groups have taken on the challenge to overcome the disciplinary boundaries through a work of linguistic and methodological integration. The work has resulted in new methods and techniques at the cross-over of many disciplines, for example statistical mechanics, biology, genetics, economic and social theory, and artificial intelligence. Much of this work has been carried out and made possible by extensive use of computer models.

Research into information technology is causing the modeling and manipulation of symbol systems¹² to become increasingly a method for the representation and processing of knowledge. At the same time, scientific research is using this software to extend the field of study to human sciences, for example into the areas of social, economic and psychological research. In human sciences the main obstacle is the peculiar nature of phenomena, «in fact they bring with them a collection of meanings which resist a straightforward transformation into objects [...]. It seems difficult to be able to reduce a feeling, a collective reaction, or a linguistic fact into such abstract structures. But when all is said and done, the issue is not to reduce them, but to represent them, even if partially, within systems of concepts.»¹³

In abstract terms, information technology tests methodologies and implements tools in order to enumerate symbols and define the relationships between them. One of the lines of research into the formalization of symbol systems is that of ontologies¹⁴. The term has been borrowed from philosophy, according to which an ontology is the study of the concept and structure of Being. In artificial intelligence, it is that which “exists” and which can be represented. When knowledge in a field is represented in a symbol system, the collection of entities which can be represented are called the universe of the discourse. An ontology implements the specification of a conceptualization, a discourse area comprehensible both to the people who write it, and to the computers that aid the difficult work needed to formalize the symbol systems, within precise domains of application.

The implementation of knowledge-based systems has further boosted the research in the ontologies: a frequent motivation for implementing an ontology is
to define a common language in order to share knowledge within a given field. Within the architectural domain an ontology can indicate that a concept defined "space" has an attribute defined "exhibition".

The concept of exhibition space cannot be univocally identified in single architectures (Fig. 1), it must be placed on a more abstract level than that of the individual artifact. This level, which can also be defined as typological, encompasses, beyond cases, suggestions of design competencies and choices which can substantiate the knowledge necessary for developing a design method and architectural education.

1.3 Strategies

Design research in architecture cannot ignore the multiplicity of criteria, tools and theories which cannot be easily brought together into a single methodology. «There is no pre-determined line: there are suitable methodologies and useful strategies, but there are no absolute methods or obligatory pre-established paths [...]»

Architecture has often been influenced by theories borrowed from different cultural and scientific contexts, however sometimes an essential comparison and deepening work on the language and method has been lacking. At present in the domain of architectural design dealing with the emerging synthesis theory does not aim to promote a likewise operation, instead to reassert the peculiarities of architectural design, which has always involved a complex dialogue and interaction between different ideas, disciplines and know-how, and to place architectural design in the trans-disciplinary context of the emerging synthesis.

In the framework of the emerging synthesis the dialogue and interaction in the architectural practice is modeled as processes, evolving and changing in time. The attention to design is not only on events in the space-place or time-situation, instead the design processes and practice attempt to formulate architectural principles within the space of the processes, allowing space and time –i.e. architecture– to emerge as we know it. The process notion requires the development of the awareness of the multiplicity and simultaneity of the interrelations between the factors involved in the design: from the individual to the social, from the building to the city and the environment.

The emerging synthesis, applied to cross-disciplinary fields, such as physical and natural sciences, has developed new methods and tools of research. For the design process, these experimental methods mark the distance from any positivist mechanism, which from certain assumptions, automatically and autonomously, produces specific design outcomes: simulation as the algorithmic automation of a design process.

Vice versa, in the context of the emerging synthesis, simulation participates in the design practice through an interactive process, across policy, planning and design. The method can be broken down into choice → simulation → evaluation → adaptation / modification → choice → ... The design process proceeds by means either of successive corrections and adaptations or of radical changes of strategy, if needed. This methodological conception is far from an algorithmic formalization, and is closer to the concept of method as strategy: «a global schema within which actions must take place.»

In the context of a strategy, simulation is not the forecast of events with a higher or lower degree of approximation or reliability, but a tool for bringing together and orienting different competencies —also from society— on the design topic and for making the contents of the project clear and hence communicable.

It is also essential that method and processes recognize the central nature of the quality of the design project. «Quality belongs to history and civilization: it cannot be ignored when operating in cultural contexts. The attempt to bring scientific processes closer to the reality of an historical and critical component, belongs to a scientific context: finding some significant information in projects for active management of the landscape, a management which cannot assign precedence to towns or areas, can be useful to promote progress in studies. Today it is possible to connect the scientific and technical worlds, in fact it is also stimulating.»
Simulation therefore as part of a design process, as the a priori definition of a design strategy. This definition is not an alternative to the possibility of a posteriori describing a style as a strategy, or «the organization and implementation of what in the individual experience escapes the web weaved by the concepts, in order to grasp the generic fact according to a method.»

Other professors of architectural design and technology of architecture can probably agree with our conviction of the relevance of strategies in education. On the other hand, it is difficult to agree on a common definition of strategy, beyond a generic assertion of a strategy as the description of a fragment of design experience. Furthermore, agreement on the importance of strategies in teaching does not mean that these are shared, particularly if they derive from the subjectivity of a fragment of design experience.

This is the theoretical core issue, with which architectural design education has to deal with. The problem is the description of strategies when «It is no longer a question of method but of style, in the sense in which style, generally speaking, is the organization and implementation of what in the individual experience escapes the web weaved by the concepts, in order to grasp the generic fact according to a method.»

Strategy is therefore the re-processing of an individual experience, the design experience, offered to students as both narration, during lessons, and knowledge oriented to practice, during the design exercises in the design studio.

1.3.1 Narration
In WINDS²⁷, a system for supporting architectural design education, the professor is asked to highlight the relevant concepts and topics during the lecture-narration. In the example in Figure 2, the lecturer has pointed out noteworthy concepts and ideas: on the basis of these the system is able to automatically recognize further occurrences of the same concepts and ideas.

The last generation of digital thesauruses, such as WordNet²³, no longer considers just the relationships between words, but also between synonyms and concepts, and differentiates the relationships between concepts and words. WINDS implements a semantic organization in which concepts can be related to words, excerpts of text, and also drawings, pictures, animations, and CAD models (Fig. 2). In Figure 2 «The words underlined are instances of previously defined indexes. Therefore this paragraph can be accessed through any of the above indexes. Furthermore co-occurrences of indexes in the paragraph increase the relevance of each index to the others. For example, if the concepts of “visibility” and “different scales” occur together many times in different paragraphs, they are considered relevant to each other. When a student works on the “visibility” issue of his design the system could give the hints of considering the design at “different scales”. That is to say that the author should take into account co-occurrences of indexes when writing paragraphs.»

Similar to an analytical index, this set of concepts is called the Concept Index of the course. The Concept Index of a course and of all WINDS courses in general constitutes an ontology, the instances of which are the individual concepts indexed in the courses.

Implementing ontologies is a challenging and laborious task, because they are normally defined starting from terms and definitions of more general concepts. These concepts and the relationships between them are formalized according to a process oriented from the general to the particular, top-down. Whereas WINDS supports the collaborative construction from the bottom-up of networks of concepts, because it allows for weak semantic relationships²⁵. To be more precise, WINDS uses concepts to index pieces of text and uses the definitions in the Concept Index to set up a web of relationships between indexed concepts²⁶.

WINDS uses the Concept Index to highlight links with related or in-depth lectures within the same course or in other courses to the student and also to the teacher, at the course writing stage²⁷. In each WINDS course there are two mechanisms for managing the relations (e.g. prerequisites, in-depth) among the lectures, relating to two different ways of fruition, respectively explanatory and exploratory (Fig. 3).

Explanatory refers to the use devised by the teacher during the course writing, and is a narrative-like sequence, as in a text, in which paragraphs and chapters follow on from one another in the order determined by the author.

Exploratory refers to non-linear access to the contents, according to a network of references, where the correlated subjects are associated one to another. In WINDS the network of references is not predetermined by the author, as usually with web pages. Instead it is the system which proposes references and associations, also between different courses, on the basis of a global ontology, built up on all the individual ontologies, defined in each course.

In WINDS a student working on one particular design topic can request further or more specific study material from the system. Using the Concept Index, the system promptly offers the student a collection of pertinent material, from which she/he can select the most relevant in order to explore the topic further. In summary, the WINDS system dynamically creates custom-made learning paths to suit the needs of each individual student.

To this aim all the courses, including the technology courses, present a design exercise. Furthermore,
the narrative flow is stored in the system in homogeneous content units, which in a text might correspond to paragraphs or sections. The lecturer establishes pre-requisites, skills to teach and educational goals for each learning unit. The result is that even the learning of a skill can be contextualized within a design strategy.

Roger Schank has suggested learning should be problem-oriented, according to an educative methodology defined as the Goal-Based Scenario (GBS)\(^28\). In GBS, learning is not an abstract activity, but is facilitated by placing skills in the context in which they will be applied, or used. So for instance, lectures on exhibition spaces must not be an aside from, separate, activity. Instead they must be directly related to the design problem, so that the student’s learning is contextualized and oriented to the design activity itself (Fig. 2).

1.3.2 Knowledge oriented to the practice

«The two folds of the method have a common feature, which consists of the necessary representation of the circumstances and ways in which a symbol system acts. It seems that it is not possible to talk about a method unless it is possible to formulate rules and directions in a language, although, as we mentioned earlier, a method does not always require these rules to be made explicit before they are put into practice.»\(^29\)

However, «One of the distinctive problems in representing designs is the richness and complexity of their descriptive content. Each design contains many related pieces of information that are often difficult to describe or to decompose. Furthermore, not all of the information embedded in complete and exhaustive records of existing designs may be immediately relevant for aiding in current design problems. An approach, which addresses these unique problems of representation of design knowledge, is to base it upon a decomposition of holistic case knowledge into separate chunks of design knowledge.»\(^30\)

Here it is necessary to make a distinction between the two main poles around which to formalize the design practice. One is natural language, which makes it possible to describe a strategy in narrative form. The other is the representation in a formal...
symbol system which, precisely because it is formalized, is also more univocal and representative.

The first pole goes into the second because it is possible to discern some emerging aspects in the practice continuum and to represent them by means of a formal symbol system.

A founding hypothesis of our design educative methodology is the awareness that the problem is not so much the representation of the design strategies in themselves, but a representation appropriate to learning, with which students can gradually develop their own, individual, design strategy. Later on, under “Case-oriented” education, we will consider the epistemological and gnoseological implications of the relationships between the general and the particular in design education.

In 1994 we proposed a representation of the design process in which the continuum of practice was discretized into a formal symbol system: acyclic graphs. In this representation the stages of the design practice are the nodes of the graph. While the structuring between the stages of the design, i.e. the implementation in an “individual experience”, are the arcs of the graph (Fig. 5).

The reference to the “individual experience” ensures that the representation is not univocally defined or even definable: in our original formalization the nodes represent “Questions, Suggestions, Arguments, Reports, Decisions”. Rivka Oxmann has proposed a formalization of the nodes into “Issue, Concept, Form”, recently implemented into WINDS as:

- **Issue** - states a design problem;
- **Concept** (Topic) - proposes a possible resolution for the issue;
- **Forms** (Documents) - state a design case, examples, a failure etc.

The symbol representation of a strategy (see example in Fig. 5) is nothing more than the description of a fragment of design experience. In the educative domain, strategies have the difficult task of explaining a design problem to the student by establishing a clear relationship between the problem itself and an idea, example, solution, skill or even a failure.

Strategies and GBS have potentially relevant implications for educative methodology, because they introduce a transition from object-oriented education to process-oriented education, in which the object is the completion of an educative process.

Usually in the design studio, the interaction between the teacher and the student occurs on the result of the design process-practice: on its graphical representation. It is up to the professor’s individual ability and willingness to understand and interpret the cognitive and creative process, behind the graphical representation of the design, in order to suggest and guide the students in the design exercise. Research into the symbol systems and the strategies may turn out relevant for devising a methodology for architectural design education, oriented to knowledge, to the cognitive aspects, and to the design process and practice.

2 CASE-ORIENTED EDUCATION

Gabetti has enquired if there can be method/s outside of science. The answer is yes: there are fields, those concerning the “individual”, such as medicine, psychology, and law, where the relationship between the general and the individual is oriented to the case.

The case as a method of «choosing sufficiently clear and distinct aspects, in order to dissociate them unequivocally, and to transmit the content using a language or ad-hoc symbolism». The case establish priority, «resigning oneself to not describing everything», and also denies any phenomenological reductionism, in favor of the «ability to orient sufficiently clear and distinct elements of the problems examined to design purposes».

Assume that the assignment of a design studio is an office building in an urban area. A student is working on the design of the façade and how it fits in the environment, the area in which the project is inserted. When further working to the design, the student realizes that the design of the façade poses problems relating, for instance, to the cooling/heating, privacy/sight, lighting/sunlight control. Basically, a design which deals with these and fur-
ther problems requires specific experience, which the design exercise aims to motivate in the student. The student will consult manuals, books and journals, and will talk to her/his teachers and other students. She/he will learn to design by designing. In other words by accumulating her/his own collection of cases which she/he will reference to.

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The experience, i.e. the cases, represent a critical element in the comprehension of what is learned, in learning by doing, by designing.

The more experience the student has collected and the more cases she/he has come across, the better she/he will know how to distinguish and to orient the specific peculiarities of the various façade systems to a design aim. According to the cognitive science and constructivism, learning an adequate number of cases will aid the student to appreciate and evaluate the distinctions and differences between them.

In the last twenty years artificial intelligence has drawn the Case-Based Reasoning tools (CBR) from the cognitive sciences. CBR is a field of research which aims to represent experience – cases – by indexing them in a computer memory, defining strategies to contextualize them, and methods for retrieving and processing them in order to support design and educative activities.

In architectural design education, the WINDS system is a significant example of the application of CBR for representing design experience. In the system the cases describe solutions, design details, and technological systems, which either represent correct uses, incorrect or inappropriate uses. In WINDS the cases are structured as learning objects, indexed according to their eminent design features, and formalized in the Concept Index (Fig. 6).

When the teacher interacts with a student, for example during the revision of a design exercise, she/he usually tends to present a certain number of cases, examples of designs and architectures. In general the professor bears the corresponding strategies and the design cases in mind, and uses them to check, correct and enrich the student’s design exercise. The cases play a key role in the narrative structure within which the teacher, starting from her/his own strategies, contextualizes and correlates the examples – cases with the design theme and the student’s exercise.

Cases can therefore be extracted as «sufficiently clear and distinct aspects, in order to dissociate them unequivocally, and transmit the method using a language or ad-hoc symbolism», as in the WINDS system.

In this regard, the importance of the teacher’s revision lies in her/his ability to relate the case to the student’s design, in order to draw the attention to the aspects relevant to the specific design exercise.

Therefore the case is an emerging example within a design strategy, which the teacher puts forward to the student, while the strategies are the representation of a fragment of design experience.

The ability to contextualize a case with respect to a design issue and to relate it to a design procedure can therefore be the trait d’union between cases and strategies.

3 THE CURRENT SUPREMACY OF CASE-ORIENTED TEACHING

In modern pedagogy we recognize important lines of research in which case-oriented methodology tends to prevail, at times to the detriment of method-oriented education. In our opinion, the roots of these pedagogical directions run deep, and go back to the North American legacy of pragmatism, of which James and Pierce were pioneers, and which reached intellectual maturity with John Dewey, pedagogue and philosopher, holder of the chair of philosophy at the University of Chicago, and later at Columbia University.

Dewey claims that the individual enacts his own knowledge in his actions, on the level of praxis. «The scientific attitude may almost be defined as that which is capable of enjoying the doubtful; scientific method is, in one aspect, a technique for making a productive use of doubt by converting it into operations of definite inquiry.» The aims of the method are to tackle difficulties, solve problems and design feasible possibilities. According to Dewey, the scientific method is the most effective tool for pursuing these aims. However, «There is no kind of inquiry which has a monopoly of the honorable title of knowledge. The engineer, the artists, the historian, the man of affairs attain knowledge in the degree they employ methods that enable them to solve the problems which develop in the subject-matter they are concerned with. As philosophy framed upon the pattern of experimental inquiry does away with all wholesale skepticism, so it eliminates all in-
vidious monopolies of the idea of science. But their fruits we shall know them.»

We have given the primacy to Dewey the philosopher on to Dewey the educator, because we believe that his functionalist pedagogy could sometimes have been misunderstood by his functional education which, on the contrary, tends to give the primacy to the know-how over the knowledge in order to adapt it to the requirements of the labor market. Dewey’s comments on knowledge do not claim the supremacy of concrete actions over thought, or practice over theory; rather they confirm the insoluble nature of thought and action. It would be interesting to explore to what extent Dewey’s pragmatic theory of knowledge has affected the epistemological foundations of Papert’s constructivism and Schank’s cognitive theories.

Dewey, pragmatically, founded cognition on practice: «ideas are neither copies of the world, nor representations linked principally to one another, but rather ingredients for rules and for plans of action.» Where the development of “modern” society has promoted and at the same time required a new interlace of culture and technology. Because of the increasing complexity of the technology and the binding of the science with the practice, a response has been the proliferation of ever more sector- and professional-oriented know-how: more specialized individuals with skills oriented to their specific role in business or society. Otherwise the response is the perspective, complying with the social circumstances, of knowledge combining the capability to work intellectually and industrially, which in other words combines culture with practice.

According to Gabetti, in architectural design the reference to the social is in the historical dimension, where «quality belongs to history and civilization». The deepest sense of Gabetti’s historicism is in his having proposed and experimented design practice based on a concept of history as participation to both society and science-technology: «the attempt to bring scientific processes closer to the reality of a historical and critical component, belongs to the scientific domain: recover some significant directions in the plans for an active preservation of the landscape, a preservation which cannot favor certain towns or areas, but instead it could turn out useful to promote the progress in the research. The connection between science and technology, today, is possible, and is even stimulating.»

4 AN AGENDA FOR EDUCATION

Reconsidering, today, an agenda for education in architectural design and technology of architecture, we consider it important to plan for possible mutual contributions between method-oriented and case-oriented education. A synthesis between method-oriented and case-oriented education, between the design studio and the lectures, the École Polytechnique and École de Beaux-Arts has been attempted several times since the nineteenth century, initially by the reform proposed by Viollet-Le-Duc, later applied in the School of Berlin, then with the innovative teaching of Bauhaus, Ulm, and recently in the experiments with the “second design studio”. Today this synthesis has received a further boost from educative theories -constructivism, learner-centered teaching and GBS- and the tools developed by the research, above all in the field of artificial intelligence. We hope that this synthesis will provide the education in architectural design and technology of architecture with methodologies and tools to meet the needs for specialist competencies and permanent training and, at the same time, to provide an answer to the increasing fragmentation of knowledge, which is ever more torn away from any methodology or “cultural” interpretation.

REFERENCES AND COMMENTS

4 Gabetti, “Progettazione architettonica e ricerca tecnico-scientifica”, p. 57.
6 «It is not a pointless exercise to compare descriptive geometry with algebra; the two sciences have very close links. There is no descriptive geometry construction that cannot be translated into algebra; and providing the problems do not have more than three unknown values, every analytical operation can be considered the written version of the geometrical evidence». Gaspar Monge, Géométrie descriptive: Leçons données aux Ecoles normales an III de la République (Paris: Baudouin, 1799), pp. 15-16.
7 According to Monge, descriptive geometry has a direct, applied “character” which «enables it to take the place of analysis in the solution of numerous matters» Monge, ibid, pp. 15-16.
8 Monge attributes descriptive geometry with an important role of link between science and technique. Not an alternative role to that increasingly played by analysis in research and science – mathematics as a tool for investigation and understanding – the role it was attributed by Descartes in the founding act of the méthode. René Descartes, Discours de la méthode pour bien conduire sa raison & chercher la variété dans les sciences plus la distiquet, les méêores, et la géométrie, qui sont des essais de cette méthode. (Leida: Maire, 1637).
9 Monge promotes descriptive geometry to a complementary role of the analysis, at an applied level, on the plane of the relations between science and technique. He conceives descriptive geometry as having a dual role, both practical and
methodological. Practical, «the large-scale manufacture of machinery in the 19th century would not have been possible without descriptive geometry.» (Frederick Artz, *L'éducation technique en France au XVIIIe siècle* (Paris: Alcan, 1939), p. 10.); infrastructures, buildings and machines began to be designed according to the construction-manufacture (dimensioned); methodological, aimed at the formalization of problems and their solutions.

Pascal and Leibniz had already designed and built calculating machines.


One of the priorities of the “modern movement” was to overcome this separation, which was above all methodological and linguistic, by promoting a central technical-intellectual figure.


Santa Fe Institute, *Emerging syntheses in science: proceedings of the founding workshops of the Santa Fe Institute* (Redwood City: Addison-Wesley, 1988).

Newell and Simon define a symbol system as «a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called an expression (or symbol structure). Thus, a symbol structure is composed of a number of instances (or tokens) of symbols related in some physical way (such as one token being next to another). At any instant of time the system will contain a collection of these symbol structures. Besides these structures, the system also contains a collection of processes that operate on expressions to produce other expressions: processes of creation, modification, reproduction and destruction. A physical symbol system is a machine that produces through time an evolving collection of symbol structures. Such a system exists in a world of objects wider than just these symbolic expressions themselves.» Allen Newell, Herbert A. Simon, “Computer Science as Empirical Inquiry: Symbol and Search”, in *Communication of ACM* 19:3, 1976: 116.


There are currently 24 courses in WINDS, pertaining to architectural design, technology of architecture and project management.

At the beginning of the 1970s Horst Rittel and colleagues formalized a graph representation defined an Issue-Based Information System (IBIS), for the formalization and discussion of “ill-posed” problems, i.e. problems where the definition of the problem itself is not clear. Werner Kunz, Horst W.J. Rittel, Issues as elements of information systems (Berkeley: Institute of Urban and Regional Development, University of California, 1970).

Each participant [to the design studio] can add Suggestions nodes to Questions nodes to offer possible solutions and opinions, setting up a link of the “answer to” type, indicated on the monitor by an arrow between the two nodes. Arguments nodes are added in the same way. An Argument can motivate (pros and cons), explain, or deepen a Suggestion node. “Groupware and Design Education in Architecture”, p. 157.

The Ecoles de Beaux-Arts have traditionally been more “case-oriented”. The interaction between tutors and students is oriented to the object: the design is developed in the atelier (studio) and during this process the tutor discusses and interacts with the students uninterruptedly. The teaching materials are the porte-feuille (portfolio), a large folder which contains the lecturer’s work, and also works by best students. As well as this, the examples of architecture were right in front of the students in Paris, at that time the capital of world architecture.


Dewey, ibidem, p. 220.

