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Study of the Conceptions Related to Learning of Complex Concepts: The Case of the Ecosystem

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Abstract. To what extend does the apprehension of a so-called "systemic" thought ensure success in the process of learning of complex concepts? That is the main question underlying this didactic research. This study tries to approach the conceptions of the teachers about the concept of the system and its complexity, by emerging modes of reasoning and by identifying the educational choices related to the learning styles. An approach to categorization of conceptions is carried out; it highlights particular complexity barriers in the case of the concept of the ecosystem. The analysis of educational choices related to this teaching of the ecosystem can be used to develop hands-on activities to introduce the systems approach as a didactic approach to the teaching of the concept of the ecosystem.

Keywords: system, conceptions; complexity; ecosystem; systemic approach

Introduction

Ecology, this 'science of ecological systems' as described by specialists, has been recognized by (Haeckel, 1866) as the science of the relationships between organisms and the surrounding world, (Dajoz, 1983) it was defined as the science of knowledge of the existence of interactions for (Buican, 1997) it was the science of the relationships with the environment. Its history dates back to nearly 150 years, introduced many inputs (concepts, methodology) to enable the understanding of the ecosystems, their diversity, their structures and their functioning. According to conventional physics, the second law of thermodynamics known as Carnot's principle states that any system evolves in the direction of greater disorder. This principle is used to measure the degree of disorder of a system at a microscopic level and applies only to closed systems. Discoveries in biology have shown that any open system naturally evolves into a more complex structure. The interaction "system - environment" can overcome this apparent contradiction. In the case of the ecosystem, emerging concepts as organization, order and Exchange, have been linked to translate a tangle and a layout of connection, paving the way for the complexity, recognized in other areas such as biology, sociology, economics, urbanization, organizations, etc. The complexity of ecosystems cannot be understood without a comprehensive approach, taking into account the interactions between components while keeping the overall unity of the ecosystem; an approach based on the concept of system, so-called 'systemic approach', allows to better understand the various aspects of the complexity.

In the field of education, the learning of the ecological concepts should, with references to the prescribed lead to understand the complexity of the ecosystem. However, do teachers have a conceptual approach, method, tools and techniques sufficiently adequate for shaping and addressing this complexity?

The concept of a system: A complex concept

The idea of "system" is old; its use can be found in Arab science confused with the notion of model or tool which is used in everyday life. Management of water and irrigation of agricultural land, constituted a basis for reflection on the system model.

The premises

The relationship between the systemic approach and the concept of system were reported by many specialists. De Rosnay (1975) considers that «the *systemic approach is based on the concept of system."* "*This term often vague and ambiguous, [is] yet used today in a growing number of disciplines because of its power of unification and integration*. Since the last century, Bertalanffy (1973) had sought to identify, in *the General systems theory*, the common concepts of system and its properties, and proposed to define a system as ' *a complex of elements in interaction*".". Taking this point of view, De Rosnay (1975) defines a system by « *a collection of elements in dynamic interaction, organized around an objective* ».

Le Moigne (1983) considers a system as « *an object in an environment with goals, which performs an activity and sees its internal structure evolving over time, yet without losing its unique identity». Based on the concept of complementarily between the elements of the system, the same author then defines «a *set of interacting components where the modification of one of them causes the modification of all the others » (This modification is clearly based on the relationship and not on the elements) ».* Emphasis on the interrelationships, Morin (1977), talks about ' *An overall unit organized around interrelationships between elements, actions, or individuals '.*

Sketching the history of some of these definitions, Durand (1979) adds other definitions of Linguistics, relating them either to a classic rationalist approach, or to the systemic approach. This set of definition highlights the concept of the system which can be summarized as follows (it is not an arithmetic sum, but the characteristics of the interrelationships between elements):

$$\textbf{System} = \sum_{1}^{n} (\textbf{Elements}) + \sum_{1}^{n} \textbf{Relations}\ (\textbf{elt}/\textbf{elt} + \textbf{elt}/\boldsymbol{Env})$$

(elt: element ;) Env: environment)
Which can be boiled down to:
System = set of structures + set of operating
Understanding a system takes into account the structural aspects (elements) and the functional ones (interactions). Once one takes into account the interaction of new properties, so-called emerging, appearing as the flow of dynamics, reorganization and feedback, which gives the complexity of the concept of the system, the ecological system does not escape from this perspective. Understanding this complexity through

a process of conceptualization and description of links. That is the subject of the systems approach. What makes Le Moigne write in (1990) "*the concept of the system, understood as an intelligible and finalized tangle of interdependent actions, was quickly adopted to describe the complexity*"».

Macy conferences, organized in New York by the 'Josiah Macy Foundation' at the initiative of Warren McCulloch neurologist had met at regular intervals from 1942 to 1956 a group of specialists from various scientific backgrounds (mathematicians, logicians, anthropologists psychologists and economists) and their work has been the source of cybernetics and cognitive science, areas much used to the emergence of systems. Until then scientific research based on the method of Descartes advocated dividing and isolating each item or variable to be studied separately. With cybernetics it is, not to deal with elements taken in isolation, but to seek links between these elements, particularly through feedback. Already since the XXVII century, the complementarily between the part and the whole was a main concern. Pascal (1669), in his *thoughts,* part I, art. 6, said "the flame cannot exist without air: therefore, to find the one you need to know each other [...] I would not know the parts without knowing the whole, nor to know the whole without knowing the specific parts ".

The systemic: science or art?

Walliser (1977) has engaged in an analysis for wondering about the scope and limitations of the systems approach and make clarifications. Donnadieu & Karsky (2002) evoke "the systemic exploration" as well as a practical conceptual approach, to 'think and to act in the complexity. The systemic appears as a methodology and an approach that seeks to define a rational system design approach (physical, biological or social) and analysis based on modeling. The challenges associated with the complexity that the systemic attempts to answer, faces obstacles under the designs around the notion of system, as well as those regarding didactics related to educational choices.

The work of De Rosnay (1975); Walliser (1977); Le Moigne (1983); Durand (1979); Giordan & Souchon (1991, 2008); Donnadieu & Karsky (2002), have helped to conceptualize the systemic approach, its methods, its areas of application and its analysis tools. Aracil (1984) has described, for its part, the evolution of the systems in his *Introduction to the dynamics of systems* and even indicated that this dynamics was based on models such as theorized and symbolized by Forrester.

Modeling is used in the systems approach as a means of conceptualization. One of the modeling techniques based on the schematisations, which can be found in the literature of the designations of the concept map type, introduced in the field of education by Novak (1990, 1991) and in the field of didactics by Giordan & Febvre (1990).

Conceptual analysis of this approach, Giordan & Souchon (2008) describe it as a practical approach for " *pass identification of major concepts to a conceptogramme »* and clarify that in General," *the systemic approach is much more a description and analysis of situations, structures and processes'.*

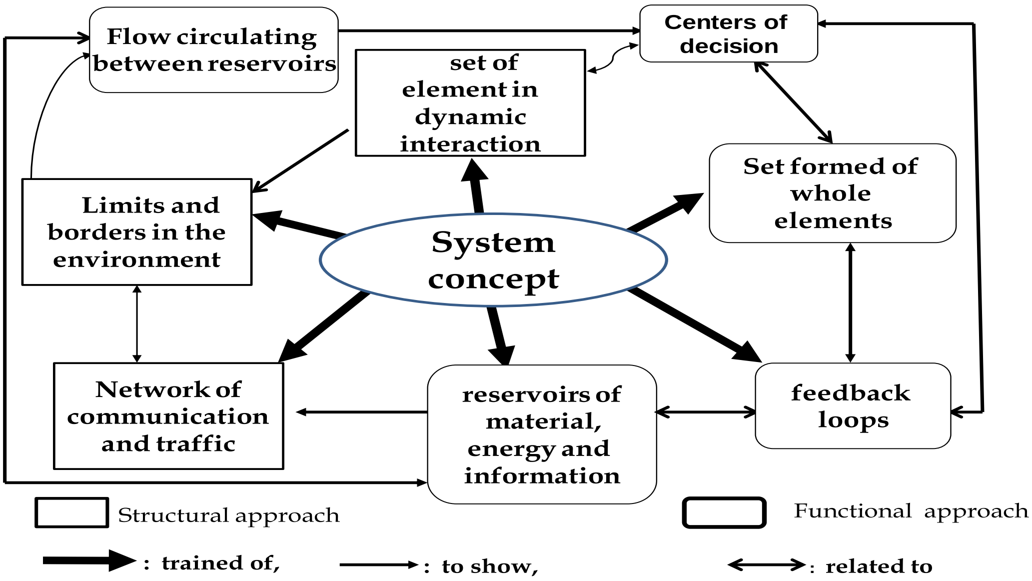

Figure 1: representation concepts defining the notion of system networked

Slightly present in the literature, the term systemic approach tends to refer to an educational dimension versus "systemic approach". In our case, we are actually applying the ecosystem approach in the classroom, in order to build an instruction based on scientific concepts functioning in system.

Issues and research methodology

If several authors have focused on analysis conceptions (Giordan, 1978; Giordan & Martinand, 1988; Giordan, 2002, 1999; Giordan & Vecchi, 1987; Sanner, 1983) in understanding the mechanisms that they under tend in learning; and on the analysis of the issues of complexity (De Rosnay, 1975, Morin, 1977, 1990, 1999; Donnadieu & Karsky, 2002) in connection with the ways of thinking, few references are interested in interactions 'designs - complexity - learning '. On the educational front, the usual modes of learning are to rethink to introduce the systemic approach.

This study chose to start with the main players in the process of teaching / learning: teacher. Analysis of their designs, about the concept of system, could provide information on their modes of reasoning. Similarly, analysis of educational tools selected by the teachers for the teaching of the concept of ecosystem following training on the systems approach can provide information on the degree of understanding of systems thinking in the learning of complex concepts.

Beyond knowledge of the concept of system alone, this study sought to see the degree of influence related to this concept in the process of learning and especially if the only apprehension of systemic thought enough for learning of complex concepts. Works such as those of Giordan & Souchon (2008) developed the systems approach as a conceptual framework for the study of complex ecological concepts, that of sustainable development. Morin (1990) stresses that a disciplinary barrier prevents the assumption of multidimensionality. Relevant training and a practical guide available to teacher teaching resources to integrate the aspect of 'complexity' in learning.

Research on the conceptions of the teachers in connection with the systemic approach, the following research questions have been put forward in the below statements:

1. Doesn't the notion of system appear in the teachers' concepts as a limited frame with a structural dominance?
2. An education based on a teaching approach that is systemic allows a better understanding of the complexity of the ecosystem concept? A complementary training, predominantly "functional" would be more relevant?

The methodology was of a qualitative type, it relies on semi-structured questionnaires. The structuring of the results is based on grids per items which allow to group responses to the various questionnaires.

The questionnaires were made up by the following questions:
A system consists of elements interacting.

What is a system for you (**Question 1**)?
Examples of systems (**Question 2**)?
How does a system work (**Question 3**)?
What are the types of interactions in a system (**Question 4**)?
What are the relationships between the parties and the system (**Question 5**)?

A system is in relationship with its environment:

What are the nature, extent and density Exchange (**Question 6**)? What are the sensors in place (**Question 6b**)?
Y' there the boundaries between a system and its environment (**Question 7**)?

A system meets the disruptions that it receives from its environment. These disturbances modify the structure of the system (**Question 8**)?

If so, how?
If not, why?

In the post-test questionnaire we have added the following questions:
What is a systemic approach for you (**Question 9**)?
How is it different from the classical approach (**Question 10**)?

Beyond these issues, the study focused also on the modes of reasoning in relation to the concept of system in various areas of biology to the economy, and on the degree of involvement in the understanding of complexity. The study focused on teachers of SVT (life and Earth Science) 2nd year secondary Tunisian (17-19 years old) concerned with the teaching of the ecosystem. It is held during the school years 2008 / 2009 and 2009 / 2010. Pre-test questionnaires, conducted respectively with two groups: 19 teachers (Group 1) and 17 teachers (Group 2) of the Regional Directorate of Tunis 2 education.

A training for teachers on the systemic approach took place in the same meeting, after the responses to the questionnaires. It focused on the basis of the systemic approach, its basic concepts, his educational contributions and some application domains. Practical examples were discussed. At the end of the training session, teachers were asked to apply the systems approach in a class situation during the teaching of the concept of the ecosystem, the didactic framework aimed at enabling students to build an instruction based on scientific concepts in operating in a system?.

At a second meeting, post-test questionnaires were conducted with the teachers of the same groups. A sheet of the teaching tools used in class, by each of the teachers of the group, described the chosen tool and its benefits. An interview was conducted with some teachers of each group on the issues listed in the pre-test and post-test to complement the written replies. In the descriptive profiles, and to determine the degree of understanding of the systems approach as a pedagogical choice by teachers, the following issues were raised.

Where/which of the following teaching tools have you used in the classroom for the teaching of the concept of ecosystem (**Question 1**)?
-A concept map or a conceptogramme
-A folder prepared by each student on a theme chosen in advance
-Output on the field with the students in the class
-A debate in class from a specific document or topic
-Another tool, to describe
Describe the benefits of the educational tool that you used in the classroom: how did they allow you to help students understand the ecosystem, the network relationship between the components, the hierarchy of relationships, the exchange with the environment (**Question 2**)?
Can you describe the contributions of the schematisations compared to other educational tools in the teaching of the ecological concepts (**Question 3**)?
Which are the most successful teaching educational tools you can use according to the systemic approach ecological concepts (**Question 4**)?
Selected teaching tool:
Justify your choice:

Our approaches to analysis are supplemented by a grid that allows you to categorize the replies to the questionnaires and analysis of educational choices, either in the structural approach or in the functional approach (see figure 2).

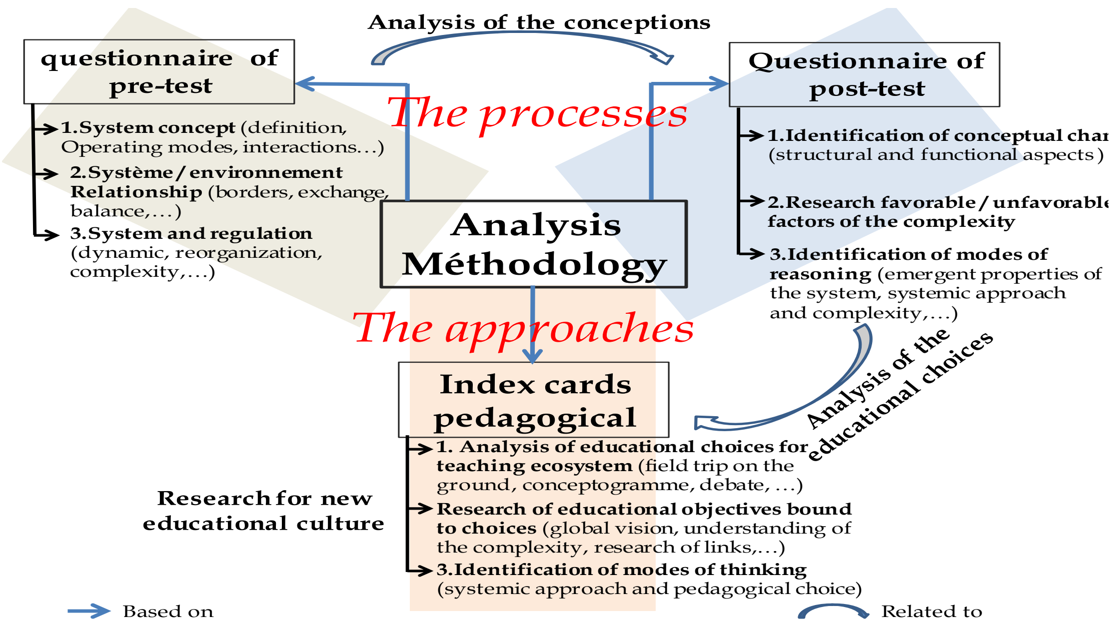

Figure 2: analysis approaches and methodologies being used

Conceptions and modes of reasoning systems: previous barriers highlighted

These studies showed significant numbers of results. Questionnaires for both the pre-test and the pos-test responses benefit the structural approach with regard to the definition of the system, its operation and the complementarities between its parts. Double answers to questions about whether or not there are boundaries between the system and its environment, the lack of answers to some other questions about the dynamics of the system and its exchanges, express some uncertainty and number of ambiguity, in the way of thinking of teachers around the notion of system. Some emergent properties of the system, such as reorganization, regulation and flow, can be expressed loosely: feedback used to balance the system, relationship between the parties and the system that can be positive or negative, importance and density of exchanges at the origin of the survival of the system, which would prevent accession to the complexity of the system. Reference, often socio-professional order among teachers, appears to be an obstacle to think on the concept of the system outside the realm of teaching. The justification on the notion of borders, the sensors involved in trade and the reorganization due to external disturbances, is 'obvious' if the concept of a system is planned in areas other than biology.

> ➢ According to you ' has it borders between a system and his environment?
>
> ☒ **Yes** ☒ **No**

Excerpt from the AO teacher responses

> ➢ Does a system answer the disturbances that it receives from its environment? Oui (Yes)
>
> • Do these disturbances modify the structure of the system?
>
> ☒ **Yes** ☒ **No**

Excerpt from the CR teacher responses

Examples of responses reflecting the blur and ambiguity around the concepts of borders and regulation in the concept of system.

Table 1: comparison of trends between the answers to the pre-test and the post-test for each group of teachers

Behavior change

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6 (a and b)	Question 7	Question 8
Group 1	**79 %** to **74 %** Set of elements **16 %** (**unchanged**) Organized / structured	**92 %** to **89 %** Physical biology **8 %** to **11 %** Sociology	**85 %** to **88 %** Complementarity **10 %** to **5 %** Rules and laws	**26 %** to **50 %** Action / retroaction **42 %** to **33 %** Positive/ negative	**31 %** **to** **25 %** Complementarity **37 %** **to** **31 %** Exchange / balance	**68.4% to 40.2% (SR)** **N: 81 %** Exchange **I: 46% to 19 %** Balance **D: 67% to 83 %** Variability 6 **(b)** **50 %** Relay **(unchanged)**	**58 %** **to** **83 %** With border **42 %** **to** **17 %** Without border	**85 % to 94 %** Modification of structure (+) **15 % to 5 %** Modifying structure (-)
Group 2	**71 %** to **43 %** Set of elements **12 %** to **36 %** Organized / structured	**86 %** to **84 %** Physical biology **14 %** to **16 %** Sociology	**35 %** to **69 %** Complementarity **47 %** to **8 %** Rules and laws	**18 %** to **23 %** Action / retroaction **70 %** to **54 %** Positive /negative	**36 %** to **45 %** Complementarity **36 %** to **9 %** Exchange / balance	**82.3% to 50% (SR)** **N: 46% to 50 %** Exchange **I: 43% to 20 %** Balance **D: 12% to 67 %** Variability 6 **(b)** **42% to 50%** Relay	**81 %** **to** **93 %** With border **18 %** **to** **7 %** Without border	**94 % to 87%** Modification of structure (+) **6 % to 13 %** Modifying structure (-)

SR: no response; **N:** nature, **I**: importance, **D**: density

Percentages expressed at the forefront are relative to the answers to the pre-test, those second place belongs to answering the post-test.

The configuration of the replies to the questionnaires of the post-test expresses a 'timid' change at the level of the designs incorporating the functional aspect of the system. The systems begin to be more recognized in sociology and economics, the complementarity appears in the mode of operation between the parties and the system, regulation and dynamics become source of equilibrium of the system. There is a possibility that the teacher adheres to a thinking taking into account the dual approach of the systems. Responses which continue to express a blur, ambiguity on notions such as feedback and reorganization, constitute a challenge and change of design may not be sustainable, it needs to be strengthened.

The systems approach is a didactic approach meant to clarify to teachers with the ultimate objective to enable learners to achieve this change in way of thinking.
When the situation is at the experimental level, we can recognize the results, but how to generalize them, to make them "educational" and put them within reach of all teachers? Educational tools selected by each of the teachers can be seen as 'limits' to changes in designs. Only the inclusion of the systemic approach as curriculum option and the training of teachers in this learning process can enhance the

understanding of the systemic thinking and address the complexity in the learning process of complex concepts. In responses to the post-test questionnaires, some teachers interviewed have changed the responses between questionnaires and interview. With the second group, this change reflects a "trend" towards answers and justifications related to a way of thinking taking into account the functional aspects of the systems. Appropriate training of teachers on the systemic approach could facilitate the understanding of the complexity of the systems and the development of its emergent properties.

Comment and discussion: Obstacles facing the generalization of the concept of system

Teacher training on the systemic approach and analysis of case studies, participated in the change in SVT teachers' responses towards more functional aspects of the systems The notion of system is now thought into areas such as sociology and economics, and the types of interactions and relationships between the parties and the system, promote complementarily and exchange. The operating mode of the systems and their dynamic integrate regulation and balance. The major difficulty remains regarding the ability of teachers to put into practice the systemic approach and enable learners in their turn, to achieve a change in way of thinking that integrates complexity. Proposals for responses based on ‘global’ and ‘blurry’ ideas seem to prevent linking structural and functional aspects for a better conceptualization of the concept of system. The sustainability of a change the designs in support of functional system approach would need to be strengthened through training in the didactic approach promoting a way of thinking which apprehends the complexity of systems. The analysis of designs highlights 'what works' or 'adverse' factors in order to access the complexity of the concept of system (see figure 3).

In connection with the notion of system, key concepts such as borders, dynamics and flows, are seen differently if we place ourselves on the side of the structural approach or the functional approach. In the case of designs promoting systemic approach borders are seen as ‘boundaries’ between elements or subsystems, the dynamics appears to be necessary interactions to ensure system balance and exchanges are expressed in terms' of 'tools' and 'relay'.

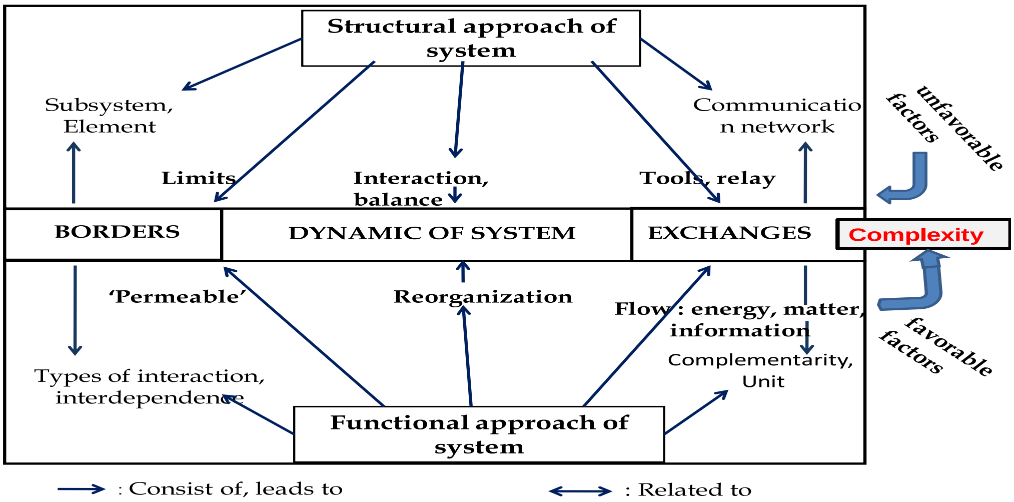

Figure 3: the complexity of the concept of system-related concepts

With the conceptual change, the same concepts are translated differently; borders are seen as non-watertight limitations to exchange. The dynamics of the system is related to the concept of reorganization which enjoys the system to ensure its survival and the exchanges are designed as energy, material and information flows. In the first category of designs, the key concepts appear as 'obstacles' to access the emergent properties of the system. Only the complementarity between structural and functional approaches to make the concepts of borders, dynamics and Exchange factors 'favourable' to the complexity of the concept of system.

Table 2: summary of the results of the analysis of tools teaching of groups 1 and 2

	Question 1 Selected educational Tools	**Question 2** Benefits of the chosen educational tool	**Question 3** Contribution of the schematisation	**Question 4** Tool to foster systemic approach
Group 1	Conceptual C. **3** % Folder **14**% Output **42** % Debate **19** % Other **21** %	Understanding **5** % Research of network **31** % Exchange with the environment **19** %	Exchange **18 %** Evaluation **29 %** Network **47%** Viewing **6 %**	Conceptual C. **9** % Exit **68** % Debate **5** % Other **18** %
Group 2	Conceptual C. **11** % Folder **20**% Output **25** % Debate **22** % Other **22** %	Understanding **50** % Search Network **29** % Exchange with the environment **21** %	Exchange **29** % P. emerging **15**% Network **21**% No answer **35**%	Conceptual C. **12** % Output **50** % Folder **6**% Other **31** % No response **3**%

The choice of teaching materials remains in the same orientation as the designs. The field trips are the most widely used educational tool. On the one hand it is prescribed in the curriculum, and secondly the teacher 'dares' not try a new teaching tool, some have done at our request by trying other options such as the conceptual map. The benefits of applied educational tools focus on the understanding of the ecosystem, looking for links to establish a network of relations between its elements or the identification of the exchange between the ecosystem and the environment. Although teachers recognize that the schematisations have important educational inputs as emergent properties, the overall vision and evaluation, these contributions have not favoured with the chosen educational tools.

The case of educational tools that promote the more systemic approach, recalls once again a usual paradox in teaching: a new educational choice still requires some time to be implemented. Although the conceptual map is a teaching tool selected and tried, the field trips that may help to conceptualize the ecosystem are a choice influenced by socio-professional appearance.

A didactic strategy, as part of the systemic approach would encourage teachers to make use of this tool and to integrate the complexity in the learning process. Didactic aid may strengthen this strategy and enable teachers to learn about the systemic approach. The evolution of the designs must be 'worked' and a pass-line must ensure a certain 'transition', through socio-professional status and continuing education, to build up new pedagogical approaches to develop a new educational culture.

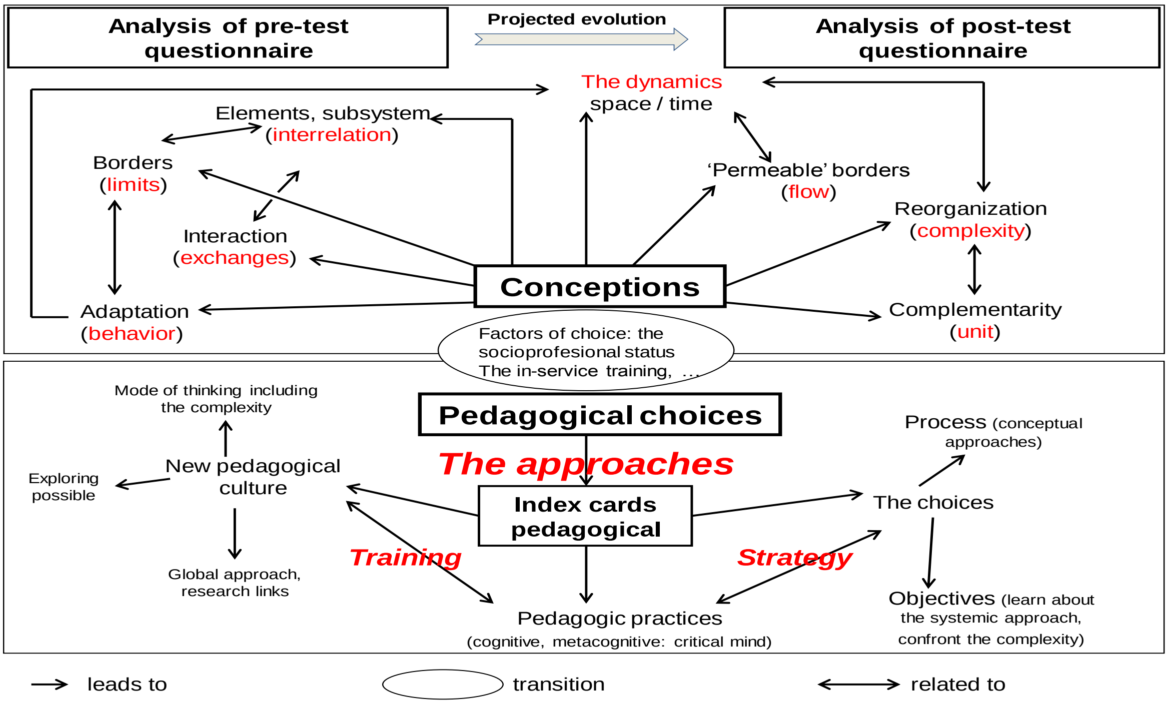

Figure 4: summary of the analysis of questionnaires and educational sheets

Complexity and systemic approach

The McManus (1990) reported that the systemic used the theory of modelling to represent the complexity and model it. The schematisations constitute a model for complexity. Introduced in education by Novak (1990) and applied in the case of education to the environment and sustainable development by Giordan and Souchon (2008), the schematisations are tools to address the complexity of learning and assessment.

Using computer tools, the use of the schematisations is commonplace in the field of education; however there is a teaching tool of limited application and a pedagogical choice unknown to teachers. The characterization of the systemic approach to the classical approach reveals that the 'complexity' aspect is difficult to recognize in the responses of Group 2.

Table 3: summary of responses to questions 9 and 10 of the post-test

	Question 9 Characterization of the systemic approach		**Question 10** Characterization of the classical approach	
Group 1	Allows the vision overall	**59%**	Analysis by dissociation	**88 %**
	Establish a network of interactions	**41%**	Ineffective facing complexity	**12 %**
Group 2	Allows the vision overall	**73 %**	Analysis by dissociation	**90%**

In the learning of the ecological concepts, 'a conceptogramme' can be a conceptual tool for non-linear thinking and explaining the interactions and feedbacks, so as to develop the 'circular causation' to clear the hidden face of the complexity of the systems, emergent properties.

Conclusion

The vagueness and ambiguity appear when it is placed in the register of the common knowledge of systems: borders, exchange, regulation and dynamics. These knowledge-related designs are quite easy especially if the teacher is answering questions such as nature, importance and density of exchanges or regulating the system to disturbances which undergoes its environment. Obstacles arise to imagine 'leaky borders ' playing the role of limits, but at the same time allowing the exchanges between the system and its environment. Training on systemic and its foundations, offers teachers an opportunity to rethink the concept of system, broaden the scope of this concept in various fields. A new way of thinking, based on research of links, is now possible building on the interaction and the notion of 'all' characteristic of systems. Despite the reported difficulties, a 'shy' change of conceptions appears when issues of post-test, especially about the definition of the system, how it works, the types of interaction between components and boundaries. The spatio-temporal evolution, the reorganization of the system to the disturbances and Exchange fluxes are notions which are difficult for teachers to imagine using in various fields. These are factors described as "preventing" the apprehension of the complexity. This difficulty is especially found in the descriptive notes where the teacher persists in choices of classical approach methods, despite a request to apply the systemic approach in the teaching of the concept of ecosystem. Extending this research to other groups of teachers could reveal details of the ideas and modes of reasoning of each but would also make known this process as much as possible. Ultimately, it would be advisable that learning through systemic approach be reflected in educational objectives and practical steps included in the official Programmes, offering in parallel educational resources for teachers. Such a proposal should be supported by appropriate training of teachers in the functional approach to systems.

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