The Learning Process Mediated by Intelligent Tutoring Systems and Conceptual Learning

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ABSTRACT

Inspired in actual educational occurrences and largely based in the theory of concept formation, Conceptual Adherence is proposed as a way to increase adaptability to Intelligent Tutorial Systems (ITS) and perform it in the just time of the learning action. This paper assumes many ideas about learning, educational assessment, concept formation, social learning (due to Vygotsky) and self learning, to introduce the idea of Conceptual Adherence. Intelligent Tutoring Systems (ITS) are pointed as an efficient educational software for the teaching/ learning process centered in student. ITS' architecture and adaptability are examined. The process of problem solving by many ways with "look back" proposed by Polya is pointed as an instance of Concept Adherence application.

Keywords*: Learning; Concept Formation, Adaptability; Intelligent Tutoring System; More Capable Peer; Problem Solving, Conceptual Adherence.*

1.– Introduction

The increase of knowledge generation and the worldwide access to information turns the teaching and learning processes a permanent marathon. The access and use of computers to supply informations to teachers and learners became a challenge that needs to be winning. Computer Based Teaching is a way to solve these problems, from Electronic Books and Encyclopedias to Intelligent Tutoring Systems (ITS). ITS research shows that the main problem is their *adaptability* to learners due to the individualization of the learning process [Wenger 1987].

This paper proposes the concept of Conceptual Adherence as a way to increase ITS *adaptability*.

Conceptual Adherence is a path constructed from the *Learners Level of Real Performance* (detected point) to a Level of Potential Performance (target point) through a Zone of Proximal Development, ideas due to Vygotsky, by dynamically finding the learner's skill on the subject been studied.

The learner's skill and knowledge are constructed by his/her navigation on sets of *webs of conceptualization* or *concept formation webs*, concept by concept. A *concept formation web* represents the many ways to reach solutions to given problems.

By short, this paper includes: ITS definitions and its usual architecture, *adaptability* of a ITS to learners and to a learning model, concept formation definition and the concept formation web, conceptual adherence definition and construction, skill acquisition through problem solving.

2.- Learning, Behavior and Assessment

Learning, by the viewpoint of modern Cognitive Psychology, is the acquisition of a form of knowledge, ability or skill, through *concept formation*, involving mental process and the use of experience and practice [Honderich 1995].

When educators evaluate behaviors they are not evaluating the learning, the behavior assessment generally does not correspond to the real accomplished learning [Rappaport 1984]. The next two instances will show this.

In the idealized following situation, we will describe the traditional teaching/learning process used in classroom practice. In this situation, a teacher intends to explain a pedagogical topic to many students, interested (*supposed)* in this learning process.

During the class, the teachers explain enthusiastically the subject matter and evaluate learning by the behavior of some of these students. This evaluation is performed by: making queries, accepting and analyzing answers, providing examples and counter-examples, writing and drawing in the blackboard or showing slides, videos etc. Some of those students understand perfectly the subject matter; others do not understand. Sometimes teachers can teach but students do not learn.

In other idealized situation, a teacher intends to explain a pedagogical topic to only one student admittedly *interested* in learning. This is an

individualized teaching/learning. This educational process is centered in the student [Rogers 1969], that is, this process considers his needs, but this is not a classical classroom occurrence. The individualization of the learning process is not the classroom practice.

By short, the process of knowledge transmission to a group of students is very different from the process of knowledge transmission to a single student. In the first case, teacher could not detected and control effectively the learning process. In the second case, the teacher can control all the learning process just in time. The learning process proposed by this paper is more related to this second kind of learning.

3. - ITS Definitions and Architecture

Intelligent Tutoring Systems (ITSs) are special educational software that involves Artificial Intelligence (AI) techniques and methods to represent the knowledge, as well as it conducts the learning interaction.

The dynamic behavior of the ITS permits some autonomous capabilities as: generate examples and exercises or adjust actions and adapt to the right level of difficulty by measuring of the student's performance [Wenger 1987]. These capabilities are named *adaptability of ITS*. The individualization of the learning process, more exactly named the education centered in the student, as shown, is the challenge of the research in this area.

ITSs are educational systems that incorporate knowledge about teaching and learning evaluations, and interact with students supporting their actions. ITS can explain student's behavior and conclusions. The knowledge, information, control process etc, in a traditional ITS architecture (see **Figure 1**), are basically stored/structured in the following modules:

(a) *Communication module*: an intelligent interface (generally whit multimedia resources) that allows the communication between the system and the students, and vice versa.

(b) *Domain module*: composed by the pedagogic objectives, topics and procedures. Concepts, objects, rules, examples, counter-examples, Socratic dialogues, exercises, problems, informations, phrases, recommendations etc, are disposed in this module in a web.

(c) *Tutorial module*: is composed by tutorial rules, it directs the interaction between the system and the student. Didactic decisions are made by references to the student model and to the domain knowledge model.

(d) *Student model module*: provide a mapping between *student models* previously stored and the learner's actual mental state, during an interaction.

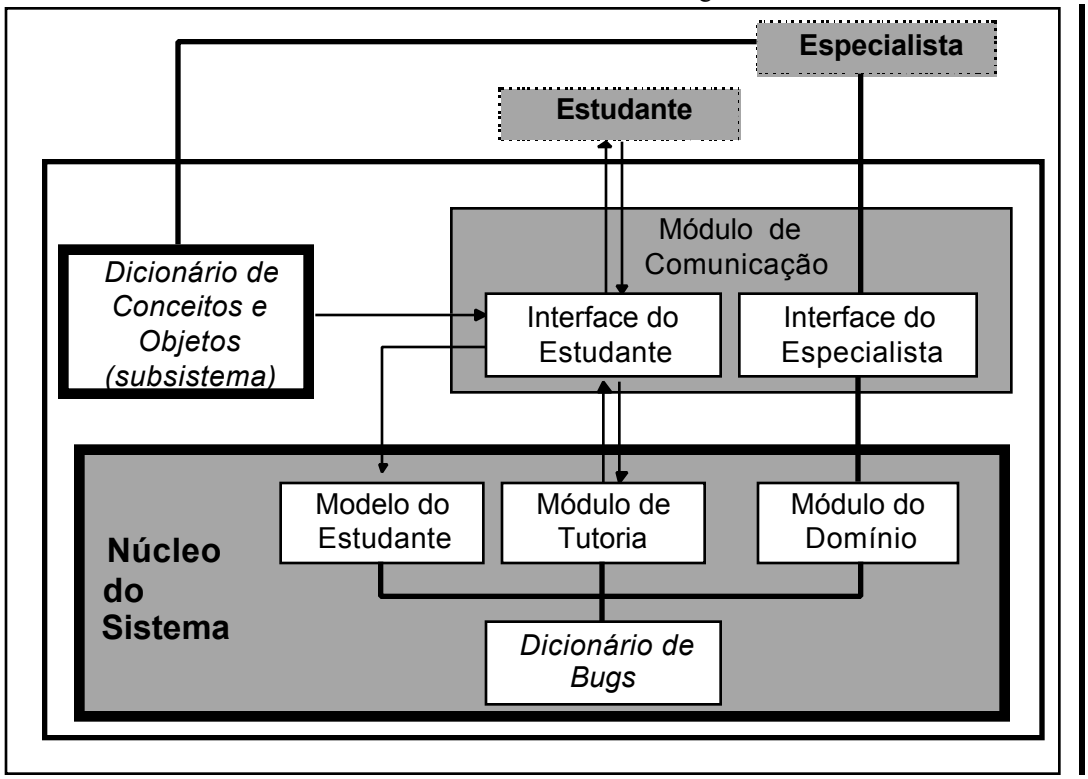

Figure 1: The architecture of an ITS

According to Wenger [Wenger 1987], the individualization of learning via ITS, that is, the *adaptability* of an ITS, is largely determined by the coverage and precision of the information contained in the student model module. This paper proposes the concept of *Conceptual Adherence* as a way to increase ITS's *adaptability*.

4. - Concept Formation

The notion of concepts and concept formation will be discussed here.

Concepts are a specific classification based in common attributes of objects, people, events, phenomena, instances or specific ideas. By short, a concept is a general idea derived or inferred from specific instances or occurrences [Lalande 1993]

According to Vygotsky [Cunningham 1996] the human language is a mechanism for thinking and it plays a central role in *concept formation*. The c*oncept formation* or the *conceptualization* always involves external experience transformed by internal process through the mediation of language. In a concept formation process, two inner (mental) operations are used: *abstraction* and *generalization*.

Abstraction is an operation that allows making a shortened form of objects, peoples, events, phenomena, instances or specific ideas, by separating up what is important in it. Generally, an abstraction is represented by a *linguistic* or *symbolic label.* On the other hand, *generalization* is an operation that allows the application of a *label,* obtained through the abstraction, to a set of objects, people, events, phenomena, instances or specific ideas. The results or consequences of these inner operations, respectively the label and the set of labeled items or objects, are: the *comprehension* and the *extension* (see **Figure 2**).

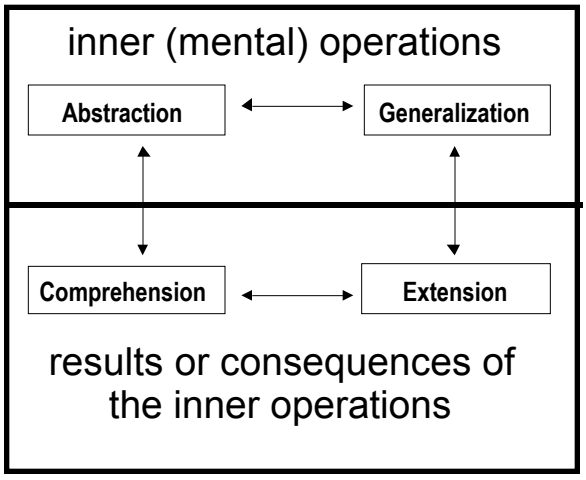

Figure 2: Operations and results or consequences of conceptualization

A high level of abstraction generates a short level of conceptual extension and, conversely, low levels of abstraction generate a high level of a conceptual extension (see **Figure 3**).

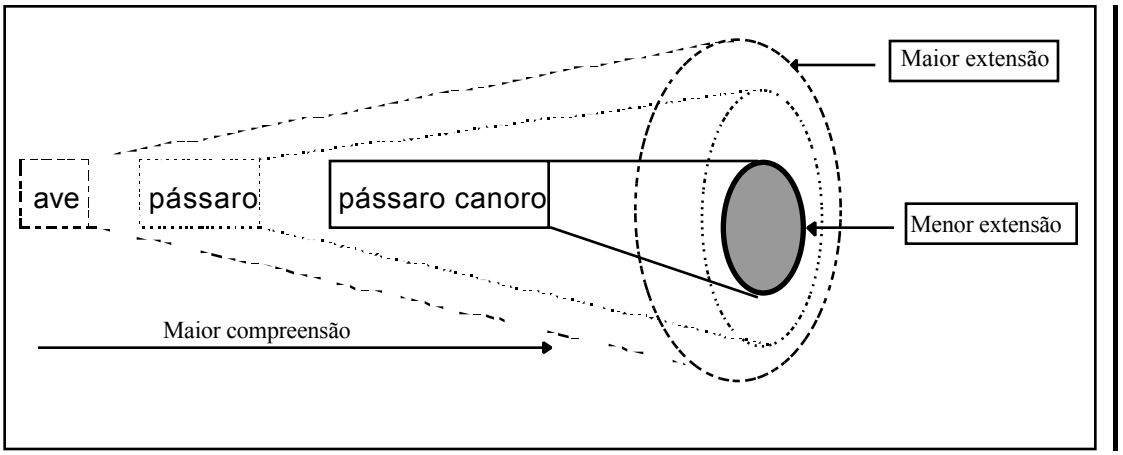

Figure 3: The comprehension and extension of (labeled) concepts.

5. - Vigotsky and the More Capable Peer

Lev Semynovich Vygotsky was born in 1896 in Tsarist Russia. He was noted due to his studies in the philosophy of history and psychology, and his researches and theories on learning, development and structure of human consciousness.

Vygotsky's ideas of *the level of assisted performance, the level of independent performance, zone of proximal development* and the idea of *most capable peer,* will be discussed here.

The essence of Vygotsky's theories of learning and developing is based in the following ideas [Cunningham 1996]:

- Humans are able to construct their own knowledge.
- The knowledge is not only constructed but is co-constructed too; that is, *learning can involve more than one human.* It is very important and necessary to assisting humans to use strategies to promote their intellectual capacities.
- The learning can guide the development, that is, learning impact development; learning skills can hasten the development.
- The development cannot be separated from its social context.
- The language plays a central role in mental development.

According to Vygotsky, a knowledge or learning level that a human is currently capable to attain only with help is called *the level of assisted performance (level of potential performance).* The knowledge or learning level that a human is capable to attain without help is named *the level of independent performance (or level of real performance)*. The area between these two levels is the *Zone of Proximal Development*.

According to Vygotsky's theory [Vygotsky 1978], inner speech cannot exist without social interaction. In a gradual developmental process, the symbols (first used in communication) are incorporated in the interests of social cooperation, and the mind evolves to reflect the social reality. The process of trying to communicate with others,

according to this theory, results in the development of word meanings. Is the word meanings that allows to form the structure of consciousness.

A book, a text, a graphic, a table, an *intelligent tutorial computer system (ITS)* or another person can help the learners when they are in a level of assisted performance and want to go to a higher level. In this theory, these assistants are named *most capable peers.* Vygotsky believed that *a human could perform on a higher level of knowledge to any type of the social interaction.*

In **Figure 4,** we can see the interpretation of Vygotsky's ideas about learning; numbers and letters can help to understand the sequence of actions.

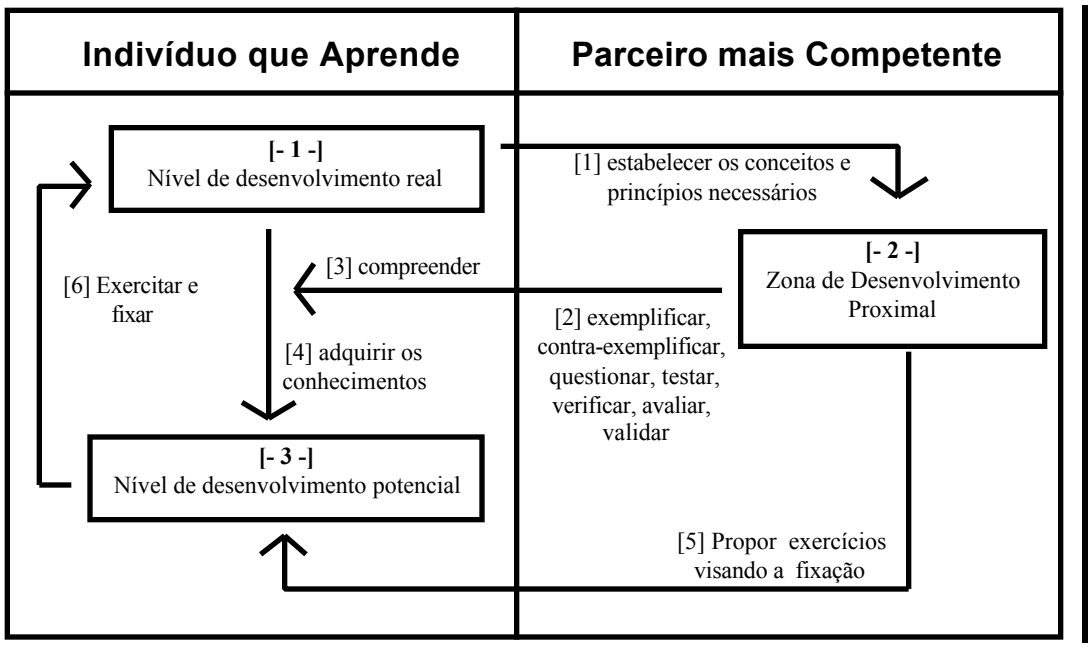

Figure 4: interpretation of Vygotsky's ideas about learning

The computational environment, as modeled here, many times resumes the role of *most capable peer* of novices or learners, other times novices or learners resume the role of the *most capable peer*. This switch between the computer and humans role is the real idea of the *many ways problem solving representation model* (see **Figure 7 and 8**).

6. – The Conceptual Adherence

Conceptual Adherence is proposed as a way to increase ITS *adaptability*. *Conceptual Adherence* is a path constructed from the learners' Level of Real

Performance to a Level of Potential Performance through a Zone of Proximal Development by dynamically finding the learners skill on the subject been studied. The learner's skill and knowledge is constructed by his/her navigation through a *concept formation web* that represents the many ways to reach solutions to given problems (problems properly said or questions) via Socratic dialogs. This web presents problems as well results, examples and counter-examples (see **Figure 5**).

In **Figure 5** terminal nodes are connected (recursively) to others *webs of conceptualization* or *concept formation webs*.

Figure 5: A Concept Formation Web (or Web of Conceptualization)

6.1. – Some Definitions of Adherence

- *Conceptual adherence* is a systematic and interactive process involving two persons: a learner and the most capable peer (a human or a *computer*).
- *Conceptual Adherence* is the process that allows to the most capable peer to evaluate the learner's concept formation (abstraction and generalization) through the comprehension and extension of a required concept.
- The *conceptual adherence* only occurs when the learner can *really convince* the most capable peer about his knowledge upon an specific concept.
- The levels of a concept comprehension and extension will be flexible to allow a local and instantaneous adaptability, independent of the student model, and allows the consequent *conceptual adherence* certifying.
- When the *conceptual adherence* does not occur, the most capable peer should start a new process of concept presentation to supporting the process of adherence to such required concept.
- When the *conceptual adherence* occurs the most capable peer can start a new process of concepts presentation or can interrupt the process.

7. - Problem Solving Processes and The Conceptual Adherence

According to Morris [Morris 1976], the Cognitive Psychology distinguish between *learning for retention*, in which a person is *informed* about the correct response and is expected to be able to perform it at some later time; and *problem solving,* in which the person must *discover* the correct response for himself. The process of *concept formation* through *conceptual adherence* is a kind of learning that involves learning for retention (via

examples and counter-examples) and problem solving (via Socratic dialogs, answering questions and solving problems properly said). Extending the Morris's idea, we are interested in three kinds of learning: learning by retention, learning through problem solving and learning about the problem solving process. The learning and the skill acquisition about solving problem process is broached in the following item. The third kind of learning is a metalearning.

The idea of *conceptual adherence* can be extended to the *learning about the problem solving processes.*

7.1. - Problem Solving Processes

Human problem solvers present their solutions and answers, generally in very concise terms, after the problem solving process is completed [Wilson 1993]. The problem solving activity require the combination of previously *known and unknown concepts*, objects, ideas, formulas, reasoning about hypothesis, and *trying of many ways to solving*. Solvers do not usually report this process.

There are many others problematic occurrences in a problem solving process. Karl Dunker [Dunker 1972], a Gestalt psychologist, coined the term ***functional fixedness*** to denominate what occurs when a problem solver *does not understand a concept or object* (graphics, tables, drawings, pictures etc) used in a unconventional context or in a unfamiliar usage or way. This difficulty occurs when a meaning of a concept or an object is not immediately perceived. Solvers' understanding former concepts have to be changed to incorporate the new meaning now perceived.

Gyorgy Polya, in his book, "How To Solve It - A new aspect of mathematical method" [Polya 1975], introduced general techniques to solve problems in mathematics. He suggested many procedures that often help in the problem solving process but do not assure total success. These procedures are: (1) understanding the problem, (2) make plans, (3) carrying out a plan, and ***looking back*** after getting an answer. ***Getting an answer*** is not the main goal of this process.

To Polya, ***look back*** (see **Figure 6**) means: *to reinterpret the problem, to interpret the result, choose another way to solve the same problem, use the result or the method for some other problem.* In schools, when a problem is solved isn't customary deriving a different way to solve it. "Teachers and researchers, however report that developing the disposition to look back is very hard to accomplish with students" [Wilson 1993]. L*ook back* in schools generally is not possible because *problems* are used like examples of a subject matter. In this case problems only involve contingent ideas, not used like a challenge, involving a diversity of unrelated ideas when it is necessary to identify and work with distinct subject matters. The dispute and anxiety of *getting answers* is another reason for *no looking back* in schools. Time spent *to look back* is another obstruction to this procedure.

Looking back activities are a good way to retrieve, amplify and fix knowledge. These activities are important to learners' skill and expertise acquisition in any field of knowledge. Wilson proposed the adoption of problem solving and looking back activities as an instructional method: "it is what you learn after you have solved the problem that really counts" [Wilson 1993].

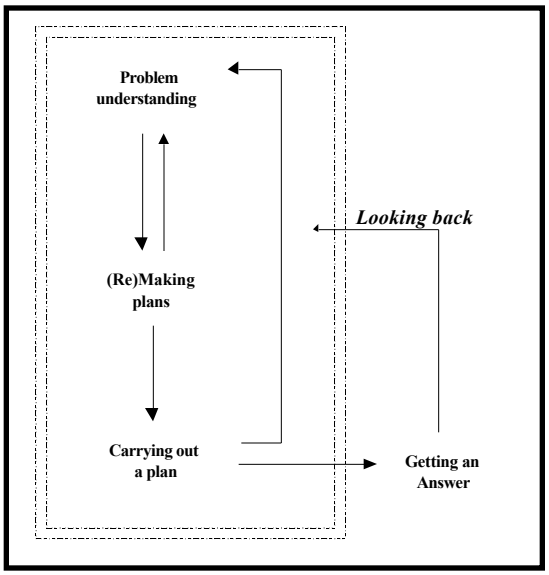

Figure 6: *Polya's problem solving process.*

7.2. - The Adherence to a Problem a Step

The *conceptual adherence* and its generalization, the *adherence to a problem step,* allow the proposition of the *many ways problem solving representation model* (see **Figure 7**). In this model, the learner should adhere to a problem solution choosing a step in many possible solutions of this problem using the *conceptual adherence* when is necessary to understand a concept or as object involved in this step. The adherence is thus extended to the step like a generalization of the conceptual adherence.

The expertise on problem solving processes by many ways is an important requirement in many fields of human activities. The skill acquisition in this matter is promoted by the *many ways problem solving representation model* via the *look back* technique.

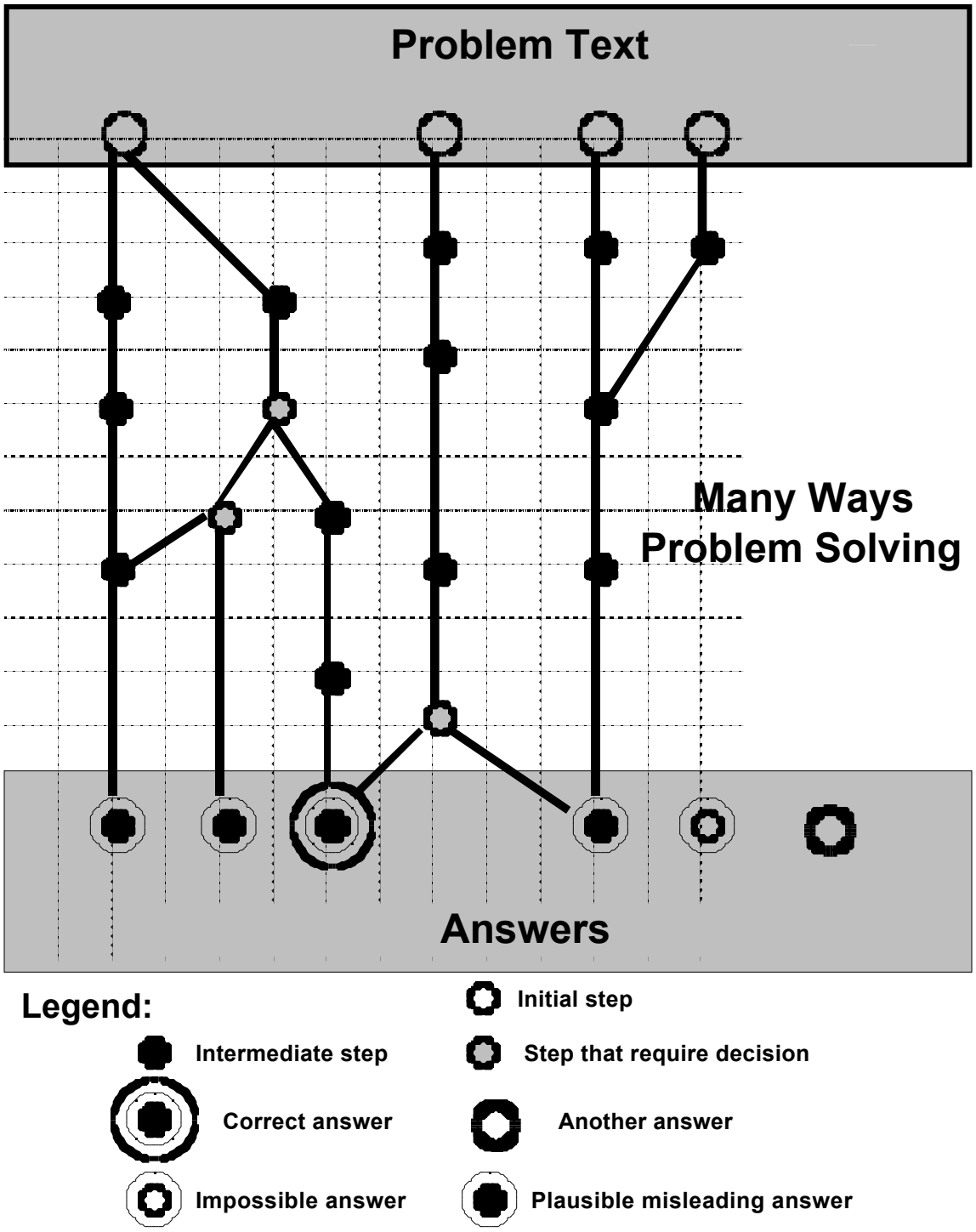

Figure 7: The Many Ways Problem Solving Representation Model

In **figure 8** is proposed a pattern for mapping author's or teacher's activities like:

- propose and write a problem text,
- present problem solutions by many ways,
- predict or prognosticate bugs,
- propose the correct answer and plausible misleading answers.

The main characteristic of this pattern is to provide a model for problem solving mapping combining system's, expert's and human solvers' attitudes, called a *many ways problem solving representation model*. This model will be used to implement Vygotsky's "most capable peer" educational concept for Intelligent Tutoring System through the conceptual adherence process.

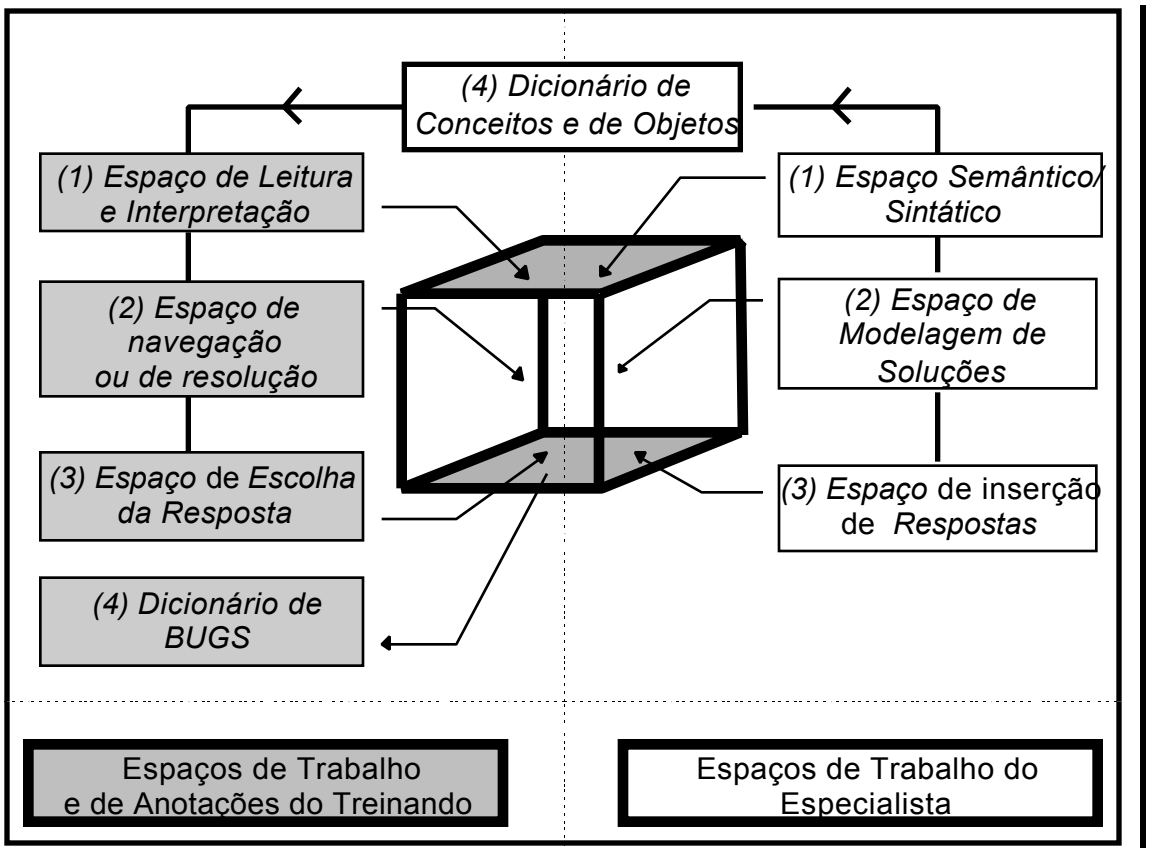

Figure 8: The Many Ways Problem Solving Representation Model Working Spaces With Conceptual Adherence

8. – Conclusions

The knowledge transmission process to a group or a single student differ. ITSs need to incorporate techniques to adapt the learning process to each user. To do this, properly and achieve adaptability conceptual adherence are proposed.

This paper proposes the introduction of some educational and technical ideas in classroom habitual practice. The use of Intelligent Tutoring Systems, provided to perform the c*onceptual adherence,* is a new manner to center the learning process in student particular needs, in the exact time of a concept formation process.

The *conceptual adherence* represented by a concept formation web is a new approach for ITS adaptability suggested by this research.

The conceptual adherence allows the adaptability independently of the *student model* and in the exact time of the teaching and learning action is performed among the ITS and the student. The ITS architecture suggested is an original idea to the computational implementation of the Vygotsky's idea about *more capable peer* actuation.

The generalization of the conceptual adherence notion generates the idea of *adherence to a problem solution step* that allows the proposition of the *many ways problem solving representation model* as was shown in this paper.

9. - Bibliography

[Cunningham 1996] Cunninghan, Donald. ***Learning And Cognition in Education***. INTERNET: http://education.indiana.edu/cep/courses/p540/vigosc.html, 1996.

[Dunker 1972] Dunker, Karl. ***On Problem-Solving***, translate by Lynne Lees 1945 /reprint 1972, In Grolier Encyclopedia, Grolier Eletronic Publishing, Inc., 1995.

[Lalande 1993] Lalande, A***. Vocabulário Técnico e Crítico da Filosofia.*** São Paulo, Martins Fontes, 1993.

[Morris 1976] Morris, Charles G. ***Psychology - An Introduction***, Engleewood Cliffs, New Jersey, Prentice-Hall, Inc.

[Honderich 1995] Honderich, Ted. ***The Oxford Companion To Philosophy***. Oxford, Oxford University Press, 1995.

[Polya 1975] Polya, Gyorgy . ***How To solve It - A new Aspect of Mathematical Method, Princeton*** University Press, 1975.

[Rappaprot 1984] Rappaport, C.R. (Coord.) ***Psicologia da Aprendizagem***. São Paulo, EPU, 1984, Temas Básicos de Psicologia, vol. 9.

[Rogers 1969] Rogers, Carl R. ***Freedom for Learn***. Columbus, Ohio, Charles E. Merryl Publishing, 1969.

[Vygotsky 1978] Vygotsky, L.S***. Mind in society: The development of higher psychological process***. Cambridge, Massachusetts: Harvard University Press, 1978.

[Wenger 1987] Wenger, Etienne. ***ARTIFICIAL INTELLIGENCE and TUTORING SYSTEMS - Computational and Cognitive Approaches to the Communication of Knowledge.*** Los Altos, CA, Morgan Kaufmann Publishers, Inc., 1987.

[Wilson 1993] Wilson, P. S. (Ed.) ***Research Ideas for the Classroom: High School Mathematics***. New York, MacMillan, 1993.