ITS-I: Intelligent Tutoring System with Integrated Cognition, Emotion and Motivation

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Abstract

The traditional ITS concepts generally do not cover emotion and motivation and do not observe the necessity to integrate these aspects with cognition. This work proposes an extension of the ITS concepts, describing the theoretical and practical basis of ITS-I – the Intelligent Tutoring System with Integrated Cognition, Emotion and Motivation.
Its aim is to individually assist the students, regarded as whole beings, helping them in the learning process. In order to do that, variables are captured during the tutoring process, to inform inference structures to inform the integrated student model. This model and the information on motivation, emotion and cognition are used by a Diagnostic Module to prescribe the learning-teaching activities to the student, along with motivational actions. The proposed architecture has been implemented in a computer program called ECoM, that made it possible to experimentally evaluate the concepts proposed here.

1. Introduction

The observation of students as whole beings and the belief that educational software must take in account their wholeness and individuality, reinforces the interdisciplinary issues inherent to ITS development, increasing its complexity. The construction of ITS involves taking decisions in various knowledge areas, such as computer science, pedagogy and psychology.

According to Burns and Capps [4], to be considered an ITS, a software must keep three characteristics. The first is to be related to a knowledge domain from which the tutoring system should "know" enough to behave like an expert, in terms of being able to infer solutions or to solve problems. The second aspect is that the software must be able to evaluate the apprentice knowledge levels. The third characteristic is that the cognitive strategy should be designed to reduce the knowledge gap between the expert and the student. This proposal defines a three-part ITS architecture, extending the structure proposed by Carbonell [5].

Despite its great importance, only recently the emotional and motivational aspects have been ITS researches' objects. According to Goleman [13], emotional interference in the mental life of students is well known by teachers. Anxious, angry or depressed students do not learn well; it is an illusion to think that learning environments that do not consider motivational and emotional factors are adequate [13].

Unfortunately the expectations of Carbonell and his colleagues for ITSs has not been achieved so far. Despite many progresses in the area, the personalised assistance to the student is far behind where it should be, not only because of hardware and software limitations, but also due to the lack of knowledge and modelling on psychological and pedagogical issues.

In order to provide personalised assistance to the student, in this proposal it has been added emotional and motivational aspects, integrated with the cognitive issues of a previously existant ITS. The resultant architecture, named ITS-I, includes:

- Student cognitive model, like in the original ITS.
- Student emotional model, to reflect the student's behaviour and the temperament.
- Student motivational model, to reflect the profile of motivation and necessities that seem to guide the student actions, to predict which environment favours the learning process.
- Modelling integration of the three issues - cognition, emotion and motivation.
- Cognitive teaching/learning strategies.
- Motivational strategies, intended to stimulate the student, and to fine-tune the tutoring environment in order to reduce anxiety, insecurity and dependency.

The ITS-I architecture provides the backbone to support the integration of the cognitive, emotional and motivational aspects of the tutoring system [14]. The proposal has been implemented in the program EcoM, which provides basic food chain teachings to first/second year school children. It was used in a experiment to check the following hypotheses:

- It is possible to build the cognitive and emotional models based on information captured by the ITS-I during the tutoring process.
- It is possible to define a motivational strategy that uses the cognitive and emotional student models, along with the motivational history, in order to generate motivational actions to help the student in the learning process.
- It is possible to build the cognitive, emotional and motivational models of the student in a same integrated ITS-I architecture.

The experiment analysis has pointed positively to the validity of the proposal.

2. Primitives

The implementation of an ITS-I requires communication channels in order to allow the tutoring system to get some "awareness" of the student's cognitive, emotional and motivational states. The identification and exploitation of such channels are not the goals of this paper. However, more information can be found in these references: [17] [18] [23] [24][25].

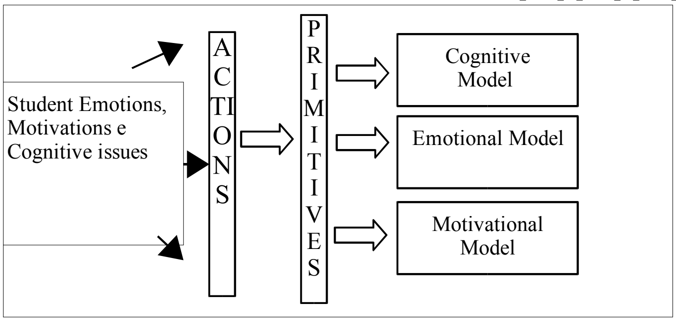

Figure 1 – Relationship between emotions, actions, primitives and models

The *primitives* are basic information about the student's actions, captured during the tutoring process. They provide the information to the inferential devices for the cognitive, emotional and motivational models, as shown in the figure above.

Many *communication channels* may be used to capture the primitives, and many different types of primitives may be defined. Three channels have been chosen and implemented so far in this research: questionnaire, self-report and interaction history. This choice is justified by the need to improve the quality and quantity of captured information, as well as the reliability of the inferences. Other possible channels are web-cams, microphones, supervisor's report and so on. However, these resources require a more sophisticated setup of hardware and software.

The class supervisor fills up the *questionnaire* before the tutoring process starts, providing information such as the name, age, sex, and previous knowledge of the student.

The *self-report* is answered by the student during the tutoring process. The EcoM shows the self-report screen to the student when it is needed more information to take a decision. Figure 2 depict different schematic faces shown to the students to describe their moods in a particular moment. Each picture is associated to an universal emotion as defined by Ekman [10] to classify human face expressions. The interface was proposed to be used by 7-8 year-old children, based in Cozby [6] experimental research. Each face is associated to a positive or negative value to represent the student emotional state in a particular moment.

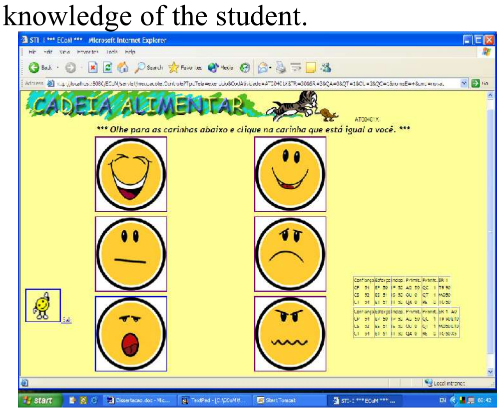

Figure 2– Screen to capture emotional states

The interaction history is recorded at every interaction with the student[1]. Each record keeps information on the way the student works and about the learning activities he or she has carried on[2]. The primitives implemented and captured by the EcoM so far are:

Answer delay – time between interactions.
Response situation – information on the answers, either right, wrong or null. Null answers apply to activities that do not require direct action, such as reading a text.
Help demand – the total amount of help demand during an activity.
Solution tries – the amount of different tries or approaches to solve the proposed problem.
Right answers – the total amount of right answers during an interaction session.
Preferred help-sequence – the student is able to ask for help any time, either *before* or *after* sorting out the problems. The most frequent sequence is registered in this primitive.
Current mood – it is a self-report on the student's mood: *very happy*, *happy*, *bad*, etc.
Repetitions – stores the amount of retries during the learning activity.

3. Cognitive Model

The student's cognitive model should observe the student knowledge in relation to the knowledge domain widely, for the student's behaviour is based in relations much more complex than "she knows this" or "he does not know that". A short-sighted vision of the human being does not reflect the learning universe and the relations with the environment and with the learning objects. The human being has specific skills that are manifested in the relation with the objects, such as logic precision, creativity, and solution seeking, among others. The student is guided by emotional forces such as will, tendencies, and desire, which act over the acquired knowledge to develop skills that are relevant for the learning process. Observe the Figure 3, which represents the student's cognitive model.

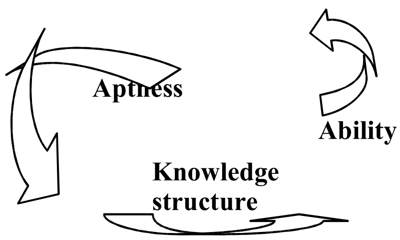

Figure 3– ITS-I Student's Cognitive Model

The EcoM's architecture is an extension of Carvalho's work [7][8], which is based on the expert overlay student model approach. Using a model already tested seemed to be a good choice for the research could focuses mainly on the emotional and motivational issues. The EcoM's subject domain is modelled through a partial semantic network that relates the concepts to the edges labelled "of the kind" or "may be", forming a knowledge tree[3] about food chain.

In this hierarchical arrangement of the cognitive structures, the concepts of higher level are more significant. The sequencing of the contents proposed by Ausubel [2], consists in progressively tell their differences, from the broader to the narrower concepts, establishing at the same time the relationship between the contents of the same level to get to an integrated knowledge framework.

4. Emotional Model

The ability of perceiving the emotions of other people, or the empathy, depends on the perceptive skills of the observer. Robert Rosenthal [21], has shown in experiments with his students that the others emotions may be perceived mostly through non-verbal language. Lepper and his colleagues [15] pointed out that in tutoring sessions the affective diagnose

[1] In this context, interaction is the period of time between the beginning and the end of a learning activity. Many actions may occur and be caught by the communication channels during an interaction. An action may be, for instance, a demand for help, a click on the screen, or an answer to a posed question.
[2] The learning activities can be *lessons, examples, exercises* and *tests*, and are related to the knowledge domain. They represent an interaction space with goals, timings and characteristics well defined by the expert teacher, through the authoring tool [11].
[3] The Knowledge Tree is a hierarchical structure used to describe the knowledge domain.

depends more on the cognitive evaluations and inferences than on facial expressions, body language, intonation or other paralinguistic suggestions. An ITS-I also could “experiment” this kind of empathy, showing then the viability of this sort of modelling, despite the limitation of a machine for “observing” the humans’ behaviour. There are yet other works that have shown the viability for diagnosing and modelling student’s affection based on cognitive evaluation [18] [23] [25].

By observing a teacher in the classroom one can see that many factors are involved in the teaching/learning process. In the cognitive exploitation of the knowledge domain, the perception of the facts and the decision taking process are surrounded by “non rational” aspects involving students and teachers. To transport the “non rational” behaviour of the teacher to the ITS-I, it is necessary to study motivational and emotional aspects to apply in the context, mainly in regards to the accommodation of the teacher to the needs of the student [3] [25].

The emotions are composed by subjective, behavioural and physiologic components [9]. The subjective components are the feelings and the thoughts. The behavioural include facial expressions, gestures, and actions that occur in response to the emotions. The physiologic components are related to physical functions, such as sweating, blushing, breathing fast, and so on. The subjective and the physiologic components need proper communication channels to be captured, such as magnetic resonance devices, thermometers or stethoscopes to observer the brain or the body. The behavioural components, however, may be “observed” through the primitives captured and stored in the interaction history of the student, and through the inferences held over her behaviour pattern. For instance, the lack of persistence in a task can be modelled in terms of the frequency of demand for help. The behaviour of a student who asks for help without trying to solve a task may indicate lack of confidence. Some behaviours that could be identified through the student interaction with the tutor are *effort*, *confidence* and *independence* [3] [20] [22] [23] [24] [25].

The **effort** is defined as the persistence and energy spent on a task to acquire a particular knowledge. The **confidence** is the sense of control and the domain of the environment, as demonstrated by a learning progress gradual and continuous. The **independence** is the ability to execute the task and to acquire knowledge without asking help in excess. It is clear that this set of behaviours does not encompass the wholeness of the human being. The intention here is to model and implement a structure to represent emotion for widening ITSs’ horizons and to support learning in a individual way. This work may be further extended to a more generic structure where the expert could, tell which behaviours should be modelled and which actions should be related to primitive variables to indicate these behaviours. It may include then some primitives captured by more sophisticated communication channels.

The student behaviour is initially defined based on momentary primitive variables. With the persistence of the behaviour, the temperament is deduced. According to Goleman, the temperament can be defined in terms of the moods that typify our emotional life, being considered as a set of innate individual characteristics. For instance, low effort and lack of confidence may imply in shy temperament. Jerome Kagan [11] proposed four types of temperament - shy, daring, optimistic and melancholic – and sustained that each one is due to a different pattern of brain activity. Goleman [13] defined behaviours that are related to these temperaments. This knowledge was transported to the ITS-I area to define the temperament of the student, providing the needed information to establish an individualised environment.

The **daring** temperament is characterised by the eagerness to explore the unknown, by the easiness to transpose new barriers with little perturbation. In opposition to this, there is the **shy** temperament. The **optimistic**, in this context, is connected to energy and good vibration, as opposed to the **melancholic** temperament.

Temperament is not destiny [13]. Put another way: does our biology determine our destiny or may a shy child become a confident adult? The question is: if this particular emotional set can be changed after the experience, when and how should the tutoring system change its expectations about the temperament of the student? To answer this question we propose a scale of gradual inferences relating the current behaviour and the temperament.

The figure 4 shows the emotional structure, represented by dashed squares. The Emotional Structure is composed by a series of information that are obtained through the communication channels (primitives) and other inferred information (in the dotted boxes). These are the basis for the tutoring system decisions.

The primitives are captured by the tutoring system and are submitted to a set of production rules which maps them to behaviours. The behaviours are then mapped into temperaments. These rules are specified by the expert teacher, through a authoring tool. The values of the captured primitives, the behaviours (tertiary, secondary e primary) and the inferred temperaments are stored in three temporal spaces: the current value, the average value and the gradient. The latter represents the primitive tendency, whether it is decreasing, increasing or it is stable.

The primitives are used to infer the behavioural patterns – effort, confidence and independence. These patterns may indicate the behavioural tendencies as time advances. The model illustrated in figure 4 is intended to organise the behavioural chronology in a scale to graduate the behaviours. There, the tertiary behaviours influence the secondary behaviours, which eventually influence the primary behaviours. They are composed by the same sort of patterns, but are related to the persistence of their occurrences. The behaviour patterns determine the temperament – shy, daring, optimistic and melancholic.

However, the influence of the primary behaviours in the temperaments is significant, whereas the tertiary ones do not influence so much. The secondary behaviours act as balancing elements between the two extremes.

The emotional structure enables the tutoring system to diagnose and model the emotional states of the student. However, this structure alone is not enough to enhance the individual assistance. What makes it useful are the motivational actions prescribed based in the information represented by the dashed rectangles in the figure 4.

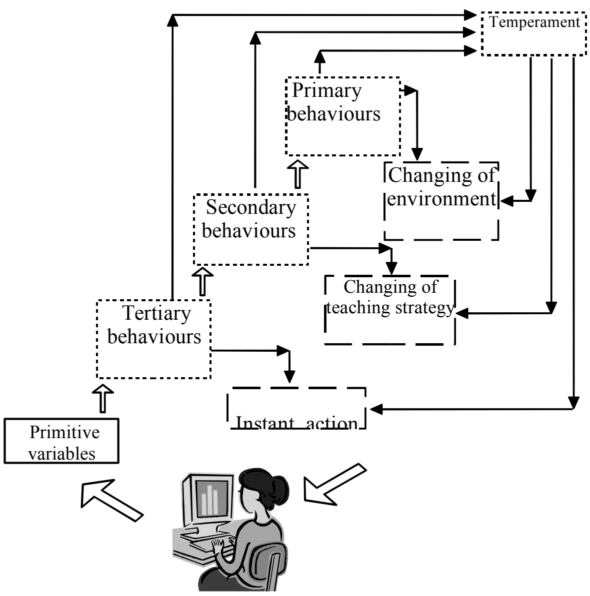

Figure 4 – Emotional Structure

5. Motivational Model

The motivational diagnostic is based on the cognitive model and emotional model, along with the relationship between the two models (Cognitive-Emotional Model). For instance, the effort of a student modelled after her progress is a relatively reliable indicator of intrinsic motivation [9] [12] [13].

The tertiary behaviours are indicators for the tutoring system to act instantly. For instance, it can decide to trigger a motivational agent that can be a process represented by a wizard or other character to "provoke" or prompt the student for some immediate action (telling a joke, for example). The secondary behaviours define the necessity for changing the cognitive strategy. They will be trigged after some persistence of a tertiary behaviour, and will cause a deeper customisation of the tutoring process, as the immediate acts seem not to be effective. The requirement of some persistence of the behaviour to start a bigger change is intended to balance the tutor behaviour avoiding considering drastic changes of the student temperament without good reasons. Finally, a changing in the primary behaviour imply in a major change in the tutoring system environment.

For instance, the tutor may decide to keep a help agent permanently present to act as a companion for a child who shows long term low confidence.

The tertiary, secondary and primary behaviours determine what the tutoring system has to change to keep the student motivated. The temperament, on its turn, defines how the tutor should carry on the changing. As an example, the tutor may not propose daring learning activities when the child shows shy temperament.

This way, the diagnostic and the motivational prescription has been modelled and implemented in the ECoM system, producing a motivational history. However, a task left as future work is the motivational profile model, to indicate the best way to motivate a particular student.

6. Cognitive, Motivational and Emotional Strategies

The three strategies has been implemented in the ECoM system through a rules set [16] that provides the student with individual assistance, either in cognitive, emotional or motivational issues.

The cognitive strategies contain the guidelines to help learning the subject domain. It is a sequence of teaching clues, to enable successful presentation of particular topics, or to trigger an action that may help the student to learn. The product of such strategies is the prescription of cognitive actions based on the student's cognitive model.

Observe the example below: the identifier of the topic in the *knowledge tree* comes in brackets; "good" and "enough" are qualitative degrees of learning; "average", "exercised" and "tested" are learning states; "disable" and "suspend" are pedagogic actions; "lesson", "test" and "exercise" are types of activities.

If average (Plants) is good and *exercised (Plants) is enough and tested (Plants) is enough*
then disable lesson (Plants), disable test (Plants), suspend exercise (Plants).

The emotional strategy enables the tutor to know about emotion demonstrations through actions, that is, how to identify and infer emotions through actions, and how to map these actions into behaviour and temperament. The product of the emotional strategy is the student's emotional model.

In the example below the primitives *demands for help*, *most frequent order* and *amount of tries* are tested in order to infer the increasing or reduction of the *effort index*.

If Demand for Help >= 2 and Most frequent order = help response and Amount of tries = 0
then Decrease 3% of the Tertiary Effort, Decrease 2% of the Secondary Effort,
Decrease 1% of the Primary Effort

The motivational strategy allows the tutoring system to infer motivation states based on the cognitive, emotional and cognitive-emotional models. The product of such strategy is the prescription of motivational actions which help keeping the student in a state that favours apprenticeship.

The motivational actions occur in three levels, as shown if figure 4. In the system EcoM, to each level there correspond a specific set of actions. The student's emotions are inferred through the primitives and matched against the motivational strategy to define the action to be executed. The student temperament will indicate the action instance. For example, let us suppose that a set of rules has shown the need of an actor to say some phrases to the student (figure 6). The rules that are related to the behaviour have indicated the type and the opportunity for trigging this particular activity. After that, the temperament of the student is used to choose the message to be uttered, in order to match the student's profile. For instance, if the students profile suggests shyness, the actor may say: "Well, this is fun, I like it… let me do it with you!"

The set of actions implemented in the EcoM system to each motivational level follows:

Instant actions

Motivational actions – a motivational actor says encouraging phrases.

Cognitive strategy change

Selection – activates or deactivates the cognitive strategies according to the student's temperament (the disabled activities may be enable again in the future).

Get back – enables that some cognitive activities already done to be visited again.

Environment change

Change of presentation patterns (colour, themes, etc.).

Continuous help –help may be started without the student's demand.

Motivation action – an agent talks to the student. This activity remains active up to some visible action occurs. The agent plays a companion to the student.

This action has been implemented aiming at testing the motivational structure. Many other kinds of actions could be created, including more sophisticated ones, such as learning or teaching agents.

7. ITS-I Architecture

Carvalho [7] [8] proposed an ITS architecture that observes the pedagogic aspects, but the emotional and motivational issues were not modelled in that architecture. This paper describes an extension for that architecture, by integrating pedagogical, emotional and motivational aspects, possibly improving the personal assistance to the student. The new architecture is showed in figure 5.

In the ITS-I architecture the cognitive, emotional and motivational models are dealt with by the Diagnostic Module, which consults the knowledge databases (the Student Background, the Student History and the Student Knowledge), the emotional data (the parameters provided by the expert teacher) and the motivational data.

The tutoring system then prescribes the cognitive and motivational activities, guide by their respective strategies. The Tutor Module accepts indications from the Diagnostic Module and interacts with the student presenting the activities selected. The motivational strategy precedes the cognitive strategy in case of conflicts. The expert teacher uses the Tutoring Tools [19] to generate the Strategies and Activities database.

While interacting with the student, the Tutor Module captures the primitives that are stored by the Diagnostic Module in the Interaction History database.

The emotional and the cognitive modules, which are parts of the diagnostic module, consolidate the primitives after examining the interaction history and the database with the information about learning, behaviour and temperament of the student. The emotional module assigns the current values for the primitives and stores the averages and gradients in the student model. After that, the emotional module infers the behaviour and temperament records.

In the emotional strategy the primitive classes are organised according to their influence into the tertiary behaviours. There are also information about how tertiary behaviours affect the secondary behaviours and how these last affects primary behaviours. The student's temperament is also inferred, based on the set of behavioural patterns contained in the emotional strategy.

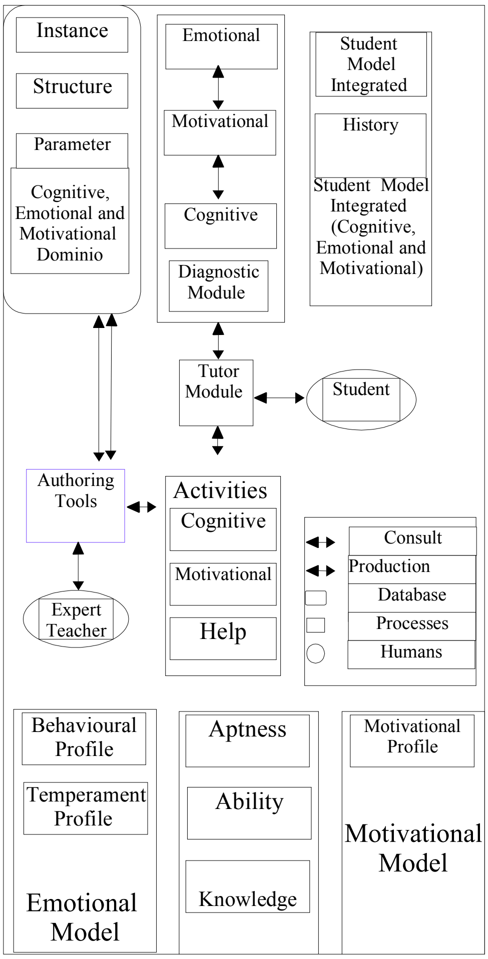

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Figure 5 – ITS-I architecture

The motivational module evaluates the presumed emotions of the student based on the motivational strategy, emotional model, cognitive model and the emotional-cognitive model. The motivational model makes its prescriptions in order to deal with motivational diversions or even just to keep the student motivated. For instance, the motivational module may look for a *help* activity that seems more convenient for the student in case of eminent risk of lack of motivation (figure 6). If the condition persists, the motivational module exchanges information with the cognitive module to orient the choice of the next cognitive activities, and to try a alternative teaching strategy.

If the condition still persists, the diagnostic module may indicate environment changes, such as the replacement of the colour and shape of the background and so on. The motivational module runs asynchronously to supervise the tutoring activities.

The importance of the participation of experts in different areas is justified by the multidisciplinary characteristics of the ITSs. Disciplinary and pedagogy experts are required to describe the knowledge tree, the cognitive strategy, the knowledge instance and the cognitive and help activities, using specific authoring tools. An expert in emotion and motivation, however, should describe the motivational strategy, the emotional strategy and the motivational activities.

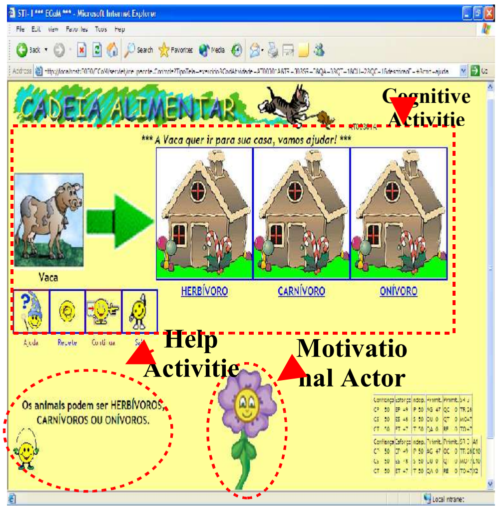

Figure 6 – EcoM's leaning activity with cognitive, motivational and help features

8. The experiment

An experiment has been carried on to validate the proposed architecture, observing scientific research issues [6] [20]. A sample of 22 $1^{st}/2^{nd}$-degree children was selected from a primary school in Brasília, forming four groups, two as control, and two as experimental groups. The four groups used the EcoM system. The control groups had the motivational module disabled, and worked just with the cognitive activities. Each tutoring session lasted up to 40 minutes. During the sessions the children interacted with the EcoM, without human interference. The four groups were submitted to control tests before and after the experiment to evaluate their knowledge on food chain. The independent variable was the presence of the motivational module. The dependent variables were the amount of demands for help, the most frequent sequence, the number of tries, the response delay, the number of repetitions, and indexes for the satisfaction, effort, confidence, independence, shyness and optimism.

The *before* and *after* tests were marked producing the average values in the table below.

Average	After-Test	Before-Test	After – Before value
Experiment	**7,45**	**6,21**	**1,23**
Control	**7,11**	**6,72**	**0,39**

Apparently both groups learned with the tutoring sessions, but the experimental group seemed to have learned more than the control group. According to the next table, the variables amount of demand for help, number of tries, number of right answers, response delay, and repetitions seemed to have achieved better values in the experimental group. The students asked less for help in the experimental group (0.15 X 0.42). However, the right-answers average of the experimental group was better than the control group one, although their number of tries was smaller than the one of the control group. The repetitions average of the experimental group was significantly better than the one of the control group (5.20 X 2.49). The experimental group also had a bigger repetition index. This might indicated that they were more deeply interested in understanding the subject in study.

Average	Demand for Help	Number of Tries	Right answers	Repetitions
Experimental	0,15	3,46	2,64	5,20
Control	0,42	3,50	2,57	2,49

Most of the other variables (effort, confidence, independence, shyness, optimism, and melancholy) also presented a more stable and positive behaviour for the experimental group. These values were confirmed in the answers of the self report, used to generate the satisfaction variable. The initial value of the variable was 50, to represent the average student. Both the groups started with values greater than 50, what implies good disposition for learning. However, after the fifth questionnaire, the values of the control group had a tendency to get lower, whereas the experimental group kept obtaining stable values.

After preliminary analysis, the correlation between the dependent variables groups and the differences between the tests (after and before) has been calculated in order to verify the factors that may have influenced the learning process. The results are presented in the table below. According to Davidoff [9], a correlation coefficient provides information on the relation between two variables, varying from –1 to +1. When the result is positive, it indicates that the measure groups vary in the same direction. Higher values indicate closer correlation. Negative values suggest different directions and the lower the value, the lower the correlation is.

The following table shows some aspects that were initially regarded as relevant to the learning process. However there are no strong correlation between learning and the variables *help demand*, *most frequent sequence*, *navigation depth* and *number of visited nodes*. The factors that had influenced the most are: *number of tries*, *amount of right answers* and *repetitions*, followed by the emotional factors.

Despite the small amount of sampled data, these have proved being sufficient to allow drawing preliminary conclusions that indicate the proposed architecture as viable and able to create an environment that can assist the student in a personalised and productive way.

Variable	Correlation Coefficient	Variable	Correlation Coefficient
Visited Nodes	-0,31	Help demand	-0,23
Navigation depth	-0,23	Most frequent sequence	-0,07
Shyness / Daring	0,06	Optimism / Melancholy	0,06
Confidence	0,09	Independence	0,10
Satisfaction	0,14	Response Delay	0,15
Effort	0,20	Expertise	0,21
Right Answers	0,36	Number of Tries	0,47
Repetitions	0,59		

9. Conclusions and future work

In this work a computational model to extend ITSs concepts including emotional and motivational issues has been developed and tested.

The ITS-I architecture encompasses more than just definitions of models and domains. In its definition the issue of capturing information about the student during the learning process has been observed, aiming at providing the inference basis to generate the integrated student model, which is composed by the cognitive, emotional and motivational models. The diagnostic module uses these models along with the student data to prescribe various learning activities to the student.

Consequently, the student has been regarded as a whole individual. The ITS-I has proven to be able to offer a learning environment that is suitable to apprenticeship, with some advantages in relation to traditional ITSs. Future work should extend the subject domain, include new learning objects and increase the test duration in order to confirm the preliminary conclusions. Besides, the motivational student model should be formalised and tested.

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