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Using an Animated Pedagogical Agent to Interact Affectively with the Student

Thesis presented in partial fulfilment of the requirements for the degree of Doctor of Computer Science

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LIST OF ABBREVIATIONS

2D	Two Dimensions (space $\Re^2$)
3D	Three Dimensions (space $\Re^3$)
ACL	Agent Communication Language
Adele	Agent for Distance Education – Light Edition
AI	Artificial Intelligence
AR	Affective Reasoner
BDI	Belief-Desire-Intention
CAI	Computer Aided Instruction
BDC	Behaviour Decision Center
DTD	Document Type Definition
EAD	Distance Education
E-mail	Electronic-mail
DAÍ	Distributed Artificial Intelligence
GIA	Group of Artificial Intelligence at UFRGS
GIS	Graphical Interface of Simulation
ITS	Intelligent Tutoring System
LTC	Local Training Center
MCOE	Multi-Agent Co-operative Environment
NCSU	North Carolina State University
OCC	Ortony, Collins e Clore
Steve	Soar Training Expert for Virtual Environment
TSC	Technological Shoe-Making Center
UFRGS	Universidade Federal do Rio Grande do Sul
UIT	Unit of Intensive Treatment
UML	Unified Modelling Language
USC	University of Southern California
VET	Virtual Environments for Training
WWW	World Wide Web
ZPD	Zone of Proximal Development
XML	eXtensible Markup Language

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ABSTRACT

This work proposes an animated pedagogical agent that has the role of providing emotional support to the student: motivating and encouraging him, making him believe in his self-ability, and promoting a positive mood in him, which fosters learning. This careful support of the agent, its affective tactics, is expressed through emotional behaviour and encouragement messages of the lifelike character. Due to human social tendency of anthropomorphising software, we believe that a software agent can accomplish this affective role.

In order to choose the adequate affective tactics, the agent should also know the student's emotions. The proposed agent recognises the student's emotions: joy/distress, satisfaction/disappointment, anger/gratitude, and shame, from the student's observable behaviour, i. e. his actions in the interface of the educational system. The inference of emotions is psychologically grounded on the cognitive theory of emotions. More specifically, we use the OCC model which is based on the cognitive approach of emotion and can be computationally implemented.

Due to the dynamic nature of the student's affective information, we adopted a BDI approach to implement the affective user model and the affective diagnosis. Besides, in our work we profit from the reasoning capacity of the BDI approach in order for the agent to deduce the student's appraisal, which allows it to infer the student's emotions.

As a case study, the proposed agent is implemented as the Mediating Agent of MACES: an educational collaborative environment modelled as a multi-agent system and pedagogically based on the sociocultural theory of Vygotsky.

Keywords: Afectivity in Human-Computer Interaction, Affective Computing, Animated Pedagogical Agents, Artificial Intelligence in Education.

RESUMO

Um Agente Pedagógico Animado para Interagir Afetivamente com o Aluno

Este trabalho propõe um agente pedagógico animado que possui o objetivo de fornecer suporte emocional ao aluno: motivando-o e encorajando-o, fazendo-o acreditar em suas próprias habilidades e promovendo um estado de espírito positivo no aluno, que é melhor para o seu aprendizado. Este suporte cuidadoso do agente, suas táticas afetivas, é expresso através de comportamentos emotivos e mensagens de encorajamento do personagem animado. Devido à tendência social humana de antropomorfizar software, nós acreditamos que um agente de software pode realizar esse papel afetivo.

Para escolher as táticas afetivas adequadas, o agente deve conhecer as emoções do aluno. O agente proposto infere as seguintes emoções do aluno: alegria/tristeza, satisfação/frustração, raiva/gratidão e vergonha a partir do comportamento observável do aluno, isto é, as ações do aluno na interface do sistema educacional. A inferência das emoções é fundamentada psicologicamente na teoria cognitiva das emoções. Mais especificamente, nós usamos o modelo OCC o qual é baseado na abordagem cognitivista das emoções e é possível de ser implementado computacionalmente.

Devido a natureza dinâmica da informação sobre o estado afetivo do aluno, nós adotamos uma abordagem BDI para implementar o modelo afetivo do usuário e o diagnóstico afetivo. Além disso, em nosso trabalho nós nos beneficiamos da capacidade de raciocínio do BDI para o agente deduzir o *appraisal* do aluno, que lhe permite inferir as emoções do aluno.

Como um caso de estudo, o agente proposto é implementado como o Agente Mediador de MACES: um ambiente para ensino colaborativo à distância modelado com uma arquitetura multiagente e baseado psicologicamente na abordagem Sociocultural de Vygotsky.

Palavras-chave: Afetividade na Interação Homem-Computador, Computação Afetiva, Agentes Pedagógicos Animados, Inteligência Artificial na Educação.

1 INTRODUCTION

1.1 Scientific Context of this Work

This thesis is interdisciplinary and finds its place at the intersection of three main areas: Education, Computer Science and Cognitive Science. Education and Computer Science because we are interested in developing computational solutions for a more effective learning, and Cognitive Science because we aim at handling the emotions in a learning situation and because we based the affective part of our work on the cognitive psychology of emotions.

The field of the Computer Science that studies the potential use of computational resources for learning is called Computer in Education. Some researchers of Artificial Intelligence (AI) interested in Computer in Education study the possibility of using techniques of Artificial Intelligence in order to turn the educational software more customized to the user. Pedagogical theories and sophisticated techniques of user modelling have been investigated.

On the other hand, due to the traditional dichotomy in the western society between reason and emotion, which was inherited from Descartes' dualist vision of the mind and body, little attention has been paid to the role of the affectivity in cognition. But, some recent works of psychologists and neurologists have pointed out the important role of the affectivity in some cognitive activities such as, for example, decision taking (DAMASIO, 1994) (GOLEMAN, 1995) (IZARD, 1984).

Thus, researchers of Artificial Intelligence have considered the emotions in intelligent systems modelling, appearing thus a new field of research in AI: "Affective Computing". Picard (1997) defines Affective Computing as "computing that relates to, arises from or deliberately influences emotions". In fact, the affective computing area is divided in two major branches of research interest. The first one studies mechanisms to recognise human emotions or to express emotions by machine in human-computer interaction. The second branch investigates the simulation of emotion in machines (emotion synthesis) in order to discover more about human emotions and to construct more realistic robots.

Moreover, due to the recent studies about the important role of the motivation and the emotions in learning (GOLEMAN, 1995) (PIAGET, 1989) (VYGOTSKY, 1962), techniques of affective computing have also been studied in order to model the emotions of the student in educational (computational) systems. Although the researchers have investigated how to use the student's emotions to choose pedagogical tactics more adequate for the student, little attention has been paid to the artificial tutor's role of engaging and inducing positive emotions in the student, as teachers do in real class. As Izard's work (1984) shows, even induced emotions can foster or impair the learning.

Aiming at contributing to the works in affective computing applied to education, we propose an animated pedagogical agent responsible for motivating the student and for promoting positive emotions in him more adequate for learning. In order to respond appropriately, this agent infers the student's emotions. This work improves the GIA's previous researches in affective modelling (BERCHT, 2001) (PROLA, 2003) by considering other student's emotions such as satisfaction/disappointment, joy/distress, gratitude/anger and shame. Another contribution of our work is to profit from the reasoning capacity of the BDI approach to infer the student's emotions from his actions in the system interface. The agent reasons about the student's actions and events in the educational system and to which emotion these events lead according to the student's goals. We benefited from the previous works of the GIA in BDI, which resulted in the X-BDI tool that was used for the implementation of this thesis.

This animated agent is part of the multi-agent architecture of the MACES educational environment. The implementation of educational systems through multi-agent architectures has been one of the topics of research of our group, as show the works of (BICA; VICCARI, 2000) (D'AMICO ET AL., 1998) (GIRAFFA, 1999) (SILVEIRA; VICCARI, 2002).

1.2 Motivation

Due to their motivational potential, many educational systems have been implemented as animated pedagogical agents (JOHNSON; SHAW, 1997) (JOHNSON; RICKEL; LESTER, 2000a) (LESTER et al., 1997a) (PAIVA; MACHADO, 1998) (RICKEL; JOHNSON, 1998a). The animated pedagogical agents are tutoring agents that use multimedia resources for providing to the student an animated character with characteristics similar to intelligent human beings. These characteristics, such as facial expressions or understanding of human emotions, associated to a good dialogue interface with the user, turn the agents more attractive to the students since they explore more life-like interaction modes (ELLIOTT; BRZEZINSKI, 1998). The animated pedagogical agents offer great promise to increase the communication capacity of educational systems (JOHNSON; SHAW; GANESHAN, 1998) and increase the ability of these systems to engage and motivate the students (LESTER et al., 1997b).

On the other hand, the way that emotions affect learning has already been pointed out by psychologists and pedagogues (GOLEMAN, 1995) (PIAGET, 1989) (VYGOTSKY, 1994). According to Piaget (1989), the accelerating or perturbing role of affectivity in learning is incontestable. A good part of the students which are weak in mathematics fails due to an affective blockage (PIAGET, 1989). Coles (1998) stresses that poor learning can produce negative emotions; negative emotions can impair learning; and positive emotions can contribute to learning achievement and vice versa. Izard's work (1984) shows that induced negative emotions impair performance on cognitive tasks, and positive emotions have an opposite effect.

Although researchers have investigated the recognition of emotions in learning, little attention has been paid to the role of the artificial tutor in motivating, engaging, as well as promoting positive emotions in the student, which is adequate for a more effective learning. This way, we propose an animated pedagogical agent that catches the student's affective state, by his[1] observable behaviour, and applies tactics in accordance with

[1] Just to maintain the text of this document clearer and consistent, we use "he" to denote a student and "she" to denote a teacher.

student's affectivity; i. e. promotes actions that aim to adapt the system to the student's affective state. These affective tactics can be (1) domain-based tactics to motivate and encourage the student or (2) emotional behaviour in order to promote a student's positive mood. Therefore, we chose to represent it as an animated character with empathic characteristics (see section 4.8.2) and which interacts with the student through speech and emotional behaviour. In order to respond to the student in an effective way, the Mediating Agent must interpret the student's affective states correctly and must have an affective model to store this information. We recognise the following student's emotions: joy/distress, satisfaction/disappointment, gratitude/anger and shame. Due to the dynamic nature of the students' affective information, we adopted a BDI (BRATMAN, 1990) (RAO; GEORGEFF, 1995) approach to implement the affective user model, an approach that has been applied by the Group of Artificial Intelligence at UFRGS (BERCHT; VICCARI, 2000).

This agent is part of the multi-agent architecture of the project "A Computational Model of Distance Learning Based on Sociocultural Pedagogical Approaches". This project is related to situated learning, i.e., the conception of cognition as a social practice based on the use of language, symbols and signs. The objective is the construction of a distance learning environment implemented as a multi-agent system composed of artificial and human agents, and inspired by Vygotsky's socio-interactionist theory (VYGOTSKY, 1978). This environment is described in more detail in Section 5.

1.3 Objectives

This thesis has as main goal to define, model and implement an animated pedagogical agent that has the role of improving the interaction of the student with the tutor by adapting the educational system to the student's affective states. More precisely, this agent has the function of providing emotional support to the student and promoting in the student a positive mood that is more adequate for learning.

As pedagogical studies show (see section 4.8.1), the student learns better if he receives suitable emotional support by teachers. Through careful scaffolding, the teacher can increase the student's motivation, increase his confidence, and decrease his fear of making mistakes. Even the induced positive emotions show to foster learning, on the other hand the negative emotions show to impair learning (IZARD, 1984).

We believe that this emotional scaffold can be tactics presented as animated behaviours and encouragement messages from an animated pedagogical agent. More specifically, we are *interested in the effectiveness of these affective tactics when presented as emotive animated behaviours and encouragement messages of a lifelike tutor*.

Besides, in order for the agent to respond appropriately to the student, it should infer his emotions. This work *infers the following student's emotions: joy/distress, satisfaction/disappointment, gratitude/anger and shame*, which we think that are appropriate to the learning situation. We psychologically based the inference of emotion on the OCC model, which follows the cognitive approach of emotion.

We adopted a BDI approach to implement the inference of emotions and the process of the choice of affective tactics. In our work, *we profit from the reasoning capacity of the BDI approach to infer the student's emotions according to the cognitive approach of emotion*. The agent reasons on the student's goals and beliefs, and the worlds' events, or the student's actions in order to infer the student's possible emotions.

As a case study of our hypothesis, we are going to handle the affective aspects of the interaction between the artificial tutor and the student in the educational collaborative environment MACES. The pedagogical agent proposed in this thesis is implemented as the Mediating Agent of MACES architecture.

1.4 Methodology of Work

When I began my PhD study in March 2000, I worked with my colleagues Adja Ferreira de Andrade (PhD) and João Luiz Jung (Master) and our supervisor Rosa Viccari on modelling a collaborative educational system. After some studies, we decided to base our system on Vygotsky's sociocultural theory because it provided a pedagogical support related to collaborative learning and also related to the importance of social interaction for learning. In the first two years, we worked on the definition and on modelling of the system. This collaborative educational system is called MACES.

Each of us (João, Adja and me) has been responsible for studying and developing a determined aspect of the collaborative system. Adja opted to study the cognitive diagnosis and João was interested in the semiotic part of the work (the presentation of instructional content). In this period, I was already influenced by Bercht's work and by the importance of affectivity in learning and, thus, I chose to work with affectivity and learning in MACES.

In our system, the affectivity is present in the interaction (1) between the tutor and student; and (2) among the students when they interact in a chat tool. The affective aspects of the interaction between the tutor and the student can be recognised by the student's observable behaviour; and the affectivity among the students is recognised by the sentences in natural language exchanged in the *chat* tool. As the two types of interaction in the system require very different computational techniques and psychological and pedagogical study in emotional modelling, it was necessary to limit our work on emotion to just one of these two situations, and so we chose to work specifically with the interaction student-tutor. We decided first to improve the interaction between the student and the tutor (the first situation cited above) in the system since aspects studied in the first situation can be profited to handle the affective aspects in the latter in a future work.

We began by studying how to infer the student's emotions. As the GIA group does not have electronic sensors to infer user's emotions from his bodily expressions (such as heart rate monitor, electromyogram sensor, etc), we opted to recognise the student's emotions from his observable behaviour.

This way, we psychologically based the inference of emotions on the cognitive psychology of emotions, since we need a psychological theory that allows the agent to reason on the possible student's emotions by having some information from the student's beliefs and goals, and events of the world. It means the agent needs to reason on the cognitive aspects of the emotion that elicit the emotions of the student. It was still necessary to choose a theory of the cognitive psychology of emotions that could allow us to implement computationally the inference of emotions.

During this thesis, we had the help of two psychologists interested in education: Regina Verdin, PhD student at PGIE - UFRGS and Jean-François Bonneville, researcher at the Leibniz Laboratory in Grenoble – France (where I made my PhD stage). They gave us good insights of where to find the necessary information to concretise this work. To determine a manner of recognising the student's emotions, we began a study of observation of French students in class with the aid and work of the

psychologist Jean-François. We spent almost one year at doing this kind of experiences. But we had a major difficulty, MACES (the educational system where our agent is inserted) was not yet implemented. It was difficult to verify the student's emotions in real class, when MACES offers an environment of work very different from a real class (with different tools and where the students interact through internet communication tools).

So, we opted to adopt an existing theory of emotion: the OCC model (ORTONY, CLORE; COLLINS, 1988). The OCC model was chosen because it provides a model that can be implemented computationally, which is well known and fairly adopted in the Affective Computing community. The OCC model asserts that emotions arise when events of the world are evaluated according to their desirability in relation to the goals of a person. So, we needed to know the goals of the student and the events that can arise in our educational system. To determine the student's goals, we had two possible solutions: (1) to observe students using MACES and to apply questionnaires afterwards; and (2) to find in psychological and pedagogical studies some researches that had already studied the goal of students in class. The fist possibility was again difficult to accomplish, since MACES is not totally implemented yet. The psychologist Regina Verdin showed us the work of Ames (1990) which is fairly accepted by the pedagogical community and which considers that students have performance and mastery goals. To determine the student's goals we have used the MSLQ questionnaire (PINTRICH, 1991) which was developed by a group of researchers in psychology and education of National Center for Research to Improve Postsecondary Teaching and Learning and the School of Education at University of Michigan. The events were determined based on previous paper about MACES (ANDRADE et al., 2000) (JUNG et al., 2001) (JUNG et al., 2002).

The next step was to determine the agent's emotional behaviours and the messages of encouragement which are its affective tactics. It was necessary to create affective tactics that consider the student's emotions and his goals and that promote in him positive emotions, to foster his learning. For the idealisation of these affective tactics, we rely on some known works of psychologists and pedagogues (see section 6.7).

Also, it was necessary to define the appearance of the character and implement it. This work was accomplished by the master student Everton Bocca (BOCCA, 2003). He made interviews with psychologists and pedagogues to define the appearance of the character and implemented it.

As MACES is not implemented yet, it has been difficult for us to make a complete validation of our proposal. Therefore, we opted for a partial validation of the affective pedagogical tactics of the agent. For the validation of the affective tactics, we chose some situations (the student, with a specific goal, reacted with some determined emotions for a determined event) that we presented to pedagogues, psychologists and teachers. The idea is, based on the personal experience of these professionals, to try to determine if these tactics are effective, if they accomplish their goal of engaging the student and promoting positive emotions in him.

1.5 Some Contributions

The main contribution of this work is to define, model and implement an animated pedagogical agent (Mediating Agent) that, by considering student's affectivity, has the role of providing emotional support to him and promoting in him a positive mood that is more adequate for learning.

Our work makes still some other contributions to the research on affectivity in human computer interaction. The first one is to *model the emotions satisfaction/disappointment; joy/distress; gratitude/anger; and shame* which were not considered in the previous works of the group (BERCHT, 2001) (PROLA, 2003).

Another contribution to the research in user's emotions recognition is profiting from the *BDI reasoning to infer student's emotions*. The agent reasons about the student's actions and about the events in the educational system and to which emotion these events lead according to user's goals. This work is the *first one to offer an implementation of the OCC model in BDI* in order to infer student's emotions[2].

The use of the BDI to implement the inference of emotions is an alternative approach to other approaches found in the research literature such as probabilistic approaches like the affective model proposed by (CONATI, 2002) that relies on Bayesian networks, or rules as proposed by (FAIVRE; NKAMBOU; FRASSON, 2002) and (ELLIOT; RICKEL; LESTER, 1999). Although the Bayesian networks allow to explicitly represent the probabilistic dependencies between causes, effects and emotional states which enable to determine the student's emotions with more accuracy in situations that the user experiences a varied of emotions, it is difficult to define the required prior and conditional probabilities that are necessary in Bayesian networks (CONATI, 2002). The BDI approach offers some advantages when the system is embedded in a changing world with access to partial information (GEORGEFF et al., 1999). This is the case of the inference of the student's emotions in educational environments from his observable behaviour. We have to recognise the student's emotions from some cues about his goals, actions and events.

Another contribution of this work is to *use emotive attitudes and encouragement messages of a lifelike character to try to promote positive emotions in the student*. Although some works have tried to make agents that respond to student's emotions and show some empathic behaviours (as the works that we presented in the section about animated pedagogical agents – Section 2.5), they do not aim at promoting in the student a positive mood through messages of encouragement and emotive attitudes of a lifelike character. Although some agents as Cosmo and Vincent show some emotive attitudes, the intention is to turn the agent more believable and empathic to the student. Differently, in our work we intend that the proposed agent uses its attitudes for encouraging the student and inducing positive emotions in him, as well as to offer an emotional support to the student.

Besides, the *proposed agent profits from its knowledge about the student's affective states in order to choose an adequate action*. The tutor has more chance of responding appropriately to the real problem of the student when it knows the student's emotions, rather than manifesting a generic 'empathy' towards him. We believe that it is an advantage of the proposed agent over the other animated pedagogical agents which are presented in section 2.6. For example, Vincent shows a sad face when the student provides an incorrect answer for an exercise. If the student is frustrated, this behaviour will led him still more frustrated and depressed. The proposed agent, otherwise, considers the student's emotions and his goals in order to choose an adequate action. For example, the student that has performance goals likes to receive strong congratulations. For these students, the Mediating Agent presents different sort of

[2] We do not consider the Bercht's work the first one to implement the OCC model in BDI, since although it infers the student's emotion displeased, it does not implement computationally the OCC model in BDI. More detail in section 7.1.

praises and congratulations. Otherwise, the student that has mastery goals is more motivated to acquire new skills. For this student the agent presents a moderate congratulation and shows the student the new abilities that he obtained. The student can be disappointed, because although he accomplished successfully a task, he did not have a good performance in the section of study. In this case, besides giving a moderate congratulation, the agent also tries to motivate and encourage the student.

As the MACES educational environment is used as case study, another contribution of this work is to handle the affective aspects of the interaction between an artificial tutor and a student in the educational environment called MACES.

These contributions have led to some publications that are listed in Appendix C.

1.6 Organization of this Document

This thesis is composed of 9 chapters. The first chapter is constituted of the current introduction, and aims at presenting the scientific context, the motivation for its development, the objectives and some contributions of this work.

The other chapters are organized as follow. *Chapter 2* presents a brief introduction to agents and intelligent tutoring systems, concepts that are necessary to understand what are pedagogical agents and animated pedagogical agents, which are also presented in this chapter.

Chapter 3 presents an introduction to the BDI approach and to some pedagogical agents implemented as BDI agents. The X-BDI tool used for the implementation of this thesis and the background necessary are also introduced.

Chapter 4 provides an overview about emotions and computing. It introduces some concepts related to emotions and affectivity and the psychological theories used in this thesis. A brief introduction to affective computing (the field of computing that researches about emotions in machine) is also supplied. Together, these fours chapters form the fist part of the document, dedicated to the scientific background of the work.

Part II is formed by *Chapter 5,* that introduces MACES, the collaborative educational environment modelled with a multi-agent architecture and which the agent proposed is part.

The final part presents our contributions. Chapters 6, 7, and 8 constitute this final part. *Chapter 6* presents the aspects relatives to the idealisation and modelling of the Mediating Agent, the work proposed. This chapter describe how the Mediating Agent infers the student's emotions and choose the affective tactics.

Chapter 7 describes the implementation of this work and *Chapter 8* describes the partial validation of this work. Finally in *Chapter 9* we present some conclusions and future work related to this thesis.

The appendixes present the questionnaires used for the validation of this thesis, the MSLQ questionnaire and BDI listing of beliefs and desires of the agent.

I SCIENTIFIC CONTEXT

2 INTELLIGENT TUTORING SYSTEMS MODELLED THROUGH AN AGENT APPROACH

In the early 50's, educational software, known as Computed Aided Instruction (CAI), were characterised by being simple mechanisms to turn over pages. These programs used the electronic media to make the same as carried out in paper, without any significant profit in a teach-learning level. In the 70's researchers in Computer Science in Education observed the necessity to use techniques of Artificial Intelligence for making educational systems more flexible and customised for their users. These programs are known as **Intelligent Tutoring Systems (ITS)** (GIRAFFA, 1999) (see Section 2.4).

Currently, many of the teaching and learning systems have used the technology of **agents** (Section 2.1) for their conception. In this agents-oriented approach, the modular architecture of an ITS is substituted by a society of agents that work in a collaborative way. An ITS formed by agents is called **Pedagogical Agent** (Section 2.4).

In these systems, the agents can be a lifelike character that interacts with the user (see Section 2.5), as well as they can be cooperative agents who work in background as part of the educational system's architecture (GÜRER, 1998) (LESTER; TOWNS; FITZGERALD, 1999). In the former situation, the agents are used to facilitate the modular construction of an ITS' architecture, and for the communication between these modules. In this direction we can point to the works of (BICA; VICCARI, 2000) (D'AMICO et al., 1998) (SILVEIRA; VICCARI, 1999) (GOUARDÈRES; FRASSON, 1998) (AÏMEUR; FAHMI, 1998) (GÜRER, 1998) (GIRAFFA; VICCARI, 1998c). In the second situation, the researchers studied animation techniques for the pedagogical agents to communicate more effectively with the student through the auditory and visual canals (JOHNSON; SHAW, 1997) (RICKEL; JOHNSON, 1998b) (PAIVA; MACHADO, 1998) (LESTER et al., 1997a) (LESTER; STONE, 1997). These pedagogical agents who are personified by lifelike characters are called Animated Pedagogical Agents (see Section 2.5). In these systems the believability has an essential role, since in order for the system to be effective the student must "believe" and "trust" the agent and its knowledge on the teaching subject (see Section 2.5.6).

2.1 Intelligent Tutoring Systems

Intelligent Tutoring Systems are programs that, interacting with the student, modify their knowledge about the student (student model) through the capacity of learning. They customise the learning strategies according to the student cognitive model, which is modelled based on student's actions. The main objective of these systems is to provide a suitable instruction for the student in terms of content and form. To be intelligent, a tutor must be flexible, i.e., be able to learn with the environment and update its knowledge (VICCARI, 1989) (VICCARI; GIRAFFA, 1996).

According to Oliveira (1994), an ITS is formed basically by some functional components that can be observed in the majority of the implementations. A general architecture for an ITS can be visualised in Figure 2.1.

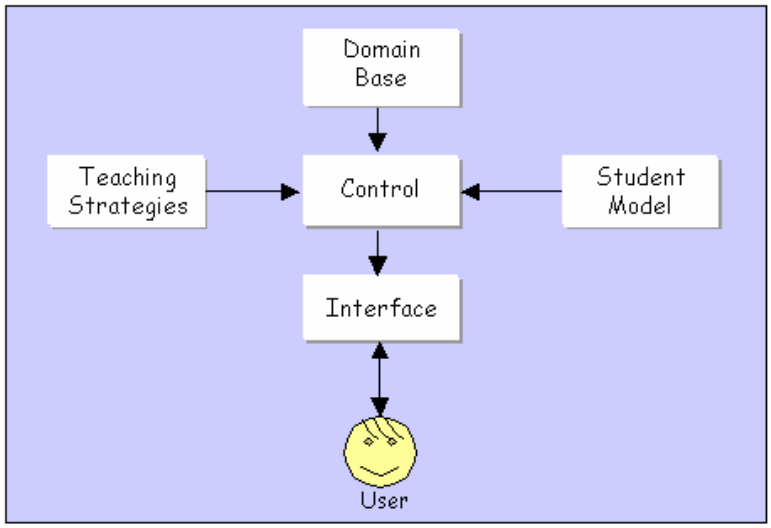

Figure 2.1: The Intelligent Tutoring System General Architecture (OLIVEIRA, 1994)

Each of the modules that compose this architecture is briefly described bellow (VICCARI; GIRAFFA, 1996):

Control Module: based on Student Model information, the Control Module selects a teaching strategy in the Strategies Base. Using the adopted strategy, it selects the educational material in the Domain Base. It presents the material to the student through the Interface module. With the information about the student, it updates the Student Model, in order to monitor his progress.

Domain Base: contains the instructional content that the tutor will present to the student.

Teaching or Learning Strategies: they are educational tactics used by the tutor for presenting to the student the knowledge in the Domain Base.

User Interface: this is the way the tutor communicates with the student. It has the function of presenting the instructional material to the student and of monitoring student's progress and behaviour in order to maintain the Student Model updated.

Student Cognitive Model: it contains information about the student that is collected from the evidences deduced from student's inputs in the system. The system uses this model for determining the appropriate actions that should by applied to the student. The basic content of this model consists of a representation of the student's knowledge on the domain and the specification of his objectives. It can also contain the student's intentions, plans, attitudes and the relevant inference procedures.

The ITS architecture previously explained is a basic and original model proposed in the 70's. We observe that, nowadays, more and more complex and sophisticated architectures have been proposed. An example is the ITS architectures modelled on a multi-agent approach (BICA; VICCARI, 2000) (D'AMICO et al., 1998) (SILVEIRA; VICCARI, 1999) (GOUARDÈRES; FRASSON, 1998) (AÏMEUR; FAHMI, 1998) (GÜRER, 1998) (GIRAFFA; VICCARI, 1998c). These ITSs are called Pedagogical Agents and are presented in Section 2.4.

2.2 Agents

The Artificial Intelligence is the subfield of computer science which aims at constructing agents that exhibit aspects of intelligent behaviour (RUSSEL; NORVIG, 1995). Although the notion of agent is central to Artificial Intelligence (AI), there is not yet a consensus about the meaning of this term.

A compilation of several definitions can be found in (SHOAM, 1997). According to the author, a software agent is an entity that functions autonomously and continuously in a particular environment always inhabited by other agents and processes. The term autonomy is not very exact and it is used in the sense that the agent carries out its activities without the constant intervention of a person.

Jennings and colleagues (1998) define intelligent agents as software programs that show adaptive, independent and oriented-objectives behaviour.

Another known definition is given by Russel and Norvig (1995) who define an agent as a system capable of perceiving the environment through sensors and acting through actuators. The figure of a generic agent according to the Russel and Norvig definition is showed in Figure 2.2.

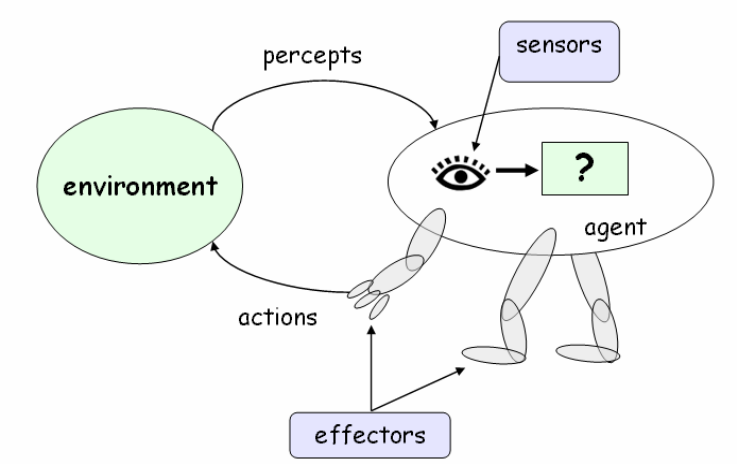

Figure 2.2: An Agent's Interaction with the Environment (RUSSEL; NORVIG, 1995)

Moulin and Chaib-Draa (1996) describe an agent by the abilities that it should have:

- Perception and interpretation of data and messages input;
- Reasoning on its beliefs;
- Decision taking (election of goals);
- Planning (election or construction of plans of action, conflict resolution and allocation of resources);
- Ability to execute plans including messages sending.

Wooldridge and Jennings (1995) define an agent as a hardware or a software-based computer system that has the following properties[3]:

- *Autonomy*: agents operate without intervention of human and others, and have some kind of control over their action and internal state;

[3] The agents that have these properties (for example, softbots and software agents) are part of the weak notion of agency. There is also the strong notion of agency where the agents, besides having the properties above, are conceptualised or are implemented using concepts that are more applied to humans. For example, the cognitive agents that follow the Sichman and colleagues' (1992) classification.

- *Social ability*: agents interact with other agents (and humans) via some kind of agent-communication language;
- *Reactivity*: agents perceive their environment and respond to changes that occur in it;
- *Pro-activeness*: agents are able to exhibit goal-directed behaviour by taking the initiative.

According to Sichman and colleagues (1992), the different capacities of the agents for problems resolution allow to classify them in two main categories: **reactive** and **cognitive agents**.

Cognitive or deliberative agents derive from the deliberative thinking paradigm: "agents that possess an explicitly represented, symbolic model of the world and in which decisions (for example about what actions to perform) are made via symbolic reasoning" (WOOLDRIDGE; JENNINGS, 1995). There is a special kind of cognitive agents based on mental attitudes or notions such as beliefs, desires and intentions – BDI agents (RAO; GEORGEFF, 1995). As the pedagogical agent proposed in this work is implemented as a BDI agent, this approach is described with more details in Section 2.6.

The reactive agents, on the other hand, do not have any internal, symbolic model of their environment, and they act using a stimulus/response type of behaviour in order to respond to the present state of the environment in which they are embedded (FERBER, 1994). Giraffa's (1999) work (MCOE) is composed of reactive (fishes) and cognitive (BDI) agents (tutor and students).

Currently, however, we can observe that reactive and cognitive agents are the extremities of a classification line where new denominations have appeared as, for example, pedagogical and software agents. As the pedagogical agents are a central subject of this work, they will be discussed in Section 2.4.

2.3 Benefits of Using an Agent Approach to Model ITS

Nowadays, many systems for educational purposes are using agents in their conception. According to Giraffa (1999), the reason for introducing agents in the architecture of such systems is because the agents intensify the pedagogical aspects of the environment due to characteristics such as pro-activity, social ability and flexibility that are inherited of the agents paradigm (see Section 2.2). These abilities are useful to overcome the traditional restrictions to build a strong student model, and to better explore the interaction and dynamic changes in teaching-learning environments.

According to Gürer (1998), the two bigger advantages in using agents in the conception of educational systems are: modularity and openness. As the agents are autonomous, they are a powerful tool to turn the tutorial system modular. Some efforts have been carried out towards implementing the components of a tutor as agents, which can be joined together to build up an ITS (SILVEIRA; VICCARI, 1999). Moreover, due to the fact that each agent is a unique module and independent of the others, it is easier to add other agents to these systems which will carry out new functionalities. As the agents are autonomous, they only need to know information about how to interact with other agents to be added to a system (for example, what type of new information the system waits for the agent to send).

The multi-agent system's modularity also allows to handle bigger and more complex problems: each agent can be specialized for its own tasks in the space problem (in terms of

knowledge and abilities to problem solving). To adapt the actions of an ITS to the student's necessities is a complex process that requires a variety of knowledge, expertise, problem resolution capacities and strategies of man-computer interaction, evaluation, pedagogy and presentation of multimedia information. Breaking this process in appropriate components that are autonomous, pro-active and flexible can reduce the complexity to construct a tutor. This modularity turns an educational system (for example, an ITS) a simpler process, where the developer can concentrate the knowledge representation, the analyses granularity and the ways of reasoning that are different to each functionality into each agent. This modularity also allows to reuse the components in different systems.

The distributed nature of the multi-agent architectures allows the functionality of an educational system to be distributed in a computer network and in different platforms. This distribution allows the construction of the tutorial system from several components that are in different platforms, allowing the use of appropriate tools without worrying about the platform. Moreover, the distributed nature of these architectures allows partial parallel processing. According to Johnson and colleagues (1998), the use of a multi-agent paradigm turns relatively easier the migration of a system developed for a single user to a multi-user system.

These agents that are inserted in an educational system and have an educational role are called pedagogical agent (GÜRER, 1998). The pedagogical agents are described with more details in Section 2.4.

2.4 Pedagogical Agents

Nowadays, we can observe that many educational systems are being implemented using an agent paradigm. These intelligent agents that have an educational or pedagogical role to facilitate or improve learning are called **Pedagogical Agents** (GÜRER, 1998). These agents can be modelled as (1) cooperative agents who work in background as part of the architecture of the educational system, or as (2) personal and animated agents that interact with the user.

In the first case, the educational system is modelled and implemented using a multi-agent approach, where each agent has a specific function in the system. These agents act in background, they are transparent to the user, and exchange information in order to carry out actions that are appropriate to a better learning. In this direction we can highlight the works of (BICA; VICCARI, 2000) (D'AMICO et al., 1998) (SILVEIRA; VICCARI, 1999) (GOUARDÈRES; FRASSON, 1998) (AÏMEUR; FAHMI, 1998) (GÜRER, 1998) (GIRAFFA, 1999).

According to Giraffa and Viccari (1998b), the architectures based on this approach are variations of the traditional and functional architecture of an ITS (domain base, student model, teaching strategies), where one or more agents implement each function of the tutor. The control is distributed among the agents, however the user sees the system as an only one, while, internally, it is composed of a society of agents. The benefits of using a multi-agent approach to implement an educational computational system were described in Section 2.3.

In the second case, the Animated Pedagogical Agents are personalized agents that are personified by a lifelike character that interacts with the student. Some examples of animated pedagogical agents are: Vincent (see Section 2.5.1), Adele (see Section 2.5.2), Steve (see Section 2.5.3) and Cosmos (see Section 2.5.4). In this work, the topic "Animated Pedagogical Agent" will be described with more details in Section 2.5, because it is a subject of greater interest to this thesis proposal.

2.5 Animated Pedagogical Agents

The pedagogical agents that use the technology of synthetic agents for the presentation of the educational content are known as Animated Pedagogical Agents. The synthetic agents[4] are autonomous and intelligent[5] agents based on the idea of behaviour simulation of alive and intelligent creatures in machines (ELLIOTT; BRZEZINSKI, 1998). In such a way, these agents use multimedia resources for providing for the user an animated character with characteristics similar to the ones of live intelligent creatures. These characteristics, such as facial expressions and understanding of human beings emotions, with a good dialogue interface with the user, turn the agents more attractive to the students (ELLIOTT; BRZEZINSKI, 1998). This way, differently from the conventional systems, the animated pedagogical agents communication has a more anthropomorphic and social nature. They exploit the natural tendency of people to engage in social interactions with computers, termed The Media Equation by Reeves and Nass (1996).

As examples of Animated Pedagogical Agents, we can cite the works (JOHNSON; SHAW, 1997) (RICKEL; JOHNSON, 1998b) (PAIVA; MACHADO, 1998) (LESTER et al., 1997a) (LESTER; STONE, 1997). The use of animated pedagogical agents for educational purpose opens new interesting possibilities for educational systems since, for example, the agents can demonstrate tasks (RICKEL; JOHNSON, 1998b) (LESTER et al., 1997b), use locomotion and gestures for focusing the student's attention on the most important aspects of the task (RICKEL; JOHNSON, 1998a) and to respond emotionally to the student (LESTER et al., 1997a) (LESTER; TOWNS; FITZGERALD, 1999) (PAIVA; MACHADO; MARTINHO, 1999). The animated pedagogical agents offer great promise for increasing the communication capacity of the educational systems (JOHNSON; SHAW; GANESHAN, 1998) and increasing the ability of these systems to engage and to motivate the students (LESTER et al., 1997b).

To delineate our research about animated pedagogical agents, we chose some cited examples in the literature. These environments are detailed in the following sections. We chose these examples based on their characteristics and their contributions to our work.

2.5.1 Vincent

Vincent is an animated pedagogical agent that has the goal of assisting the student while he accomplishes the exercises, helping in the case of some diagnosed difficulties, promoting student's confidence and motivating the student to learn. It provides the system with interactivity and personalization, offering to the student a tutor friend which will help him (PAIVA; MACHADO, 1998) (PAIVA; MACHADO, 1999) (PAIVA; MACHADO; MARTINHO, 1999).

Vincent was designed to be part of a training system called TEMAI, developed by the INESC institute for the TSC (Technological Shoe-Making Center), used by professionals inserted in diverse factories of the TSC. The architecture of TEMAI is composed of a set of learning environments; a database with theoretical explanations of the exercises; a student model; and the Vincent agent which communicates with the environment for assisting the student and updating the student model. In Figure 2.3 we can observe Vincent presenting an exercise in TEMAI.

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[4] Animated agent is used in this document as synonymous of synthetic agent.

[5] For intelligent agents notions, see (SHOAM, 1997) (JENNINGS; SYCARA; WOOLDRIDGE, 1998) and (WOOLDRIDGE, 1999).

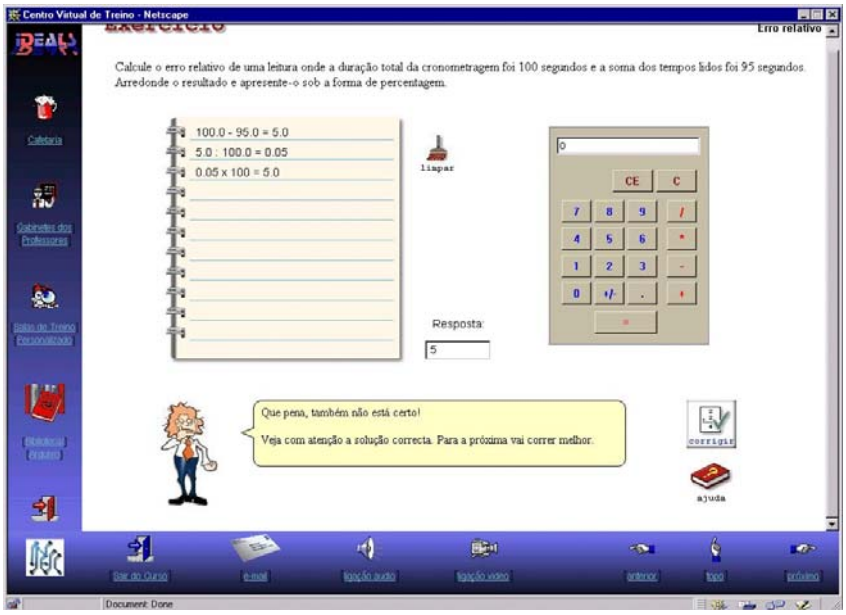

Figure 2.3: Vincent presenting an exercise in TEMAI (PAIVA; MACHADO, 1999)

Vincent was constructed to be reused; it was implemented as an independent component of the other modules of TEMAI. Vincent has an internal knowledge base that is composed by the **student model** which contains information about the results of the responses to the exercises; the elapsed time in the resolution of the exercises; and the mistakes that the student did in the exercises; a set of **visual resources**, such as images, that constitutes Vincent's physical behaviour; and a set of **audio resources**, such as sounds and audio messages, that are the Vincent's Speeches.

Vincent's architecture is composed of the Mind and Body modules. The **Mind Module** is responsible for making inferences about the perceptions of the environment and for deciding the best pedagogical action to be applied. The **Body Module** is responsible for executing the pedagogical action, selected for the Mind Module; and modifying Vincent's appearance. This module shows the animations and audio messages that were chosen for Vincent's behaviour.

Vincent has two types of behaviour defined according to its objectives: cognitive and reactive. The goal of the **cognitive behaviour** is to decide which pedagogical action must be chosen for a particular situation. Pedagogical tasks, such as encouraging the student to try to resolve the exercise, Knowledge manipulation tasks, such as updating the student model with the current student's knowledge state, and Diagnosis tasks, such as verifying errors produced by the student in the exercise, are example of cognitive behaviours. The **reactive behaviour** includes Vincent's audiovisual attitudes. The Vincent's cognitive behaviour is handled by the Mind Module of the agent, while the reactive behaviour is determined by the Body Module.

Vincent uses a set of strategy rules for deciding which strategy to apply to the student. The strategy choice depends on the student model and on the information about the student's action in the exercise. After, the Mind Module asks the Body Module to show emotional (audiovisual) behaviours appropriate to the context.

2.5.2 Adele

Another example of animated pedagogical agent is Adele[6] (Agent for Distance Education - Light Edition), a pedagogical agent with human expressions who was projected to work with students in problem solving (JOHNSON; SHAW, 1997) (JOHNSON; SHAW; GANESHAN, 1998). The Adele was developed in the Center for Advanced Research in Technology for Education of the USC (University of Southern California) in U.S.A.

The actual version of Adele works with students of medicine and odontology. It is used in educational systems of medicine of two types: diagnosis and simulation of an UIT (Unit of Intensive Treatment). In the case of an application for clinical diagnosis, the students receive material about a specific case and, then, they receive simulation cases to work on. Adele executes functions as highlighting interesting aspects of the case, monitoring and supplying feedback to the student, giving suggestions or applying a test to verify if the student learned the principles associates to the case.

Adele was implemented as a Java applet and has the appearance of 2D animated character. In Figure 2.4, we can observe the graphical interface of simulation of clinical diagnosis and the lifelike character Adele in the Figure 2.5.

Figure 2.4: Adele's Graphical Interface of Simulation[7]

Figure 2.5: Adele Persona Agent

Adele's Architecture

Adele's architecture is composed of three main components: graphical interface of simulation (GIS) (see Figure 2.4), reasoning machine and an animated persona agent (see Figure 2.5). The GIS can be implemented using any programming language and it communicates with the reasoning machine through an API. The persona agent is an

[6] A demo version of Adele can be downloaded at http://www.isi.edu/isd/ADE/ade-body.html.

[7] Adele's Graphical Interface of Simulation and Adele Persona Agent. Available at: http://computing.unn.ac.uk/staff/cgpb4/ijaied/members00/archive/vol_11/johnson/full.html.

incorporated applet that can be used in any application. The reasoning machine is responsible for the decision taking and for monitoring the student. It reads a task plan, initial state and student model in the server, when the system is downloaded in the user's machine.

Interaction with the student

The Adele character talks to the user through a speech synthesizer, when it presents an exercise, presents some hint, or when the user selects one of the buttons available in Adele's interface, which can be: "How" (how to carry out the action suggested by Adele); "Why" (why to carry out this action) and "Hint" (what is the next action to be done). This way, the student can only ask Adele questions of these three types and in relation to the presented scenes. This restricts the interaction between the student and Adele, since Adele does not have a mechanism of natural language processing to interpret the questions, verbal or typed, made by the student.

2.5.3 Steve

Steve[8] (Soar Training Expert for Virtual Environment) is an animated and autonomous pedagogical agent inserted in a 3D simulation system constructed to assist students in courses of naval training (RICKEL; JOHNSON, 1998a) (RICKEL; JOHNSON, 1998b) (JOHNSON; SHAW, 1997). The Steve goal is to help students to carry out procedural and physical tasks, such as repair and operation of complex naval equipments.

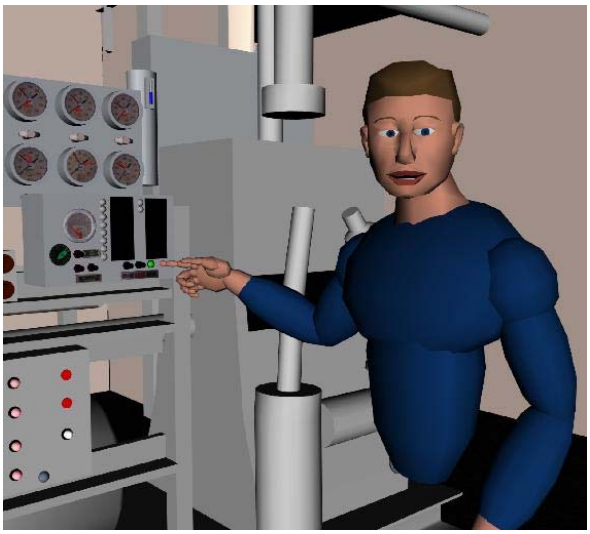

Figure 2.6: The Steve character[9]

Steve is represented by a character with gesture abilities, able to demonstrate procedures through gestures and verbal communication, having as main functions to follow and to monitor the student's learning during the interaction with the environment. Steve demonstrates tasks, explains the reason to make each step and gives help when requested by the student. Figure 2.6 shows the Steve interface.

[8] http://www.isi.edu/isd/VET/vet-body.html
[9] Available at http://www.isi.edu/isd/VET/vet-body.html.

Steve's Architecture

Steve is part of a greater system called Virtual Environments for Training (VET) that is being developed by the Science Institute of Information of USC, Laboratory of Technology of the Behaviour of the USC and Lockheed Martin. VET has two other components beyond Steve: the Virtual Reality Software and the World Simulator.

The Virtual Reality Software is responsible for the interface of the virtual world with the students. Its function is to update the student's vision of the world while he moves in the virtual world and to detect his interactions with the world. The World Simulator maintains the state of the virtual world when agents or humans interact with it. Thus, when a student interacts with the virtual world, Steve receives a message from the Virtual Reality Software describing the student's action, and a message from the Simulator describing the resultant changes in the world. This way, Steve always knows the actions carried out by the students and the resulting changes in the environment.

The environment's architecture is composed of a knowledge base (which contains the training instructional material), student model, Steve agent, and the environment of interaction with the student.

In each pedagogical interaction between Steve and the student is applied a model of tasks, which determines which actions are appropriate to a certain situation, how to execute them, and the justification for accomplishing them. The tasks representation model of Steve is based on hierarchical partial-order plans. Through this model, each agent task is described in accordance with its goals, the action to be executed, and the execution sequence of the actions and the effect of each one on the others.

The communication of Steve with the student is in natural language, using synthesized voice. The synthesis and natural language processing are made by a special program developed for the Entropic Research.

A non-verbal communication also happens in the interaction between Steve and students. Through the information from the immersion equipments used by the students in the environment, such as gloves and helmets, Steve recognises the vision field of the student, which allows Steve to verify if the student is looking at the right place in the virtual world in order to execute the next steps of the activity. Steve can move the head and eyes to locate objects in the environment in order to direct the attention for such objects; and to look at the student while it says something or waits for an action of the student.

2.5.4 Cosmo

Developed by Multimedia Laboratory of the Computer Science Department of the North-Caroline State University (NCSU), Cosmo[10] is an agent that inhabits a learning environment, the Internet Advisor, for the domain of Internet packet routing. Its function is, in real time, to demonstrate and to advise students about the best way to ship packets for one definitive destination, in a virtual world of routers (LESTER et al., 1997a) (LESTER et al., 1997b) (LESTER; TOWNS, 2000). Cosmo has the appearance of a strange creature with antennas and it is very similar to a small humanoid robot. As it coexists in an environment of computer network, the choice of a figure next to the computer domain seems natural. Cosmo can carry out a large variety of behaviours, such as moving, pointing, blinking the eyes, inclining, beating palms and raising and

[10] IntelliMedia Project – North-Caroline University - http://www.csc.ncsu.edu/eos/users/l/lester/www/imedia/

folding its antennas. Moreover, as verbal behaviour, it has 240 elocutions that vary between 1-20 seconds. Cosmo and the Internet Advisor environment were implemented in C++ and Microsoft Game Developer's Software Kit. Cosmo agent can be visualized in Figure 2.7.

Figure 2.7: Cosmo and the Internet Advisor Environment (LESTER et al., 1997a)

The Cosmo's architecture

To solve the proposed activities, the student interacts with Internet Advisor environment doing actions as dragging objects and pointing components in the world. The Interaction Handler monitors the student's actions in this environment. This module is composed of an action interpreter which detects actions accomplished by the student and changes in the environment.

When the student reaches a dead-end, which is indicated by a great period of inactivity or the accomplishment of some task in a sub-optimal way, the Interaction Handler invokes the Explanation Planner. The Explanation Planner determines the content and the structure of the agent explanation and sends this information to the Deictic Behaviour Planner (which carries out specifications of speeches, gestures and locomotion when the agent must point to an object), and to the Sequencing Engine of Emotive-Kinaesthetic Behaviour that determines the emotional behaviour that the agent must present. Then, the behaviours are sent to the Presentation Manager which manipulates the persona to exhibit them.

Emotive Behaviour Generation in Cosmo

The Emotive-kinaesthetic Behaviour Sequencing Engine (LESTER; TOWNS, 2000) in Cosmo is responsible for mounting and selecting the visual attitudes that are shown in a determined situation. This module was based on the framework Affective Reasoner (see Section 4.7.5) which associates emotional states to communication. This way, Cosmo has a repertoire of corporal emotive behaviours associated to speech acts in accordance to its intention or kinaesthetic expression.

When the Explanation System is invoked to construct a communication plan, it examines the state of the problem, an information net about the course and the student

model to determine the pedagogical speech acts that will be used to communicate to the student. These speech acts are sent to the Emotive-kinaesthetic Behaviour Sequencing Engine that selects an emotive behaviour among all behaviours that express the appropriate affective state of the speech act. This is possible because all behaviours in Behaviours Space are mapped, one by one, in emotive states that they express.

2.5.5 Animated Pedagogical Agents and their Educational Benefits

The animated pedagogical agents have a varied repertoire of emotive behaviours to respond with facial expressions and emotional gestures to the student. Due to this, these agents can also use the audio and visual channels for communicating more effectively with the student. Thus, these agents have some advantages that in other educational systems or traditional intelligent tutors are not reached. These advantages are pointed out by Johnson and colleagues (2000a).

According to Johnson and colleagues (2000a), to demonstrate a task can be more effective than to describe it. Moreover, the **interactive demonstration** by an agent offers greater advantages than a recorded video. This is because the student is freer to move inside the virtual world and can see demonstrations from different perspectives. He can interrupt the demonstration with questions, or request for the agent itself to finish the task. These advantages can be visualized in Steve (see Section 2.5.3).

Moreover, the agents can also serve as navigational guides, guiding the student inside the learning environment. Johnson and colleagues assert (2000a) that the students frequently became disoriented in 3-D immersive environments. Thus, the use of agents as navigational guides is an important instructional resource. The agents Steve (Section 2.5.3), Cosmo (see Section 2.5.4) and Herman (STONE; LESTER, 1996) (LESTER; STONE, 1997) (TOWNS; FITZGERALD; LESTER, 1998) (LESTER et al., 1997b) are used as navigational guide within their environments.

An animated pedagogical agent can also **focus the student's attention** on certain aspects of the task through gestures and gazes. This can be made in diverse ways, such as pointing to objects, looking at objects that are being manipulated by the student and looking at the student while it waits for some student's action or when speaking with the student. For example, Adele looks at the mouse selection of the student (see Section 2.5.2); Cosmo points to computers of the environment that are part of the problem solution (see Section 2.5.4). Steve (see Section 2.5.3) and Herman (STONE; LESTER, 1996) (LESTER; STONE, 1997) (TOWNS; FITZGERALD; LESTER, 1998) also point to and look at objects of the environment.

Another type of animated pedagogical agents' property is the **non-verbal behaviour**, in addition to the verbal communication. For example, Steve (see Section 2.5.3) uses a head approval movement for demonstrating to the student that it agrees with his action. In the same way, Vincent has behaviours that demonstrate approval, disapproval and wait, etc (see Section 2.5.1). The ability to present non-verbal behaviour makes it possible to use a greater variety of feedback levels than in traditional tutorial systems. The non-verbal behaviour, such as facial expressions, can be preferable because they can be less impertinent than a verbal commentary. A head movement can calm down the student without interrupting it. For example, in order to congratulate the student on some resolved exercise, Herman makes acrobatics in the screen (TOWNS; FITZGERALD; LESTER, 1998) and Cosmo smiles and applauds the student (see Section 2.5.4).

The agents also can use **non-verbal signals of conversation** for emphasizing certain aspects of their speeches. For example, the agent can knit the brows, blink the eyes or move the head to highlight words or phrases. This type of resource enables a kind of dialogue that is more natural like face-to-face communication with which people are habituated.

Recent studies with animated pedagogical agents demonstrated that animated agents that have a computational model of emotion can be more effective pedagogically, beyond providing a strong **motivational effect** in the student. This is because the emotion has an important role in the motivation. For example, Cosmo has a repertoire of behaviours to encourage and to show empathy to the student (see Section 2.5.4). Vincent has audiovisual attitudes to show the student that he resolved correctly, or not, the exercise (see Section 2.5.1). Moreover, Lester and colleagues (LESTER et al., 1997b) pointed out that, even if the agent does not have a sufficiently pro-active behaviour, it is useful to implement it as an animated pedagogical agent. The authors believe it, because the evaluation with the agent Cosmo (LESTER et al., 1997b) showed that even a mute agent, which does not offer any type of support to the student, has a motivational effect on the student. The motivated student uses the educational environment more frequently and during a greater interval of time.

Although the animated pedagogical agents are usually used as individual tutors, they can play the role of study friends or **partners in collaborative activities**. In many situations, the group activity has an important role and the student must learn to co-ordinate his actions with the actions of his colleagues. In this direction, the pedagogical agents can serve as a virtual friend, assisting the student in group activities when there are no available colleagues. Steve supports group activities (JOHNSON; SHAW, 1997). Aïmeur and colleagues (1998) implemented a 2D companying agent "troublemaker" with facial expressions that, sometimes, supplies incorrect information to the student to test and to increase his self-confidence.

According to Johnson and colleagues (1998), the use of gestures and visual expressions and the ability for reacting to the student's actions make these systems seem more real (believability - see Section 2.5.7) to the user. Moreover, the use of facial expressions can have a motivational influence in the student.

The evaluation of the pedagogical agent Herman the Bug (LESTER et al., 1997b) demonstrated that the presence of animated pedagogical agents has a strong positive impact in the students' perception of their learning experiences. The agents engage the students in their study, leading them to **reflection** and **self-explanation**.

Johnson and colleagues (2000a) state that, beyond all the benefits of the character presence that were previously cited, an animated pedagogical agent must also have the same **pedagogical abilities** of an intelligent tutoring system. Thus, it is useful that it knows to answer to student's questions, to generate explanations, to ask questions to the student, and to obtain the student's levels of ability.

2.5.6 Believable Agents

In order to turn the animated pedagogical agent more real to the user, it must be believable, i.e., the student involves himself with the agent in such a way that he believes the agent is real (BATES, 1994).

According to Loyall and Bates (1997), the term **believability** is used in the sense of believable actors in the dramatic art, meaning that the public or users can forget their scepticism and feel that the character or agent is real. To make an agent believable

involves providing it with the aspects to express its personality. An agent which represents an interactive and believable animated character is called **Believable Agent**.

There are some actions that turn the agent more real, such as the eyes movement, a pause to speak, the conscience of the body position and of the personal space, and communication in natural language.

According to Hayes-Roth (1998), in order for an animated agent to have and to maintain credibility, the agent animation behaviours must follow some premises:

- There must have a varied repertoire of different behaviours to cover a great number of situations;
- There must exist variability in the expression of a nominal type of behaviour so that it looks more alive and less robotic;
- The environment must not distract the user, but must keep it alive during dramatic events;
- There must be ambiguous behaviours that can be used in different contexts;
- There must exist attenuation of the behaviours so that the observers experience a distribution of the expressive effect, requiring different levels of interpretation;
- There must exist signature behaviours that occur with some frequency in a context to designate the key qualities of the character;
- The character must have particular attitudes that differentiate it from the others.

According to Bates (1994) a believable agent must **express emotions** according to the success or failure in the communication, as well as in other actions. Bates (1994) believes that the scientists of Artificial Intelligence must base on the characters animators' works for the construction of computational models of believable agents. This way, as well as the characters in cartoons, believable agents must express emotions.

According to Hayes-Hoth (1998), in order for an animated character to have a desired affective impact in the observer, it must have empathy. It must perceive and answer appropriately to the user's feelings. Hayes-Hoth believes that, in this case, it is not necessary that the agent has emotions or understands what they mean. It is necessary only that the character acts as if it perceives, feels and manifests emotions. This type of behaviour can be observed in Eliza software (WEIZENBAUM, 1966), a text-based interactive program that simulates a psychologist. More details about empathy in educational system can be found in Section 4.8.2.

2.5.7 Believability in Animated Pedagogical Agents

According to Paiva and colleagues (1999), when the student interacts with lifelike characters in learning situations, he waits a more human-like behaviour and not a repetitive or mechanical behaviour. The student waits, beyond the character offering the pedagogical support, that it also amuses, has emotions, has empathy, understands him, etc. And if these student's expectations are not corresponded, the believability degree of the agent is reduced and the student starts to loose his confidence on the agent. This way, the believability is a key factor in the development of animated pedagogical agents (PAIVA; MACHADO; MARTINHO, 1999).

Pedagogical agents must have special characteristics to be believable, because they are engaged in educational tasks. This way, Johnson and colleagues (JOHNSON; SHAW; GANESHAN, 1998) verified that in order for a pedagogical agent to be believable, it must also have other three functionalities, beyond the functionalities presented in Section 2.5.6:

- Pedagogical agents need to **have sufficient knowledge of the domain** to support instructional dialogues;
- The behaviour and the **appearance of the agent** influence the idea of expertise that the student has about this agent. For example, Adele has the appearance of a doctor, because it is inserted in an environment of medicine problem-solving;
- As the users can react to the agent in an unexpected way, it is necessary to make the prototipising and a vast **experimentation of the system**.

According to Johnson and colleagues (JOHNSON; RICKEL; LESTER, 2000a), the credibility is a product of two forces: (1) visual quality of the agent and (2) computational properties of the behaviour control system that creates its behaviour in accordance to the development of interactions with the user.

But, we must always remember that the pedagogical agents' goal is to promote learning. In this case, the agent behaviour must increase its believability, without reducing the learning effectiveness. This way, all behaviour that intervenes in the resolution of the problem by the student, regardless of how much they contribute to the agent believability, is inappropriate. For example, if the agent makes acrobatics in the screen while the student is carrying out a difficult exercise, it would immediately break the student's concentration.

To be believable, the agent shows kinds of behaviours that are not directly related to pedagogical activities. For example, the agent can tap the foot on the ground or breathe when it is idle. In order for the agent respect the criterion of controlled visual impact which aims at keeping the student's attention in the pedagogical activity, a technique of competition of believable behaviours could be used. In each moment, the strongest behaviour elected by an algorithm is selected and shown. This algorithm would take into account the probable visual impact of the behaviour, in such a way that the behaviour that cause greater impact is shown in situations that do not demand greater concentration by the student.

2.5.8 The Affective Impact of Animated Pedagogical Agents

Andrè and colleagues (1999) carried out a study for evaluating the level in which the agent called PPP persona contributes to learning. Two versions of the learning environment were created: one with PPP agent and another one without the agent. Agent PPP uses narration and a pole for pointing to objects in the world. Each student observes some presentations, some with technical information and others without. The results of the evaluation showed that the presence of the agent did not bring better results for the understanding of the agent's explanation by the student. 29 of 30 students that participated in the evaluation preferred the presence of PPP agent because the presentations were more amusing and less difficult (in the case of technical presentations) with the agent.

Lester and his colleagues (LESTER et al., 1997b) (LESTER et al., 1997c) carried out some evaluations of animated pedagogical agents. The investigation wanted to verify the impact of using animated pedagogical agents in the man-machine interaction in learning environments and the benefits of animated pedagogical agents for assisting students in the problem-solving activities.

A formal evaluation with 100 students of average education was carried out. They interacted with 5 clones of the Herman pedagogical agent, which was inserted in the Design-a-Plant environment; each clone interacted with 20 students.

First, Lester and his colleagues (LESTER et al., 1997b) investigated with this test the positive impact of the animated character (of animated pedagogical agents) in the student's perception of his learning experience, which is called **persona effect**. The authors verified two potential effects of agents in learning: a **cognitive effect** and a **motivational effect**.

There is a cognitive effect in superior knowledge acquisition. As agents can engage more actively the student in learning, they can stimulate reflection and self-explanation.

Even the students who worked with clones of the dumb type (agents which did not present any type of help) perceived the agents in a positive way. This demonstrates the importance of the persona effect, or either, the simple agent presence brings benefits to the student, even if it was not well projected.

This persona effect shows to have a motivational effect on students. The authors believe that the agents enthusiasm the students due to their believable presence and due to innate human response to psycho-social stimulations. As a result, the students can choose to interact more frequently with the environment and for a greater period of time. This same persona effect was visualized in another evaluation carried out with the Cosmo agent (LESTER et al., 1999). Rizzo (2000) asserts that believable agents in the interface might make the interaction with computers much easier and nicer, because they enable (especially, naïve) users to adopt communicative styles similar to those typical of human-human communication, and increase the level of interactivity and socio-emotional engagement produced by traditional applications.

2.6 Animated Pedagogical Agents: a Comparative Study

In this section we present a comparative study which shows the differences and similarities among the animated pedagogical agents which were presented in this chapter: Vincent, Adele, Steve, Cosmo and Mediating Agent (the animated pedagogical agent developed in this thesis and described in Sections 67). The used criteria are classified in three types: technical, contextual, interaction, and affectivity. The technical criteria describe the used and necessary technologies to develop and execute the system. The contextual criteria inform the context and domain. For example, an agent that teaches botany lives in a micro-world composed of plants. The interaction criteria identify the aspects of interaction between the agent and the student, such as appearance, emotions, etc. And the affectivity criteria analyses how these systems handles the student's affectivity.

Table 2.1[11] shows a comparison among the animated pedagogical agents. The table is filled as follows: each cell has a description about how the agent fulfils this criterion, or contains the symbol (??), which means that we did not find sufficient information about the respective aspect from the available papers.

[11] This comparative study is based on a previous work (JAQUES et al., 2001).

Table 2.1: Comparative Table of Animated Pedagogical Agents

	Criteria	Adele	Steve	Vincent	Cosmo	Mediating Agent
CONTEXT.	Domain	Medicine	Naval Training	Domain-independent	Internet packet routing	Domain-independent
	Context	Medical Chart	Naval Machinery	Various	Computer Network	Various
TÉCHNIC.	Programming Language	applet Java	SOAR Tcl/Tk and C, VRML	??	C++ and MS Game Developer's Kit	Java, JavaScript and Microsoft Agent for the character
	Operational System	-Agent: Any -Voice synthesizer : Windows	Virtual Training Environment VIVIDS	WWW servers and Modular Training System (MTS)	Windows and Framework for developing virtual agents in 3D	Windows (Microsoft Agent and the voice synthesizer are dependent of Windows platform)
INTERACTION	Character's Role	Female doctor	Man	Man	Robot	Young female
	Appearance	2-D, Bust	3-D, Bust	2-D, entire body	3-D, Bust	2-D, entire body
	Communication with the user	E: conventional (keyboard) S: voice text (video)	E: natural language, user's actions in the environment S: Voice, actions in the environment.	E: user's actions in the environment S: voice	E: user's actions in the environment S: Text	E: user's actions and menus S: Text and Voice (synthetic)
	Actions	Answer to: -Hints -How -Why	Simulate explanations with demonstrations. Monitoring the student.	Present audiovisual gestures. Explanations.	Explanations. Move and point out objects.	Explanations. Emotive behaviour related to student's emotions.
	Facial Expressions	Few	Looks at the student.	Varied repertory.	Varied repertory.	Varied repertory.
	Believability	Static and foreseeable behaviour. Few emotional facial expressions.	Good repertory of physical behaviour. Few emotional facial expressions.	Varied repertory of emotional physical behaviour.	Limited repertory of emotional physical behaviour.	Varied repertory of emotional physical behaviour.
AFFECT	Emotion's Recognition	No	No	No	No	Yes
	Affective Tactics	No	No	No	No	Yes

The programming language determines the portability, performance, as well as, audiovisual resources that can be used in the system. Among the cited agents, Adele is

the unique one that is portable, since it was developed in Java[12] and so can be executed in any web browser which supports Java. Steve was developed using the programming languages SOAR, Tcl/Tkl, C and VRML, and it executes in the virtual environment VIVIDS. Cosmo was developed for Windows platforms, since it has been implemented in C++ with MS Game Developer's Kit (see criteria Programming Language and Operational System). The Mediating Agent was developed in Java and JavaScript. The character was implemented in Microsoft agent and we use the Microsoft's voice synthesizer, which are dependent of the Windows platform. Although the Microsoft technologies are dependents of the operational system, we opted for these programs because they offer a package for developing animated agents easy to implement and with good aspects of interface and it is not the scope of this work the graphical implementation of the animated character. But we aim at, in future works, developing a flash version of the character which will turn the system independent of platform.

Besides, animated pedagogical agents, since they are represented by lifelike characters, must interact with objects in their environment through speech, locomotion and gesture in order to help the student with problems solving. These aspects were analysed in the criteria of interaction type. In relation to the character, all the agents have a visual identity which is suitable to the learning environment where they are inserted (see Character's Role criterion). Vincent and Mediating Agent are represented in entire body, while Adele, Steve and Cosmo are represented as bust. Although, a representation in entire body for these agents was not necessary, the bust representation is not believable, since it does not correspond to a real world representation (see Appearance criteria). The Mediating Agent has also a suitable appearance which was determined by interviews with pedagogues and psychologists in a master work (see Section 7.2 for more details).

Another important aspect in the interaction between student and pedagogical agent is the communication mode (see Communication with the user criterion). Steve is the only agent that recognises speech in natural language. The interaction with Adele is conventional and the user must choose one of the available pre-defined options. Cosmo catches the user's actions in the interface and has 240 speech elocutions. Steve can demonstrate tasks in the environment and also interact with the user through synthetic voice, as well as Adele and Vincent. Vincent is also able to interact with the user through emotive gestures and point out objects. Adele, Vincent and the Mediating Agent, beyond talking by synthetic voice, show messages in text that appear in a balloon. The student can interact with the Mediating Agent through menu options.

Steve presents a largest variety of physical behaviours. For example, Steve shows demonstrations and explanations about the simulations to be taught and revises incorrect user's actions in the simulation with demonstrations. Steve can also move and point out objects in the environment, as well as looking at the student while speaking with him (it can recognise the student's vision field by the information coming from the immersion equipment). Vincent has a set of audiovisual attitudes which expresses its feeling in relation to the user. Cosmo can also move in direction of the objects in the system. Vincent and Cosmo make explanations when the user does an incorrect action or invite the user to accomplish some exercise. Adele only answers the user to three available options of question: Hint, How, Why (see Actions criterion). The Mediating Agent has a large repertory of emotive behaviours and speeches to interact with the user.

[12] Java is registered trademark of Sun Microsystems, Inc. http://java.sun.com

Another important aspect in the interaction with animated pedagogical agents is the facial expressions, since they afford greater realism to the character, and provide another type of feedback for the user's actions, such as, disapproval, approval and wait (EL-NASR et al., 1999a) (see Facial Expressions criterion). Adele has a small repertory of physical and facial gestures, and so it is somewhat static and limited. Steve has few facial expressions, but it has good head motions. Vincent has a substantial set of facial expressions which are integrated to its audiovisual behaviour. Cosmo has also few facial expressions. The Mediating Agent has a great repertory of facial expressions for representing different emotional attitudes.

Animated pedagogical agents must also be believable[13] (see Believability criterion). It means that the user involves in such a way with them that he believes that the character is real. There are some actions that make the agent more real, such as the eyes motion, pause to speak, conscience of the body position and of the personal space, and communication in natural language. In relation to this aspect, Adele is somewhat static and its behaviour is able to be predicted. Steve presents good corporal conscience, but does not have emotional facial expressions. Vincent has a good repertory of emotive audiovisual attitudes, but they are few and presented repeatedly, which results in not so real behaviour. Cosmo does not have a great repertory of facial expressions, but have varied gestures and capacity of locomotion in the environment. The Mediating Agent has a largest repertory of behaviour for explaining, assisting the student, showing expression of emotion and salute the student. Besides, the Mediating Agent has an algorithm responsible for choosing not repeated behaviours (see Section 7.4).

Another important aspect is to handle the student's affectivity, which is the subject of this work (see Emotion's Recognitions and Affective Tactics criteria). In order to respond appropriately, the agent should infer student's emotions. No agent presented in this section, besides the Mediating Agent, infers student's affectivity[14]. The Mediating Agent recognises the student's emotions joy/distress, satisfaction/disappointment, gratitude/anger, and shame. Besides, a friendly machine should show a positive attitude towards the user. As de Rosis asserts (CARBERRY et al., 2002), we expect that our computer is "sorry for us" if we make a mistake, and "happy for us", if we succeed in a difficult task. For similar reasons, we expect that our computer "knows" what it is able to do and pretends to be able afford any difficult related to the tasks we are asking it to perform. The agents presented in this section did not present affective tactics (actions that aims to adapt the system to student's emotions). The emotive behaviours presented by Vincent have only the goal of the character seems more real (believable) to the user, but, at the same time it has few emotional behaviours to be sufficient believable. Besides, Vincent shows emotive behaviours that do not take into consideration the student's emotions. For example, it shows a sad behaviour when the student fails in a task, but this behaviour can let the student more anxious or depressed if he is already depressed with his performance. In this way, the Mediating Agent infers the student emotions in order to choose the emotive behaviours that are showed that aims at providing an emotional support to the student.

[13] See Section 2.5.6 for more details about believability.

[14] There are other animated pedagogical agents which handle student's affectivity. As they are more related to the Affectivity in Intelligent Educational Systems subject, we opted for presenting them in that section (see Section 4.8).

3 PEDAGOGICAL AGENTS MODELLED THROUGH A BDI APPROACH

Different approaches have been used by researchers to model pedagogical agents. The mentalistic approach has been adopted by GIA group (Group of Artificial Intelligence of UFRGS) as shows the works of Giraffa (1999), Bercht (see Section 3.3) and Andrade (see Section 5.3.2).

The mentalistic approach[15] describes an agent as an intentional system, i.e., having certain mental attitudes that are attributed to human beings, like "believe", "need", "desire", etc. This way, it is necessary to define which mental states are more appropriate. Following this approach, Bratman (1990) proposed the BDI (Belief, Desire, Intention) model which is based on belief, desire and intention mental states.

Georgeff and colleagues (1999) state that the BDI is mainly appropriate when the system is embedded in a changing world with access to partial information as, for example, educational environments. The beliefs are a way of representing the states of world where the information is dynamic and when the system has a local view of the world.

According to Móra (1999), mental states, as abstractions, present some advantages such as:

- They have a strong conceptual appeal because they are intuitive: we all have an intuitive understanding of what belief, desire and intention are (WOOLDRIDGE, 1999).
- This way, they are also natural concepts to agent's designers which allow to model an agent with low complexity (GIRAFFA, 1999);
- They provide succinct descriptions about complex systems, and help to understand the behaviour of these systems;
- They also can be used by the agents to reason about themselves and about other agents.

Due to these advantages, in this thesis, we adopt the mentalistic approach to student modelling and diagnosis. More specifically, we are going to use the BDI model (X-BDI) proposed by Móra (MÓRA et al., 1998) for the specification and implementation of the Mind module of the agent proposed in this work, which is described in Section 7.1.

In the next section (3.1) we present a brief introduction to the BDI approach. In Section 3.2, we present the BDI model proposed by Móra and employed in this thesis:

[15] The term "mentalistic approach" have been used by the GIA to designate agents that are modeled through mental states, such as the BDI agent. The term was originate used in the works of Giraffa (GIRAFFA; MÓRA; VICCARI, 1998a) (GIRAFFA; MÓRA; VICCARI, 1998b) (GIRAFFA, 1999).

X-BDI. Finally, in Section 3.3, we present Bercht's thesis, an affective student model implemented with X-BDI.

3.1 The BDI Model

The BDI (Belief-Desire-Attention) model is based on the notion of mental states to describe the behaviour of a cognitive agent[16]. This notion was initially described by the works of Searle and Dennet (MÓRA et al., 1998). It was developed by the philosopher Michael Bratman (1990), which gave particular attention to the role of intentions in reasoning (WOOLDRIDGE, 1999).

The BDI approach views the system as a rational agent[17] having certain mental attitudes of belief, desire, intention, representing, respectively, the information, motivational and deliberative states of the agent (RAO; GEORGEFF, 1995). A rational agent has bounded resources, limited understanding and incomplete knowledge on what happens in the environment it lives in.

The *beliefs* represent the information about the state of the environment that is updated appropriately after each sensing action. The beliefs can be viewed as the informative component of the system state. In a tutor system, the information about the student (student model), possible strategies and behaviour of the agent are represented as beliefs.

The *desires* are the motivational state of the system. They have information about the objectives to be accomplished, i. e. what priorities or payoffs are associated with the various current objectives. The desires can be generated instantaneously or functionally, and thus not requiring any state representation. They represent a situation that the agent wants to achieve. The fact that the agent has a desire does not mean that the agent will do it. The agent carries out a deliberative process in which it confronts its desires and beliefs and chooses a set of desires that can be satisfied.

The *intention* is a desire that was chosen to be executed by a plan, because it can be carried out according to the agent's beliefs (because it is not rational that the agent carries out something that it does not believe). Plans are pre-compiled procedures that depend on a set of conditions for being applicable. The desires can be contradictory to each other, but the intentions can not (WOOLDRIDGE, 1999). The intentions represent the currently chosen course of action. The intentions are persistent. An agent will not give up on its intentions – they will persist, until the agent believes it has successfully achieved them, it believes it can not achieve them or because the purpose of the intention is no longer present.

A rational agent will perform actions that it intends to execute without any further reasoning, until it is forced to revise its own intentions due to changes in its beliefs or desires. This may happen because of new events or the failure or successful conclusion of existing ones.

In our tutorial system, the agent's strategies and behaviour are described as the agent's believes. The decision of what to do and when to do it are the desires and intentions of the agent. This way, a determined strategy (belief) of the agent is activated if a desire of the agent becomes an intention.

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[16] See Section 2.2 for more detail about cognitive agents.

[17] According to Russell and Norvig (1995), a rational agent "is one that does the right thing". They state that the right action is the one that will cause the agent to be most successful.

A general BDI architecture

The process of reasoning in a BDI agent is summarized in Figure 3.1.
A BDI agent has seven main components (WOOLDRIDGE, 1999):

- A set of current *beliefs*;
- A belief revision function, *(br f)*, which determines a set of beliefs based on a perceptual input and on the agent's current beliefs;
- An option generation function *(generate desires)*, which determines the agent's desires (options available to the agent) on the basis of the current beliefs and intentions;
- A set of current *desires,* representing possible course of actions to the agent;
- A function that determines the agent's intentions (*choose intentions*) on the basis of its current beliefs, desires and intentions;
- A set of current *intentions*;
- An *action* selection function *(execute action)*, which determines an action to perform on the basis of current intentions.

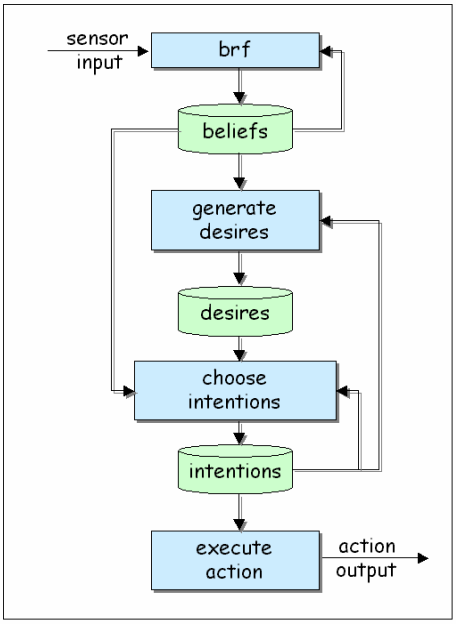


Figure 3.1: Schematic diagram of a generic belief-desire-intention architecture (WOOLDRIDGE, 1999)

A better understanding of this architecture can be obtained through the formalisation of its components. We present the formalization adopted by Weiss (WOOLDRIDGE, 1999).

Bel is the set of all possible beliefs, *Des* is the set of all possible desires, and *Int* is the set of all possible intentions. The state of a BDI agent at a given moment is a triple *(B, D, I)*, where $B \subseteq Bel$, $D \subseteq Des$, and $I \subseteq Int$.

The agent's believe revision function is a mapping that, on basis of the current percept and current beliefs, determines a new set of believes:

$$brf : \gamma(Bel) \times P \rightarrow \gamma(Bel)$$

where γ represents a set of mental states.

The 'option generation function' (*generate desires*) maps a set of intentions and a set of beliefs to a set of desires.

generate desires: γ(Bel) x γ(Int) → γ(Des)

In order for the agent to achieve an intention *x*, it is necessary that it generates options to achieve *x*, it means, it must deliberate about *how* to achieve this intention. This function generates new desires, each time more concrete, until the agent achieves the intention *x*. It is a recursive function, which elaborates a hierarchical plan structure, considering and committing to progressively more specific intentions that correspond to immediately executable actions (WOOLDRIDGE, 1999).

The deliberation process, which generates the intentions (for deciding *what* the agent must do), is represented by the function:

choose intentions: γ(Bel) x γ(Des) x γ(Int) → γ(Int)

This function is responsible for (1) dropping any intention that is no longer achievable, (2) retaining those intentions that are not achieved, but that can have a positive benefit, and (3) adopting new intentions, both to achieve existing intentions and to exploit new opportunities.

To determine which intention is going to be executed first, Wooldridge (1999) proposes two solutions. First, we can associate a priority with each intention, indicating its relative importance. The other idea is a stack, where the more concrete intention is at the top, and the more abstract one is at the bottom. The first solution is adopted by the X-BDI, the tool used in this thesis for implementation and which is described in the next section.

Finally, the *execute action* function is represented by:

execute action: γ(Int) → A.

In the next section, we present the BDI model (X-BDI) used in this thesis.

3.2 X-BDI: The Logical Model Employed in this Thesis

X-BDI (eXecutable BDI) is a BDI agent's model proposed by Móra (MÓRA et al., 1998) (MÓRA, 1999). The model can be also used as a tool for specification of BDI agents like the current formal models, as an environment for implementation and execution of agents. This way, it is not only an agent specification, but it may also be executed in order to verify the agent behaviour.

In order to reduce the distance between BDI agent's models and their implementation, instead of defining a new BDI logic or choosing an existing one and extending it with an operational model, Móra defines the notions of belief, desires and intentions using a logic formalism that is both well-defined and computational: *extended logic programming with explicit negation* (ELP) with the *well-founded semantics extended for explicit negation* (WFSX). ELP with WFSX extends normal logical programs with a second negation named explicit[18] negation. According to Móra (MÓRA et al., 1998), this extension allows to explicitly represent negative information (for example, a belief that a property *P* does not hold) and increases the expressive power of the language.

In the next sections, we describe the X-BDI model as also the X-BDI tool. We believe that these concepts are sufficient for the reader to understand the implementation in X-BDI of this thesis, which is presented in section 7.1. More details

[18] This is different of negation as failure or negation by default of normal logic programs (MÓRA et al., 1998).

about the X-BDI and the formalisms used to define the X-BDI model can be found in (MÓRA et al., 1998) (MÓRA, 1999).

3.2.1 The X-BDI Agent Model

Móra's model (MÓRA et al., 1998) does not define a complete agent, but only a cognitive structure that is part of the agent model, which is also called "Cognitive Kernel" (GIRAFFA, 1999). An agent cognitive structure Ag is a tuple $\langle \mathcal{B}, \mathcal{D}, \mathcal{I}, \mathcal{TA}_w \rangle$ where:

- $\mathcal{B}$ is the set of agent's beliefs;
- $\mathcal{D}$ is the set of agent's desires;
- $\mathcal{I}$ is the set of agent's intentions;
- $\mathcal{TA}_w$ is the set of time axioms.

This cognitive structure contains both the mental states that compose the agent and the rules that govern the interaction of these mental states. The concepts of beliefs, desires and intentions are explained in Section 3.1.

In X-BDI, when designing an agent, we specify only the agent's beliefs and desires. The agent chooses its intentions from its desires and as a refinement from other intentions.

As said before, there are no constraints on the agent's desires and, so, an agent may have conflicting desires. But intentions can not be contradictory, since it is not rational for an agent to act in order to achieve incompatible states. Further, its intentions should also be supported by the agent's beliefs, because it is not rational that an agent intents something that it does not believe. Once an intention is adopted, the agent will pursue that intention, planning actions to accomplish it, re-planning when a failure occurs, and so on. These actions must also be adopted as intentions by agents. Thus, agents must select only desires (possible intentions) that also respect those constraints.

The agent starts by choosing those desires that are eligible to be chosen. The eligible desires are those that agent believes are not satisfied, since it is not rational for an agent to intend something it believes is already achieved or that is impossible. These eligible desires may also be contradictory. Therefore, it is necessary to determine those subsets of desires that are jointly achievable. They can be more than one. And it is necessary to define which subsets are preferred to be adopted as intentions. So, the agent chooses firstly those most important desires and the agent adopts as much desires as possible. This choice is made based on preference relation defined in the desire's attributes.

Once the agent adopts its intentions, it will start planning to achieve those intentions. During planning, the agent refines its intentions, i.e., it forms new intentions that are relative to the pre-existing intentions. Since the agent commits to the adopted intentions, these previously adopted intentions constrain the adoption of new ones. In this case, during the elaboration of plans, a potential new intention is only adopted if it is not contradictory with the existing intentions and beliefs.

The agent also needs to revise its intentions in order to define new intentions or to find inconsistence among intentions and new beliefs and desires. It could revise its intentions when it believes that an intention has been satisfied or that it is no longer possible to satisfy it. But it imposes a significant additional burden on the agent, since it needs to verify its beliefs constantly. This way, in the X-BDI model (MÓRA et al., 1998), the approach adopted is to determine constraints over agent's beliefs. An agent always must maintain its beliefs consistent, whenever new facts are incorporated. The

same way, whenever a contradiction arises, the agent revises its beliefs. The agent revises its intentions when one of the constraints is violated.

In this section, we described the X-BDI model. In the next section, we present the X-BDI tool. The goal is to describe how to specify and implement an agent, from a user's point of view, using X-BDI.

3.2.2 X-BDI Tool

X-BDI is a tool for the implementation of an agent's cognitive module. In the case of this thesis it is used for the implementation of the Mind module of the Mediating Agent (the intelligent module of its architecture). Other modules of an agent (such as sensors, effectors and interface) should be implemented using other programming languages. The X-BDI should communicate with other languages, so that the cognitive module of the agent may exchange information with those other modules. This communication is made through *sockets*[19] (ZAMBERLAM et al., 2001). Figure 3.2 shows the interaction of the X-BDI cognitive kernel with other modules of the agent.

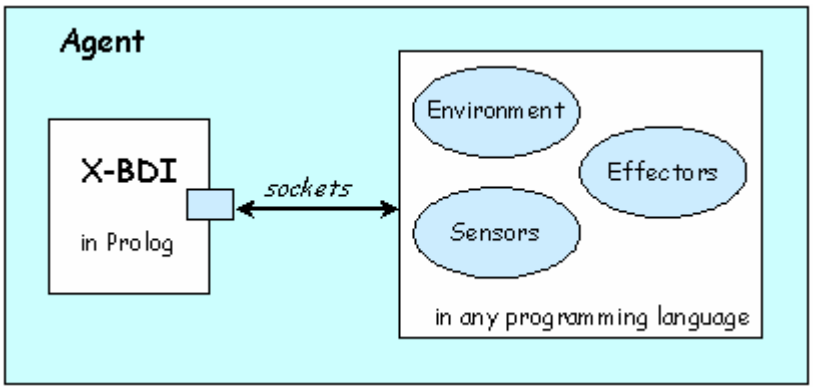


Figure 3.2: Interaction of X-BDI with other modules of the agent
(ZAMBERLAM et al., 2001)

The beliefs (including actions) and desires must be specified in a file called **bdi.a**, which is loaded when the X-BDI begins its execution. As we said in the previous section, the designer does not need to specify the agent's intentions, since the agent chooses its intentions through its desires. In the beginning of this file, the designer identifies the agent using the predicate *identity*(Agent_Name).

X-BDI presents two modes of execution:

- **Normal**: X-BDI uses a *socket* connection to send plans to be executed and to receive information perceived in the environment.
- **Choreography**: X-BDI reads the information of the environment from a file called **coreografia.a** and the plans are generated in the system interface. The environment's information is described in the file as follows:

[sense (property,time), sense (property,time), …]

19 A socket is one endpoint of a two-way communication link between two programs running on the network. A socket is bound to a port number in order to identify the application that data is destined to be sent (SUN, 2003).

The bdi.a file

As we said previously, the file **bdi.a** contains the beliefs and desires of the agent that should be described using the following predicates (ZAMBERLAM et al., 2001):

An **action** must be represented by the predicate *act*:

act *(ag, action)* ***causes*** *effect* ***if*** *condition*

where the attribute *ag* (agent's identification is optional). An action is composed of pre-conditions and pos-conditions. Pos-conditions represent the effects and consequences of an action and are represented by *effect*. The *condition* is a condition necessary to define a state or execute an action. The pre and pos-conditions can be expressed through the mental states of beliefs and desires.

Beliefs are represented by the predicate *bel* as follows:

bel (ag, p, t).

It means that the agent *ag* believes in a property *p* at a time *t*. The attribute ag e *t* are optional. If the attribute ag is not provided, it assumes that it is related to the described agent. If the attribute *t* is omitted, it assumes the current time.

Desires are described by the predicate *des*:

des (ag, p, t, prio).

It means that the agent *ag* desires the property *p* with the priority *prio* in the time *t*. Like in bel, the attributes *ag* and *t* area optional. The attribute *prio* is optional, but if specified it should have a value between zero and one.

The **current time** is specified by the predicate:

current_time(t).

In the next section (Section 3.3) we describe Bercht's thesis, which proposed an affective student model based on mental states. Bercht also used the X-BDI tool, which is also in this thesis, for the implementation of an affective model.

3.3 Bercht's Thesis: Towards Pedagogical Agents with Affective Dimensions

Bercht (2001) proposes an affective student model implemented using a BDI approach. The student model is implemented as the tutor's beliefs about the student and they are stored in the module of internal representation that the agent has for each student. The student is represented by 2 schemes: **affective and intellectual dimensions**. The intellectual scheme contains the student's information about the domain: his correct and wrong responses, the subject that he knows well or he needs to develop better. The other scheme contains information about the affective characteristics of the student.

The Bercht's (2001) affective model identifies the student's motivation by the behavioural factors[20] **effort, confidence and independence** perceived during an interaction with the tutor and student. The recognition of student's motivation by these factors is based on del Soldato and de Boulay's work (1995).

The **confidence** is represented as a value that can vary from 0 (minimal value) to 10 (maximal value). In the beginning of the session the student receives value 5 for this factor. The confidence value is updated through increments and decrements of 1 or 2

[20] The behavioural factors (such as effort, confidence and independence) are not affective states. They are only indices that allow the agent to infer the student's motivational state.

points. The value that represents the student confidence is updated according to the rules described in Table 3.1.

Table 3.1: The Confidence Model (BERCHT, 2001)

Situation	Help State	Confidence
No tentative	Ask for assistance	-1
Succeed	With assistance	+1
Succeed	Without assistance	+2
Failure	Without assistance	-1
Failure	With assistance	-2

Table 3.2 shows a model to classify the **effort** of a student in function of his persistence in the resolution of problems and help assistance to solve an exercise. The effort factor presents the following levels: absence, minimal, small, medium, big, and maximal. The initial attribution is medium that has value 3. The student effort is evaluated by the number of attempts to resolve an exercise, or by the number of steps made. A great number of steps means a high degree of effort by the student. Another important condition is if the student asked for help. If the student asks for help after little steps, it means that he made little effort to carry out the exercise, in opposition to the students that continue to look for a solution for the task without the help of the tutor agent. Another indication to measure the effort is the result of the task. If the student did not try to carry out the task, this demonstrates a low persistence.

Table 3.2: The Effort Model (BERCHT, 2001)

Task State	Steps	Assistance	Effort
Desisted	No	-	No
Desisted	Few	With assistance	Minimal
Desisted	Few	Without assistance	Little
Made	Few	With assistance	Little
Made	Few	Without assistance	Medium
Desisted	Many	With assistance	Medium
Desisted	Many	Without assistance	Big
Made	Many	With assistance	Big
Made	Many	Without assistance	Maximal

The independence model is described in Table 3.3. It considers four basic situations: the agent tutor offers a help to the student, the tutor offers a generic help, the tutor offers a specific help, and the student rejects the tutor's help.

These three factors (effort, confidence, independence) comprise the student's motivation model. But the student's motivation can vary during an interaction in a session of learning affected by causes like "disliking" the background of the lesson; by the way the tutor is conducting the dialog with the student or any different cause. The affective state **displeased** has an important role in student's motivation because it can lead to a negative mood and determines a decrease on student's motivation (CONATI; ZHOU, 2002). So, this work improves the affective model by predicting the affective student's state **displeased** by the appraisal made by the student according to OCC model (ORTONY; CLORE; COLLINS, 1988) (see Section 4.6 for more details).

The student's affective state and motivation are caught by the student's observable behaviour during a session with the system. The student's action is monitored and his behaviour upon the interface components is translated by a group of perception agents

(in the test environment Eletrotutor III) in a set of propositions (written in BDI sentences) sent to construct the user model. Indeed, the student's affective state "displeased" was adopted to be evaluated according to the OCC theory. The affective student model and the affective diagnosis were implemented in BDI using the system for modelling and developing BDI agents: X-BDI (MÓRA et al., 1998).

Table 3.3: The Independence Model (BERCHT, 2001)

Help State	Help Type	Independence
Suggested	-	-1
Made	Generic	-1
Made	Specific	-2
Not used	-	+1
Denied	-	+1
Rejected	-	+2

Bercht tested her ideas and hypothesis using Eletrotutor III (SILVEIRA; VICCARI, 1999), an educational environment implemented in the Jade Environment (SILVEIRA; VICCARI, 2002). Eletrotutor III tutor is an implemented and finalized thesis work of Ricardo Silveira at GIA/UFRGS. The subject matter covered by the system is about Physics - Electricity (Ohm's Law and its applications).

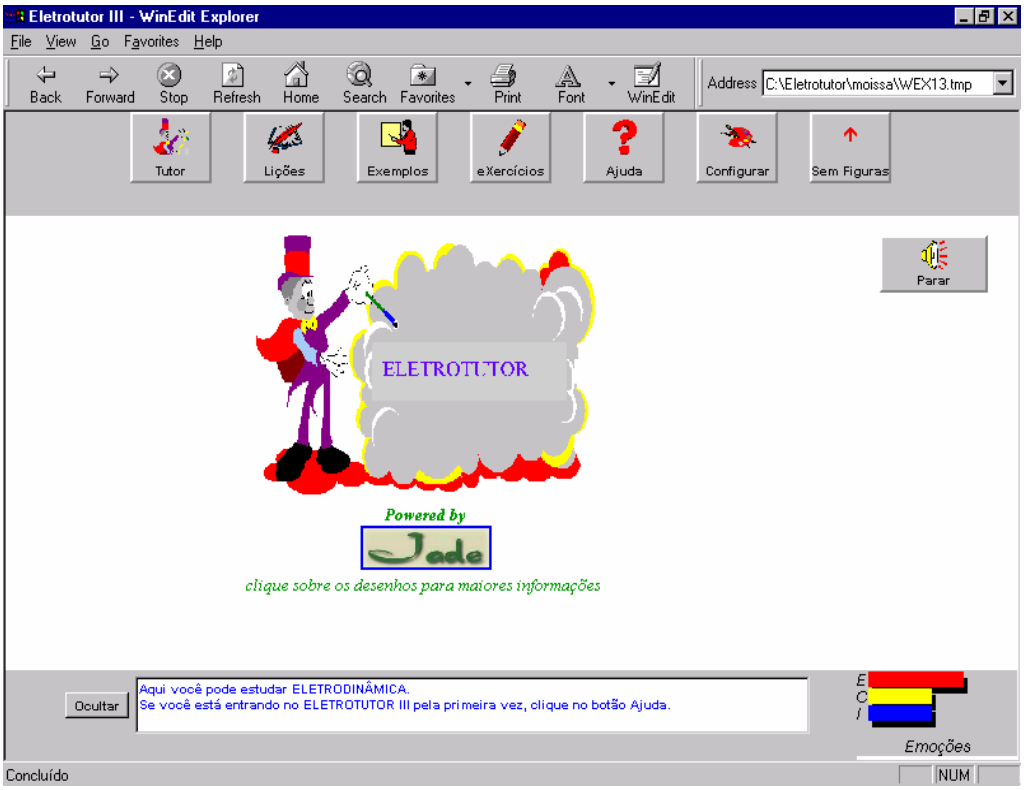


Figure 3.3: Eletrotutor's Interface Improved with Learner's Affective Modelling (BERCHT, 2001)

In Figure 3.3 we can see Eletrotutor's interface. In the lower edge of the right side we can see the degree of the factors effort (e), confidence (c), and independence (i) of the student that were detected by the agent.

3.4 Conclusion of the Chapter

Giraffa's thesis (GIRAFFA, 1999) (GIRAFFA; VICCARI, 1998b) (GIRAFFA; VICCARI, 1998c) (GIRAFFA; VICCARI; SELF, 1998) (GIRAFFA; MÓRA; VICCARI, 1998a) (GIRAFFA; MÓRA; VICCARI, 1998b) (GIRAFFA; MÓRA; VICCARI, 1999a) was the first initiative of our research group in using the mentalistic approach for implementing educational systems. The Giraffa's work presents a game (MCOE - Multi-agent *Co-operative Environment*) that simulates a lake with different vegetation and different kind of fish. It has a multi-agent architecture, composed of a society of two kinds of agents: reactive (designed and implemented using the object-oriented approach) and cognitive (designed with the mental states approach). The tutor agent and the students are modelled using a mental state approach, more specifically as BDI agents. The model of each student and the tutor contain a set of basic beliefs, desires, intentions and expectations. From this set emerges the dynamic selection done by the Tutor in order to select a cognitive teaching strategy for each student. MCOE environment demonstrates that the use of BDI mentalistic approach for pedagogical agents modelling is a powerful tool, because most of the programmer's work is to describe the set of mental states associated to each cognitive agent. It is not necessary to re-implement the tutor, but only add new mental states to the tutor agent. Besides, the mentalistic approach allows us to trace the dynamics of the interaction between student and tutor. This information about the student can be used by the tutor to improve its behaviour (Giraffa, 1999).

Another important advantage in a student model based on mental states is that it provides a more qualitative description about the student. In great part of learners' model works, the student is modelled in a quantitative way (PAIVA, 1996), in other words, through student's performance or a balance between an ideal model and the student. In a BDI model the tutor has a dynamic and descriptive model about the student which allows to compare the student with himself (Giraffa, 1999).

MCOE was the first work of the group in using the BDI approach to implement Intelligent Tutoring System. But, as MCOE explores just the cognitive states of the student, while we are interested in the affective ones, we presented here just a brief description of MCOE. More details about this ITS can be found in (GIRAFFA; VICCARI, 1998b), (GIRAFFA; VICCARI, 1998c), (GIRAFFA; VICCARI; SELF, 1998), (GIRAFFA; MÓRA; VICCARI, 1998a), (GIRAFFA; MÓRA; VICCARI, 1998b), (GIRAFFA, 1999), and (GIRAFFA; MÓRA; VICCARI, 1999a). Another work that follows the mentalistic approach to explore the cognitive states of the student is Andrade thesis. She proposes a diagnostic agent which is based on the notions of ZDP, mediation and support of Vygotsky's pedagogical theory. As this agent is part of the multi-agent architecture of MACES, it is described in Section 5.3.2, in the chapter where we describe MACES.

The group noticed that all these advantages of the BDI approach observed by Giraffa in a cognitive model of the student could also be useful and necessary for an affective model and an affective tutor. In this way, Bercht (2001) proposed an affective model also based in a mental state approach (described in Section 3.3). The Bercht's work infers the student's motivation from three factors (independence, effort, and confidence) and also infers the student's emotion "*displeased*" according to OCC model.

According to Bercht's (2001), an affective model must be enough dynamic to consider the changes in the emotional states. Since the motivation and the affectivity of the student may vary in a very dynamic way, the use of the BDI approach for the

implementation of the student's model is very convenient, because it allows frequent revisions and modifications of the information about the student.

Continuing works of the group in affectivity in ITS, we propose the use of animated pedagogical agents for applying tactics that aims to engage the student, to promote a positive mood in the student more appropriate to the learning and to give an emotional support to the student. In order to respond appropriately to the student, this agent has also an affective model of the student. The cognitive module of the agent and the affective model are implemented according to the BDI approach. A major difference of our work from Bercht's work, in using the BDI approach for affective modelling and diagnosis is to benefit from the reasoning capacity of the BDI for inferring student's emotions according to the cognitive approach of emotion. In our work, the agent infers the student's emotions from reasoning about the student's appraisal. The idea is – if a person can arrive in an emotional feeling through a cognitive evaluation (the appraisal), the agent can deduce the student's emotion through a reasoning which aims to deduce the appraisal made by the student through his behaviour. The affective modelling and diagnosis in BDI is discussed with more details in Section 7.1. Besides, we infer the emotions joy/distress, satisfaction/disappointment, gratitude/anger, and shame which were not considered in previous works of the group.

4 ABOUT EMOTIONS AND COMPUTING

Although emotions have been neglected for a long time in the situations that demand reasoning and cognition, including Education, some recent studies made by psychologists and neurologists show the importance of emotions in various intellectual capacities, such as solving problems and intelligence (DAMASIO, 1994) (GOLEMAN, 1995) (LEDOUX, 1996) (VAIL, 1994).

In the same way, researchers in Artificial Intelligence (AI) have considered emotions in modelling intelligent systems, emerging a new research area in computing known as *Affective Computing*. Rosalind Picard (PICARD, 1997) defines Affective Computing as "*computing that relates to, arises from or deliberately influences emotions*".

As our work is inserted in the Affective Computing area, we intend to provide in this chapter an overview of the research in this subject. In order to understand better these studies, we first present a definition about emotion and affectivity, and a summary about the psychology research on emotion. In Section 4.7, we present the current research in Affective Computing.

4.1 Affectivity and Emotion: Definitions

Although the term "emotion" is popularly used for many phenomena of affective order, we prefer to denominate these phenomena by the generic term "affective state" which can be seen as more wide-ranging and including beyond emotions, other states such as moods. Scherer (2000) classifies the affective states in five categories: emotion, mood, interpersonal stances, attitudes and personality traits.

Emotion: According to Scherer (2000), emotion is the episode relatively brief of synchronised responses for all or most organic systems to the evaluation of an external or internal event as being of major significance. Some emotion's examples are anger, sadness, joy, fear, shame, pride, and desperation. Ortony, Clore and Collins (1988) propose a similar but more precise definition for emotions. According to them, emotions are valenced reactions to events, agents, or objects, with their particular nature being determined by the way in which the eliciting situation is constructed. According to this definition, surprise is not an emotion, since it does not have a valence. For Dipert (1998) "the emotion is a feeling that has been caused by certain beliefs, that is directed towards a primarily conceptual and not perceptual target (typically a person or intentionally alterable circumstance), and that typically produces some physiological, behavioural, or cognitive effects". He considers that the emotion is an intentional mental state, because it is "directed toward" an object, its intentional object. For example: I am angry with Ralph, but I admire Elisabeth. Fridja (1994) also considers that emotions are intentional.

Mood: According to Scherer (2000), the mood is a diffuse affective state that consists in changes in the *subjective feeling*[21], of low intensity, but long duration without apparent cause. He mentions some examples of moods: cheerful, gloomy, irritable, listless, depressed, and buoyant. Dipert (1998) and Fridja (1994) consider that moods differ from emotions most strongly in not having an intentional object. Their causes are typically conceptual or evaluative (things are or are not going well).

Interpersonal stances: Scherer (2000) defines interpersonal stance as an affective stance taken in relation to another person in a specific interaction, colouring the interpersonal exchange in that situation. Distant, cold, warm, supportive and contemptuous are examples of interpersonal stances.

Attitudes: Attitudes are relatively tolerant, affectively coloured beliefs, preferences and predisposition in relation to objects or people (SCHERER, 2000). Examples of attitudes are liking, loving, hating, desiring and valuing.

Personality traits: Personality traits are emotionally laden, stable personality dispositions and behaviour tendencies, typical of a person (SCHERER, 2000). For example: nervous, anxious, reckless, morose, hostile, envious and jealous.

Table 4.1 shows the differences among the affective states defined by Scherer (2000) in relation to their intensity, duration, the degree of different organismic systems during the state, the extent to which the differentiated nature of the state is due to a process of antecedent evaluation or appraisal[22], the rapidity of change in the nature of the state, and the degree to which the state affects behaviour. In this table, the symbols indicate the degree in which a feature is present, where "*0*" represents the absence (the lowest) and "+++" is the highest degree.

Table 4.1: The Difference among the Affective States (SCHERER, 2000)

	Intensity	Duration	Synchronisation	Event Focus	Appraisal Elicitation	Rapidity of Change	Behavioural Impact
Emotions	++ → +++	+	+++	+++	+++	+++	+++
Mood	+→++	++	+	+	+	++	+
Interpersonal stances	+→++	+→++	+	++	+	+++	++
Attitudes	0→++	++→+++	0	0	+	0→+	+
Personality traits	0→+	+++	0	0	0	0	+

4.2 The Functions of Emotion

An important question relating to emotions is "*what are the emotions' functions*"? What is the emotions' role in our life?

Scherer (SCHERER, 1989) argues that the emotional processes are the intersection point between the milieu and the organism. The most important aspect of these processes is the evaluation of stimulus signification or milieu events in relation to

[21] Scherer defines subjective feeling as a reflection in the central nervous system of all the changes in the central and peripheral systems during an emotional episode. This process is not entirely conscientious; just a small part of the set of reflections becomes conscientious and a smaller set of reflections can be verbalised.

[22] An explication for this concept is presented in Section 4.5.

necessities, project or preferences of an organism in certain situations (in particular, in the learning process); the physiological and psychological preparation to specific action to react to the milieu stimulation; and the communication of an organism states and intentions to his social environment.

Adaptation of the organisms' behaviour to their milieus is due in great part to the emotional system. Emotions arouse the behavioural reaction and the stimulus reception. In the presence of stimulus, they substitute the more flexible behavioural modes to reaction and reflex models and to instinct mechanisms (SCHERER, 1989). The evolutionary psychology believes that it happens by the fact that humans have innate emotion circuits that reflect the survival situations confronted by prehistoric humans (CLORE; ORTONY, 1999). Perhaps the fear was elicited by the growls of predatory dogs or snakes; and the anger by having someone taken one's food. In the prehistory, individuals who have responded to these current situations with particular inclinations and feelings may have survived and passed on those tendencies.

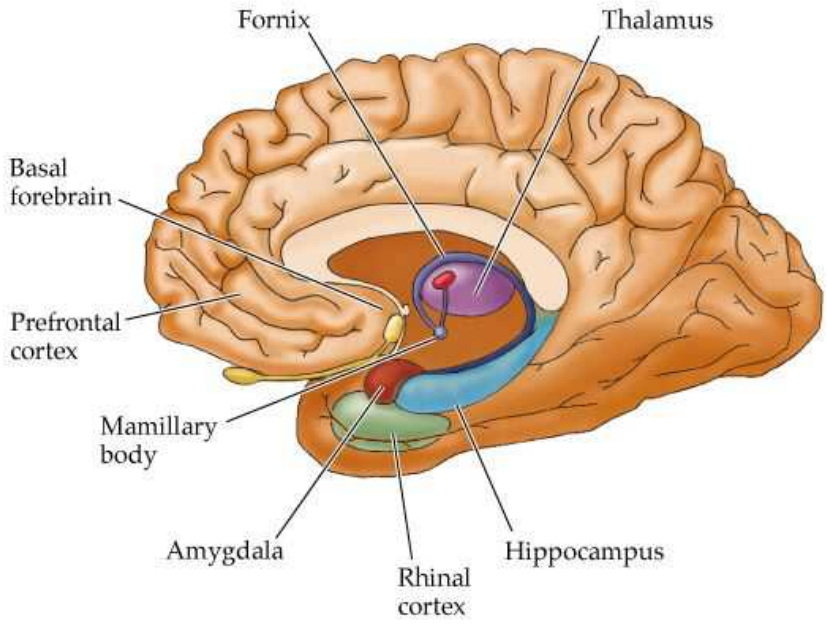


Figure 4.1: The Limbic System[23]

Ledoux (1996) has carried out experiments since 1970 with mice having the objective of determining the circuits in the brain responsible for emotions, mainly fear emotion. These studies pointed out the important role of the limbic systems for the emotion. The limbic system is a series of interconnected cerebral nucleus (neural nucleus) which have a central role in the regulation of the emotion and memory. There are two important limbic regions for the emotion: the hippocampus and the amygdale (see Figure 4.1). The scientists believe that the hippocampus has an important role in the formation and recuperation of verbal and emotional memory. The amygdale is related to the creation of emotional content of the memory, for example, feelings that have reference with fear and aggressive reactions.

In his studies, Ledoux (1996) conditioned the mice in an experience: when the animals heard a determined sound, they received an electric shock. The mice began to

[23] The Limbic System. Available at http://www.utdallas.edu/~tres/integ/hom3/display13_08.html.

show fear when they heard the sound. When the animals were already conditioned, he made new experiences where he played the sound again. In a first experience, he traced the route made by the auditory stimulus in the brain. To do this, he inserted an identifier substance in the brain that is absorbed by the neurones, colouring them. Afterwards, the brain was removed and it was divided in Sections. This experience showed that there are two routes: (1) a route from auditory canal to the amygdale; and (2) a route from auditory canal to cortex. When the communication with the amygdale was removed, mice did not show any reaction. They seemed to have lost their memory of the shock. Besides, another experiment with different sounds showed that lesions in the cortex prevent the differentiation of the sounds. This way, Ledoux observed that the amygdale route is faster, so it is responsible for a quick reaction. But as the amygdale has just the emotional memory, in this instant the individual has not conscience why he is afraid. Therefore the amygdale seems to be responsible for producing a quick reaction and the cortex for the analysis of the stimulus and of an adequate action. For example, let's suppose that we are in a forest and we hear a sound. The sound goes to the amygdale and at the same time to the cortex which defines that the sound is a branch that splits or a snake. But when the cortex concluded this, the amygdale is ready to react. Scientists believe that the hippocampus is responsible for storing all the context information, as sounds and images, but they do not know yet how the brain evaluates a situation and chooses an action to be done, which is an action and not a reaction. But some studies indicate that the pre-frontal cortex participates in this process. When a person presents a lesion in this part of the brain, he becomes incapable of taking a decision.

There seem to be two fingers on the emotional trigger; one controlled by early perceptual process that identify stimuli with emotional value and activate preparation for action (the amygdale); and a second controlled by cognitive processes that verify the stimulus, situate it in its context, and appraise its value (the cortex) (CLORE; ORTONY, 1999).

Scherer (1989) also states that the negative emotions signal the aversion or the pain and promote the reactions of avoidance, as long as the positive emotions constitute the signal to the success and the recompense.

4.3 Historical Root of Psychological Models of Emotions

According to Scherer (2000), to understand the current theories and research in emotion, it is necessary to understand the historical development of studies in emotion. This way, we present here a summary about the historical root of psychological models of emotions that is based on Scherer's paper (SCHERER, 2000).

One of the first studies about emotion was made by Plato in 430 BC approximately. Plato suggested that the soul is a structure with 3 parts: cognition, emotion and motivation. Fifty years after, Aristotle argued this division and suggested an interaction among the different components.

In 1600 approximately, Descartes insisted on the dualist vision that separates the mind from the brain and the body (DAMASIO, 1994). According to Descartes' conception, the rational soul, a distinct entity from the body, makes contact with the body through the pineal gland of the brain[24]. Descartes chose the pineal gland because it appeared to him to be the only organ in the brain that was not bilaterally duplicated and because he believed, erroneously, that it was uniquely human. Descartes laid the

[24] Available at http://serendip.brynmawr.edu/Mind/Descartes.html.

foundation of the body-mind debate about the relationships between mental and bodily phenomena. Just recently the theorists have attempted to link the antecedent evaluation of events (that it was determined by many philosophers as the nature of the emotion) to potentially stable patterns of adaptive responses in the central, peripheral and somatic nervous systems of the organism.

Darwin (1965) mainly studied the expression of emotions in the face, body and voice. In his studies about emotions, he evidenced that the emotional phenomena, particularly expression, can be met in different cultures. This study was the base of the current psychobiology of emotion that was very attacked by anthropologists and social psychologists. Nowadays, psychologists believe that the elicitation of the emotion and the emotional reaction are affected both by psycho-biological and cultural factors.

According to Willian James (1994), emotion is the perception of different corporal changes. However, James used the word emotion, which was related to the full process of emotion, to address just the reaction component, which caused some confusion. There is little evidence of the postulate of James, since there are different standards of responses for specific emotions. According to Ortony, Clore and Collins (1988), "the problem with concentrating on behaviour when considering the emotions is that the same behaviour can result from very different emotions (or even from no emotion at all), and that very different behaviours can result from the same emotion" (p. 11).

4.4 Current Psychological Models of Emotions

In this section, we present the current psychological models of emotions according to a classification made by Scherer (2000). Here, we adopt the term model as synonym of theory.

4.4.1 Dimensional Models

The Dimensional Model can be divided into two main categories: Unidimensional and Multidimensional Models. In the **Unidimensional Model**, the theorists believe that only one dimension is enough to make the important analytical distinctions between emotions. This dimension can be activation/arousal or valence, depending on the theoretician.

Previous theoreticians believed that the determinant factor of the emotion feeling was the pleasantness/unpleasantness dimension. In this approach, the most important principle for emotion differentiation is the valence which allows to differentiate the positive emotions of the negative ones.

The **multidimensional current** was strongly influenced by Wundt *apud* (SCHERER, 2000) that claimed that the nature of the emotional state is determined by its position in 3 independent dimensions: pleasantness/unpleasantness, activation and excitation.

The multidimensional models had been popularised by Plutchick (PLUTCHIK, 1980) and Russel (RUSSELL, 1991) that defined a scheme of 2 dimensions: valence and activation.

4.4.2 Discrete Models of Emotion

As discrete models of emotion, we can cite the circuit model and the model of basic emotions. The **circuit model** is based on a neuro-psychological approach that suggests that the number of basic emotions and their differentiation are determined by the

evolutionary development of the neural circuits. According to Panksepp (PANKSEPP, 1990) (PANKSEPP, 1994), there are 4 basic circuits or emotional systems which are expected to produce well organised behavioural sequences elicited by neural simulation: rage, fear, expectancy and panic. Each one of these systems produces very clear behavioural outputs and the interactions between these systems produce "second order emotive states".

Another very popular model is the **model of basic emotions**. The theorists that follow this model believe in the existence of a set of basic emotions as anger, fear, joy, sadness and disgust.

There are different criteria to classify an emotion as basic. Some theorists believe that, as Ekman (1994), during the course of the evolution, a number of major adaptive emotional strategies developed. These strategies consist of 7 to 14 basic emotions, each one with its own conditions of eliciting and its own specific physiological, expressive and behavioural patterns of reactions. Others base the idea of basic emotions on empirical evidence for the universality of verbal labels, facial expression patterns, and antecedent eliciting conditions.

Actually, this model has been receiving critics (ORTONY; CLORE; COOLINS, 1988) (AVERILL, 1994). According to these researchers, this model is vague. (ORTONY; CLORE; COOLINS, 1988) state that a major weakness of this model is in the manner that the basic emotions are supposed to be related to the other non-basic emotions, that is, the other emotions are a mixture of these pure basic emotions. There are some emotions that are unreasonable to say that they are compound of others. For example, the OCC model shows that reproach can not be seen as a compound emotion of anger, as the theory of basic emotions believes. Another difficulty is that there is no consensus about how to classify an emotion as basic. There are many approaches and confusion because there are many ways in which an emotion can be said to be basic. Averill (1994) cites some of them: emotions can be classified according to their prototypicality, i. e. on the basis of their resemblance to some prototype (the best exemplar); level of classification that can be class inclusion or part-whole; and principles of organization, where emotions are organized according to coherent systems of behaviour by their functions. According to Averill, to define the basic emotions, it is necessary to choose a criterion and if the psychologists want a general theory of emotion “they must transcend parochial allegiances. Basic emotions have no more place in psychology than basic animals in biology or basic diseases in medicine” (p. 14). Ortony, Clore and Collins also argue that there seems to be no objective way to decide which theorist’s set of basic emotions might be the right one.

4.4.3 Meaning Oriented Models

In the classification Meaning Oriented Model, there are the Lexical, Social Constructivist and Componential Models. In the **Lexical Model**, the idea is that the language allows the theoreticians to discover the structure of the psychological phenomena. It is arguable how the lexicon of the emotion in a language in particular can be mapped in psychophysiological processes that are largely unconscious.

For the **Social Constructivist Models**, the meaning of the emotion is constituted or constructed by socioculturally determined behaviour and value patterns. The theoreticians of this area do not deny the existence of the psycho-biological reaction component of emotion, but they think that this has a secondary role. They believe that the meaning conferred by the sociocultural context in relation to the interpretation of the

elicitation situation and the role of the emotion reaction in the person's sense-making and social interaction have more central role for the emotion.

The theoreticians that follow this model are also interested in the Lexical Model because they believe that emotion labels in a language reflect the structures of emotional meaning in the respective culture.

For the **Componential Model**, the emotions are elicited by a cognitive evaluation of antecedent situations and events; and the patterning of the reactions in the different responses domains (physiology, expression, trends of action and sensations) is determined by the outcome of this evaluation process.

The cognitive psychologists are interested in the cognitive evaluation of antecedent situations and events that elicit emotions, it means, the cognitive component of the emotion. According to Clore and Ortony (1999), the emotions in human beings are characterised by the presence of 4 main components: a cognitive component, a component of motivational- behavioural, a somatic component and a subjective-experiential component. The **cognitive component** is the representation of the emotional meaning or the personal significance of some emotionally relevant aspect in the perceived world of the person. The **motivational-behavioural component** is concerned with inclinations of an individual to act on the construal (interpretation) of the world that these representations represent and their relation to what is actually done. The **somatic component** involves the activation of the autonomic and central nervous systems with their effect in the body. The **subjective-experimental** component is responsible for the part of "subjective feeling" and, therefore, it is more elaborated in human beings that look to label the emotions that they are feeling.

It is the union of these components that compound the emotion. For example, the anger can not be identified as any one component in this classification. According to Dipert (1998), it is not correct to point toward the "feeling" of anger and say that this is the anger. The feeling alone does not include the distinctive intentional of anger, or its precise object, and it does not include the means by which this feelings were produced, namely the normative beliefs about wrong-doing, that are constitutive of anger.

According to Scherer (2000), a frequently encountered source of confusion relates to tendency, based on popular usage of terms, to treat *feeling* and *emotion* as synonyms. This is some confusion between the phenomena of emotion as a whole, consisting of several components cited above, and an individual component: in this case, the subjective-experimental component responsible for the subjective feeling.

The current focus of the psychological emotion research is the cognitive component of the emotion, mainly, the elicitation of the emotion through antecedent evaluation. This approach has been influencing several works in affective computing. The cognitive approach of emotion is presented in Section 4.5.

4.5 The Cognitive Approach of Emotion

The cognition theoreticians of emotion mainly focus their studies on the cognitive component of the emotion (see Componential Model in Section 4.4.3), or either, in the process of "appraisal". The idea is that emotions depend on the meaning perceived of the situations and appraisal is the evaluation of value or the emotional meaning for the situation (CLORE; ORTONY, 1999). According to Scherer (1999), the central idea of the appraisal theory is that "the emotions are elicited and differentiated on the basis of a person's subjective evaluation or appraisal of the personal significance of a situation, event or object on a number of dimensions or criteria". Emotions require cognitive

processes to generate or to retrieve preferences or meaning. They are activated by an individual's interpretations in relation to the happy or irritating aspects of an event, i.e., it is the appraisal that elicits the emotions.

Studies that measured emotion's intensity in relation to the appreciation showed that the emotion intensity varies in relation to the cognitive appreciation (FRIJDA, 1989). The emotion's intensity vary in accordance with the pertinence degree and the personal significance of an event, with its visible and controllable aspect and with the threatening or neutral manner which the sensations or events are encoded. For example, the apathy is the result of the perception of impossibility in controlling the disagreeable events (SELIGMAN *apud* FRIJDA, 1989). The depression has a relation to the auto-critic judgement and to the impotence feeling. The procedures to modify these beliefs seem to alleviate the depressive patients.

The emotions are elicited by cognition and, at the same time, they are constituted by cognition. The emotional experience is composed of cognition, i. e. by an individual's perceptions of the events that affect him (FRIJDA, 1989). The different types of cognition generate different types of emotional experience; and our cognition, our perception, are part of the indications that allow us to label our experiences, as anger, fear, and happiness. According to Frijda (1989), these two functions of cognition in emotion are complementary. Anger can be born when we observe that a person wants to damage us; but the anger feeling is a conscience of the spite of another person. In the first case, the cognition is related to the interpretation of the events; in the last case, the cognition is related to conscience. Clore and Ortony (1999) state that the emotion is constituted of cognitive event, but this does not mean that it is a cognitive process. Or either, not all cognitions are emotions (FRIJDA, 1989), because cognition is just one of the components of emotions, as explained in Section 4.4.3.

According to Clore and Ortony (1999), emotions, besides demanding cognitive appraisal, are always **related to an object**, as also pointed by Dipert (1998) and Scherer (2000). Thus, fear is an affective state that is an emotion because it is related to an object (the object of fear). The anxiety, in turn, is not an emotion, because it is an affective state without an object. Thus, according to these authors, the cognitive theory of emotion does not need to worry about other affective states, mainly those that precede cognition.

There are two routes for emotional appraisal: bottom-up and top-down (CLORE; ORTONY, 1999). In the bottom-up route, the appraisal is carried out congregating interpretations of data of the perceived world. People are constantly evaluating situations in accordance with the personal relevance, or either, if they are good or bad. The emotions described in the OCC model (Section 4.6) are examples of emotions that follow the bottom-up model. The bottom-up model is related to the cortex route of the emotion that LeDoux (1996) described in his experiences (see Section 4.2 for more details about LeDoux experiences).

In the top-down route, instead of having an online evaluation of the current situation, it is carried out a reintegration of an analysis carried out a priori. For example, a case of a veteran of the Vietnam War that was in panic working in the garden of his house because he met the same surrounding of traumatic situations as in the Vietnam War. In this case, there is an unconscious evaluation of the object that generates the emotional reaction, which generates a fast and immediate reactive response. We can see that the top-down model is the amygdale route that was studied by LeDoux (1996) in his experiences with mice (see Section 4.2).

Clore and Ortony (1999) suggest that these two routes of activation of the emotion can have different functions: fast action (in the case of the top-down route) and flexibility of action (in the case of the bottom-up route).

Picard (1995) classifies the emotions in cognitively generated emotions and non-cognitively generated emotions that follow the classification of Damasio (1994). The cognitively generated emotions are not the emotions classified as primary for Damasio. The primary emotions are those that generate first an emotional response and then activate a set of emotions and they reside in amygdale. An example of primary emotion is the fear of a person when seeing an object that seems a snake. The primary emotions defined by Damasio are the emotions activated for the route top-down proposed by Clore and Ortony. According to Clore and Ortony, there is a process of identification of the object that is cognitive, but that happens before the cortex. Therefore, the person does not have conscience of this process (processes that occur before cortex can be unconscious), but for the authors the detection of significance (unconscious identification of a snake) is already a cognitive process. The secondary emotions, according to Damasio (1994), are those that involve a physiological response in conjunction with a cognitive understanding of an object. In this second case, there is conscience, like the bottom-up generated emotions proposed by Clore e Ortony.

4.6 The OCC Model

Ortony, Clore and Collins (1988) constructed a cognitive theory of emotion that explains the origins of emotions by describing the cognitive processes that elicit them. For example, the hope feeling appears when a person develops an expectation that some good event will happen in the future. This theory results in a psychology model which explains the origins of 22 emotion types. This model is called **OCC model** due to the initial letters of the authors' name.

In accordance with the cognitive theory of emotion (as we explained in the begin of this section), emotions appear as a result of an evaluation process called *appraisal*. The OCC model assumes that the emotions can arise by the evaluation of three aspects of the world: *events*, *agents*, or *objects*. Events are the way that people perceive things that happen. Agents can be people, biological animals, inanimate objects[25] or abstractions, as institutions. Objects are objects viewed *qua* objects. There are three kinds of value structures underlying perceptions of goodness and badness: *goals*, *standards*, and *attitudes*. The *events* are evaluated in terms of their desirability, if they promote or thwart one's *goals* and preferences. *Standards* are used to evaluate *actions* of an agent. The actions of an agent are evaluated according to their obedience to social, moral, or behavioural standards or norms. Finally, the *objects* are evaluated as appealing depending on the compatibility of their attributes with one's tastes and *attitudes*. The OCC model is illustrated in Figure 4.2.

The elicitation of an emotion depends on a person's perception of the world – his *construal*. If an emotion such as distress is a reaction to some undesirable event, the event must be construed as undesirable. For example, when one observes the reactions of players at the outcome of an important game, it is clear that those on the winning

[25] In the OCC model, an object can be viewed as an inanimate object or an agent. For example, a person who buys a car that shows many problems might blame the car for its misfortunes. In doing this, he would be treating the car as an agent, rather then as an object. In treating as an agent, he would disapprove; in treating as an object, he would dislike.

team are elated while those on the losing team are devastated. In a real sense, both the winners and losers are reacting to the same objective event. It is their *construals* of the event that are different. The winners construe it as desirable, while the others construe it as undesirable and it is these construals that drive the emotion system. The emotions are very real and very intense, but they still issue from cognitive interpretations imposed on external reality, rather than directly from reality itself. This is the cognitive basis for emotions (ORTONY; CLORE; COLLINS, 1988).

Besides, the emotions are valenced affective reactions, it means that all emotions involve some sort of positive or negative reaction to something or another. So, surprise is not an emotion because it can arise in the absence of a valenced reaction.

A central idea of the model is the type of emotion. An emotion type is a distinct kind of emotion that can be realised in a variety of recognisably related forms and which are differentiated by their intensity. For example, fear is an emotion type that can be manifested in varying degrees of intensity, such as "concern" (less afraid), "frightened", and "petrified" (more afraid). The use of emotion type has the goal of being language-neutral so that the theory is universal, independent of culture. Instead of defining an emotion by using English words (the author's language), the emotions are characterized by their eliciting conditions.

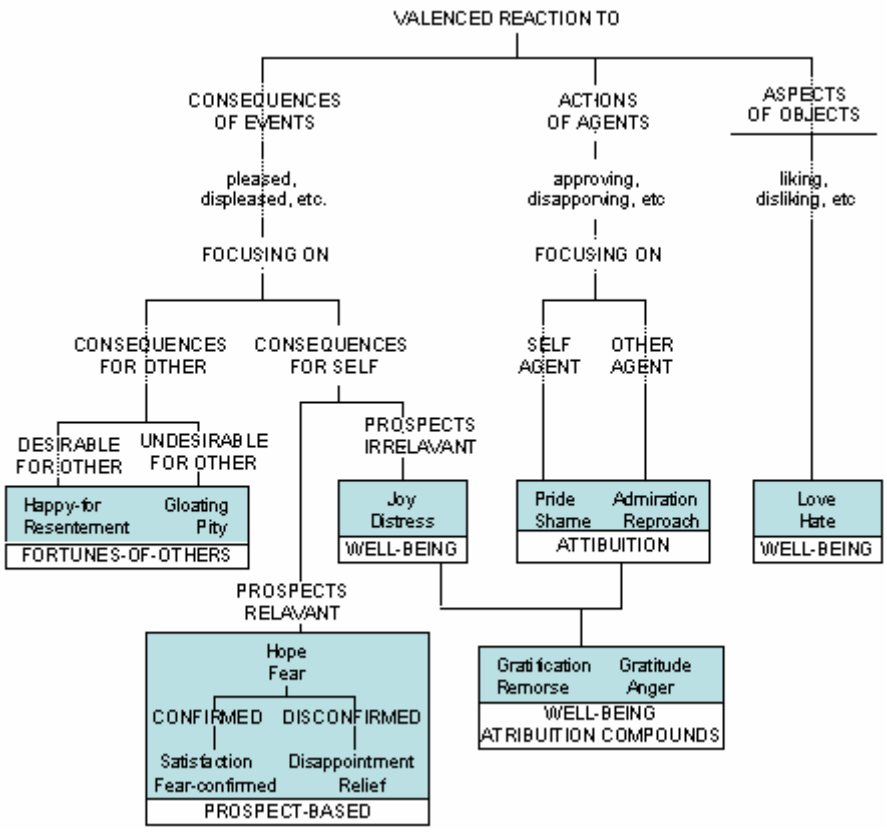


Figure 4.2: Global Structure of Emotion Types - OCC Model
(ORTONY; CLORE; COLLINS, 1988)

Besides, the emotions are grouped according to their eliciting conditions. For example, the "attribution group" (see Figure 4.2) contains four emotion types, each of which depends on whether the attribution of responsibility to some agent for some action is positive or negative, and on whether the agent is the self or another person.

The model explains the origin of twenty-two emotions. In this account, different sources of value give rise to different kinds of affective reactions. When goals are the source, one may feel *pleased* if the **event** is desirable, or *displeased* if it is not. Which specific emotion arises depends on whether the consequences are for other or for oneself. When concerned for oneself (labeled as CONSEQUENCES FOR SELF), the evaluation depends on whether the outcomes are past (labeled as PROSPECTS IRRELEVANT), like joy and distress, or prospective (labeled as PROSPECTS RELEVANT), such as hope and fear. If the prospect is confirmed or not, other four emotions can arise, such as satisfaction, disappointment, fear-confirmed and relief. When concern for other (labeled as CONSEQUENCES FOR OTHER), the outcomes are evaluated according to when they are undesirable (labeled as UNDESIRABLE FOR OTHER), such as gloating and pity, or desirable for other (labeled as DESIRABLE FOR OTHER), such as happy-for, resentment. When the **actions** of agents are evaluated according to standards, affective reactions of *approval* or *disapproval* arise. The specific emotions depend on whether the action is one's own (labeled as SELF AGENT), such as pride and shame; or someone else's (labeled as OTHER AGENT), such as admiration and reproach. The aspects of an **object** are evaluated according to one's tastes, if one *likes* or *dislikes*. In this case, emotions such as love and hate can arise. Finally, emotions like anger and gratitude involve a joint focus on both goals and standards at the same time. For example, one's level of anger depends on how undesirable the outcomes of events are and how blameworthy the related actions are.

The authors believe that this model when implemented in a machine can help to understand what emotions people experience under what conditions. According to the authors, it is not the objective of this model to implement machine with emotions, but to be able to predict and explain human cognitions (emotions recognition – Section 4.7.1). But Picard (1997) disagrees and she believes that the OCC model can be used for emotion synthesis of machines. As, we can see in Sections 4.7.1 and 4.7.3, this model is therefore used for user's emotion recognition in computational systems and for implementing emotions in machine.

This model is a highly oversimplified vision of human's emotions, since in reality a person is likely to experience a mixture of emotions (ORTONY; CLORE; COLLINS, 1988). But for understanding which set of emotions is a person experiencing, we must first try to infer each emotion separately.

In the Section 4.7.5, we describe a computational model based on the OCC theory. This computational model, called Affective Reasoner, is implemented for the construction of agents that react affectively to the user.

4.7 Affective Computing

Researchers in Artificial Intelligence have considered the emotions in intelligent systems modelling, thus appearing a new area: "Affective Computing". Rosalind Picard (1997) defines Affective Computing as "*computing that relates to, arises from or deliberately influences emotions*". Following Picard (1997), an affective (computational) system must have a few of the following capacities: (1) recognise (Section 4.7.1), (2) express (Section 4.7.2) and (3) possess (Section 4.7.3) emotions. Bercht (2001) considers that besides these ones, it may also have the ability to (4) develop some new emotions. Each of these capacities is described with more details in the next sections.

We can verify that the Affective Computing is divided in two major branches of research:

(I) Affectivity in Human Computer Interaction;

(II) Simulation of Emotion in Machine (Emotion's Synthesis).

In the first one, the researchers are mainly interested in recognizing the user's affectivity and to respond emotionally to him with the objective of adapting the system to the user, in this case, to user's affectivity. The systems that are part of this branch have the capacity of *recognizing* and *expressing* emotions.

The systems that are interested in simulating emotion in machine try to discover more about emotions in humans simulating emotion in machines (VELÁSQUEZ, 1997) (VELÁSQUEZ, 1998) (SANDER; KOENIG, 2001). Other works try to construct more realistic robots and animated agents by implementing emotions (BATES, 1994) (REILLY; BATES, 1992) (ELLIOTT, 1992). Others, like in social agents, seek to improve social interaction, negotiation and cooperation among artificial social agents by considering the affectivity (CAÑAMERO; FREDSLUND, 2000) (CAÑAMERO, 2001) (CASTELFRANCHI, 2000). In these cases, the systems usually have the capacity of *possessing emotions* and, when possible, *developing new emotions*.

This thesis finds its place in the filed of affectivity in Human Computer Interaction, since the system identifies the student's affective states (*recognise*) in order to adapt the learning to the student's affectivity by presenting emotive behaviour and messages (*emotion's expression*) that aims at promoting a positive mood for learning in the student.

4.7.1 Recognising and Modelling User's Emotions

In order for an affective computational system to interact effectively with the user, it must recognise the user's emotion to respond to him appropriately. Actually, we observe four main modes of user's emotion recognition: (1) voice (prosody) (KOPECEK, 2000) (TCHERKASSOF, 1999); (2) observable behaviour, i. e. user's actions in the system interface (for example, chosen options and typing speed) (BERCHT; VICCARI, 2000) (MARTINHO; MACHADO; PAIVA, 2000) (DE VICENTE; PAIN, 2002); (3) facial expressions (EKMAN, 1999) (WEHRLE; KAISER, 2000); and (4) physiological signs (blood volume pulse, electromyogram – muscle tension, skin conductivity, breathing) (HEALEY; PICARD; DABEK, 1998) (PICARD; HEALEY, 1997) (PICARD; VYZAS; HEALEY, 2001). Figure 4.3 illustrates these mechanisms.

In recognition by physiological signs, Rosalind Picard, of the group of MIT media lab[26], achieved good results with physiological recognising of eight emotional states (neutral, anger, hate, grief, platonic love, romantic love, joy and reverence) with a success rate of about 81% (PICARD, 2000). These results were obtained through tests made with one person in the course of twenty days, spanning about 5 weeks. The signals used were: blood volume pulse, electromyogram (muscle tension), skin conductivity, and breathing.

Wilson and Sasse (2000) propose to measure physiological indicators of stress, such as the heart rate, as an indicator of quality thresholds required by users in multimedia conferencing tools. The authors believe that it provides an affective interaction between the computer and the user, since the information is caught in real-time and the system

[26] Rosalind Picard's Affective Computing group at the MIT Media Lab: http://vismod.www.media.mit.edu/ vismod/demos/affect/

can adapt itself when it verifies that the user is under stress. Kaiser and Wehrle (KAISER; WEHRLE; SCHMIDT, 1998) (KAISER; WEHRLE, 2000) (KAISER; WEHRLE, 2001) worked on facial expression recognizing by instruments that observe the muscular activity of the face.

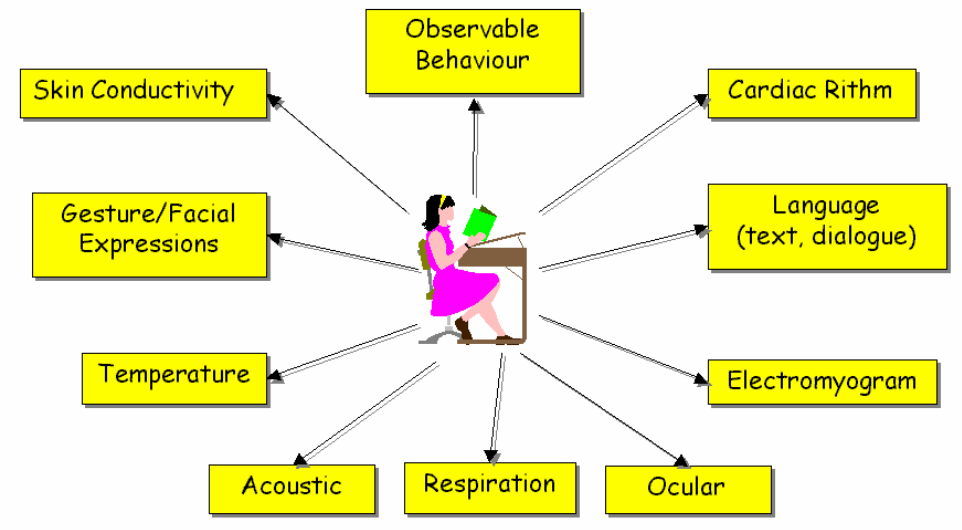


Figure 4.3: Mechanisms for Inferring the Student's Affective States

But one of the most natural mode of interaction between user and computer is the user's behaviour. Martinho and colleagues (2000) state that in a well-defined context (an educational environment), the user's **observable behaviour** may be a path to predict, recognise and interpret user's affective states. This approach was denominated **Cognitive-Based Affective User Modelling (CB-AUM)** by (MARTINHO; MACHADO; PAIVA, 2000). In our proposal, we recognise the student's affective states by his observable behaviour, which is described in Section 6.1.

According to Paiva (2000), although these mechanisms for emotions recognition are different, as they capture different expression of emotion, they can be seen as complementary and part of a large multi-modal affective sensory system. Picard (1997) believes that the best recognition is likely to come from the combination of the different modalities and including not only low-level signal recognition but also higher-level reasoning about the situation.

In order for the system to respond appropriately to the user, besides recognising the user's emotions, it must have a student affective model, area known as "affective user modelling" (AUM). Elliot and colleagues (ELLIOT; RICKEL; LESTER, 1999) define AUM as the capacity of the computational system to model the user's affective states. The affective user model must be dynamic enough to consider the changes in emotional states, since the emotion is seen as a dynamic process which happens in the form of episodes delimited in time (BERCHT, 2001).

Conati and Zhou (2002) propose a probabilistic model in order to infer student's emotions in educational computational games. The model is implemented using Dynamic Decision Networks (DNNs) that are an extension of Bayesian networks. The model considers 6 emotions (joy, distress, pride, shame, admiration and reproach) that were implemented using the OCC model. According to the OCC model, events generated by the student and the agent's actions are evaluated according to the student's goals. Events that are desirable according to user's goals elicit positive emotions and

undesirable events generate negative emotions. This way, the model contains variables that represent the student's *goals*, decision variables represent *agent's actions* (indicating points that the agent has to decide if and how to intervene) and a node class *Goals Satisfied* representing the desirability of an event. To determine the student's possible goals, it was accomplished a questionnaire for 23 students and students were observed playing the game. The goals are inferred by the student's personality (the Five-Factor Model of Personality) and by how the students play the game (for example, students that have the goal *have_fun* are more likely to move quickly). The model also makes the distinction between emotions toward oneself and toward the agent (as the emotions admiration and reproach). The student's emotion towards a peer was not implemented yet. Like our work, Conati also used questionnaires to determine the student's goals. A major difference of our work from this work and others that infer student's emotions in educational games is that we propose a methodology to infer student's emotions (which are also determined by their goals according to the OCC model) in an educational environment that is domain-independent (it was designed to teach any domain of subject). So, differently from educational games, the events that can happen and the student's goals are not so well defined as in an educational game. Besides, although the DDN allows to explicitly represent the probabilistic dependencies between causes, effects and emotional states, which enable to determine the student's emotions with more accuracy in situations that the user experiences a varied of emotions, it is difficult to define the required prior and conditional probabilities that are necessary in Bayesian networks (CONATI, 2002).

De Vicente and Pain (2002) model the student's motivational states based on factors such as control, challenge, independence, fantasy, confidence, sensory interest, cognitive interest, effort and satisfaction, that are caught by the student's observable behaviour. To determine which actions are indications of these affective factors, they observed recorded interactions of the ITS MOODS, an educational environment (DE VICENTE; PAIN, 1999).

Bercht (2001) defined a dynamic affective model based on a BDI approach that considers the factor self-confidence, independence and effort for detecting the motivational state and the affective state displeased (see Section 3.3 for more details about Bercht's work). Martinho and colleagues (MARTINHO; MACHADO; PAIVA, 2000) propose an affective user model for the collaborative game Teatrix. In Teatrix children collaborate with each other to create a story. Each child controls a character by selecting actions from a list of available actions. The affective model is divided in two parts: (1) the *user emotional profile* contains information about the "resistance" that the user experiences an emotions and how long the user experience it; and (2) the *emotions* that the user experiences according to OCC model. Like in Bercht's work, the emotions are caught by the observable behaviour of the student (actions in the game). An interesting proposal of this work is the modelling of the appraisal structure of the student. It means that, instead of describing all the rules that map the student's actions to emotions, they propose the implementation of a model that aims at, having student's tastes and goals, inferring the student's emotions according to the OCC model, as we propose in this thesis. But the model was described generically and, although this first paper was published in 2000, we have not found other publications describing more meticulously the model and it ha not been implemented yet.

4.7.2 The Expression of Emotions in Machines

Due to the motivation aspect of life-like characters, several research teams have been enriching their human-computer interfaces with characters that exhibit facial and body expressions (ANDRÉ; RIST; MULLER, 1999) (JOHNSON; RICKEL; LESTER, 2000a) (LESTER et al., 1997c) (PAIVA; MACHADO, 1998). These human characteristics, associated with a good dialogue interface with the user, will make the system more attractive because they explore more natural modes of interaction with the user (ELLIOTT; BRZEZINSKI, 1998). In Education, for example, some works use animated agents for the presentation of pedagogical content to the student, with the goal of doing demonstrations, to engage the student and motivate him (ABOU-JAOUDE; FRASSON, 1998) (ELLIOT; RICKEL; LESTER, 1999) (PAIVA; MACHADO; MARTINHO, 1999). For more details about animated pedagogical agents see Section 2.5.

To make the animated agents more credible, they can be enriched with emotional expressive power (PAIVA, 2000). To express emotions concerns present verbal and non-verbal behaviour with an emotional content in order to communicate and to induce an emotion in the user. Andrè and colleagues (1999) (2000) propose the use of affectivity for enhancing the believability of virtual characters and produce more natural conversation. According to Rizzo (2000), the agent's ability to process and display affective states, and to show emotional reactions, is crucial to improve the agent's believability, to elicit emotions in the user, and consequently to cause a more entertaining interaction between agent and user.

George and Mcillhagga (2000) use emotional faces for the children to express their emotions in avatars that inhabit a virtual game environment. Poggi and Pelachaud (PASQUARIELLO; PELACHAUD, 2001) (POGGI; PELACHAUD, 2000b) (POGGI; PELACHAUD, 2000a) work on the animation of emotional facial expression of human-like embodiment agents. Ball and Greese (BALL; BREESE, 2000a) (BALL; BREESE, 2000b) propose a Bayesian model for the generation of emotional behaviour in animated agents that presents a consistent personality. de Rosis and Grasso (2000) work on the automatic generation of natural language messages.

Besides, in Section 2.5 we presented other works related to expression of emotions in animated pedagogical agents. But, in these agents the expression of emotions is used as a mechanism to let the agent more believable, more real to the user (see Section 2.5.7 about believability). For example, Vincent shows a sad face when the student provide an incorrect response for an exercise. This attitude can be harmful if the student is already depressed and frustrated with this performance. In this way, in our work, the emotions of the agent are adapted to the student's emotions and aims at promoting positive emotions in the student, which psychologists shows to be more beneficial.

4.7.3 Emotion Synthesis (Possess Emotions)

In some cases, in order for the agents to exhibit affective behaviour (see Section 4.7.3) in a coherent manner, they are constituted of models of emotions which Picard called "Emotion Synthesis" (PAIVA, 2000). We can observe a great interest of the research community in study theories and architectures to obtain "machine emotions".

Many researchers discuss if computers can have emotions, since emotions in humans are constituted of the integration of mental, cognitive, motivational and somatic components (CASTELFRANCHI, 2000) (CLORE; ORTONY, 1999). Picard (PICARD,

1997) refers to computer emotions in a descriptive sense, for example, it is able to label its state in which it received much conflict information as “frustration”.

Besides, emotions synthesis can be used not only as a way to obtain more rational behaviour, but also to make the life-like agents more credible, i.e., more real. This way, there are several researchers interested in developing emotional agents, such as the works of (ELLIOTT, 1997) (REILLY; BATES, 1992) (LOYALL; BATES, 1997) (BATES, 1994).

For example, El-Nasr and colleagues (EL-NASR et al., 1999a) propose a model of emotional response, called FLAME, which is integrated with a model for facial expressions generation developed for the construction of agents which are able to generate and show credible emotions in real-time. FLAME uses fuzzy logic for representing a relation among events, objectives and emotions with the purpose of producing homogenous transitions between different behaviours. The FLAME model has 3 components: an emotional component, a component for decision taking and a component for learning. The agent perceives several events in the environment and send its perceptions to the learning and emotional components. The emotional component evaluates the relevance of each event and so estimates a new level for each internal variable of emotional state. As the evaluation depends on the agent’s expectation and learned experiences, the learning component keeps associations in the events history and provides inputs for the emotional component. Finally, the emotional levels are merged to produce a coherent mixture, and an adequate emotional behaviour is chosen and sent to the decision-taking component for influencing it in the choice of actions to be performed. The same emotional agent model was used in an agent called PETEEI (EL-NASAR et al., 1999b), represented as a dog in a simulation environment. The user can interact with the environment by introducing objects, catching or beating them, including the dog. The agent reacts emotionally to the actions of the user. Results of the evaluation of this environment can be found in El-Nasr work (EL-NASR et al., 1999b).

Adamati and Bazzan (ADAMATTI; BAZZAN, 2002) (BAZZAN; BORDINI, 2001) propose a framework to simulate agents with emotions. The framework allows the user to define the characteristics of a given interaction, the emotions agents can display and how these affect their actions, and hence those interactions. The OCC model is used for the analysis as the implementation of emotion in the agents. For a determined simulation, the user adds the rules that define the agent’s behaviour. Each rule contains the pre-conditions and the associated actions. And it is also necessary to define the rules for emotion generation with the associated pre-conditions and actions. The framework allows the user to verify variables that influence the decision-making when he redefines the simulation.

In the effort to construct believable agents, the Oz Project (BATES, 1994) (REILLY; BATES, 1992) constructed a simulated world inhabited by self-animating and interactive creatures based on the principles of traditional characters animation. The creatures who inhabit this world, called Woggles, have an architecture for action based on behaviour and directed to the action, and have a specific component to generate, express and represent emotion which is based on the OCC model (see Section 4.6). The use of the OCC architecture allowed the creation of agents with emotional reactions to the events. The action system uses a concept of objectives for manipulating a set of dynamic behaviours. This objective and the evaluation of the event for the agent are essential in the production of an emotional state in the creature. Each emotion in a Woggle is mapped to a behavioural feature in accordance with the personality of the Woggle. For example, the emotion fear is mapped to the “alarmed” feature in Shrimp

agent and in aggressive feature in Wolf agent. The agent must, then, generate actions that are adjusted to the features.

Other examples are: (1) the Affective Reasoner, which we described in Section 4.7.5; and (2) Velásquez's works (VELÁSQUEZ, 1997) (VELÁSQUEZ, 1998) on making-decision based on emotions.

In our work we opted not to develop an architecture of emotions in the Mediating Agent. We believe that the agent can achieve its goal, just by showing positive affective attitudes for encouraging and for inducing positive emotions in the student. Besides, the process of emotion synthesis turns the system substantially more complex.

4.7.4 Develop New Emotions

According to Bercht (2001), besides the capacities defined by Picard (1997), an affective agent can learn or develop new emotions from the emotions that it already has. In such a way, there must have mechanisms which allow it to generate and recognise new emotions. In the actual scientific literature there is not computational system that has the capacity of learning and generating new emotions. The existent affective computational systems follow a specific emotional computational model, as for example, the OCC (see Section 4.6), where the agent is able to show or recognise only emotions previously defined in the model. The emotions' recognition is restrictive to the emotions modelled in the system.

4.7.5 The Affective Reasoner Framework

A large part of emotional computational models that are based on the cognitive approach of emotions rely on the model proposed by Ortony, Clore and Collins (1988) – OCC model, which is described in Section 4.6. The Affective Reasoner Framework (AR) (ELLIOTT, 1992) (ELLIOTT, 1997), developed in the DePaul University, uses the OCC model of emotions for designing agents who are capable to answer emotionally. For Elliot and colleagues (1999), the "emotions arise naturally in many human social situations as a by-product of goal-driven and principled (or unprincipled) behaviour, simple preferences, and relationships with other agents". For example, to be boring with someone is an intermediate form of anger in the AR framework.

In the Affective Reasoner (AR) research, the framework AR was implemented in agents capable of responding "emotionally". The agents have pseudo-personalities modelled as both a set of appraisal frames representing their individual goals, principles, preferences, and moods, and as a set of about 440 differentially activated channels for the expression of emotions. For example, an agent might appraise a user's success on a task as being desirable for them (a friend), producing a happy-for emotion, and leading to an affect-oriented, other-directed, emotion-modulation expression of praise for their good work. Situations that arise in the agents' world may be mapped to twenty-six different emotion types (e.g., pride, as approving of one's own intentional action), twenty-two of which were originally theoretically specified by Ortony and colleagues (1988) in the OCC model.

To communicate with users, the AR agents use various multimedia modes. Agents have about 70 line-drawn facial expressions, which are morphed in real time, yielding about 3,000 different morphs. To speak to the user, the AR agents use a speech synthesizer, which allows to dynamically construct spoken sentences at run time and play music to enhance the expression of emotions. The agents also have a speech recognition software to respond in real time to the user, although there is not a natural

language understanding point of view (the agent has no understanding about anything except emotion states). In Figure 4.4, we can see Elliot and an agent of the Affective Reasoner Project.

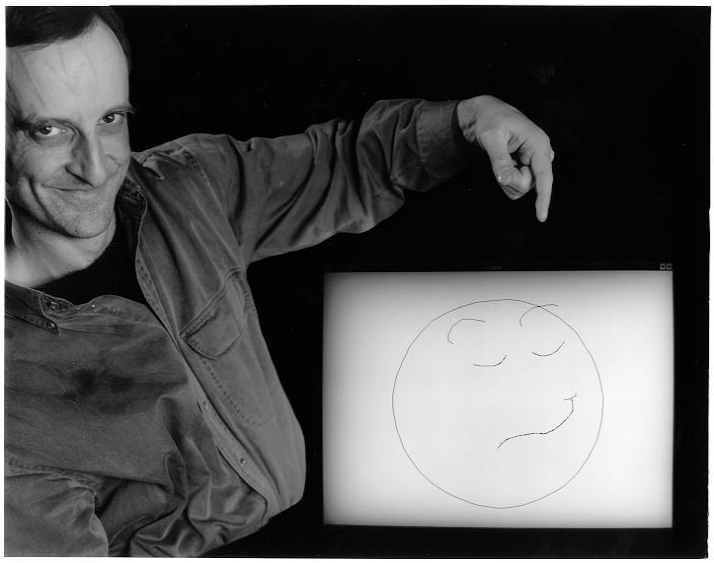


Figure 4.4: Elliot and an Affective Reasoning Agent[27]

In Table 4.2, we can see an example of interaction between Elliot and one of the Affective Reasoning project's agent, Sam. The dialogue was extracted from (ELLIOTT, 1994).

Elliot (1994) explains that, in this dialogue sequence, Sam "believes" that anger is caused when some entity performs a blameworthy act that affects one's goals. It uses dialogue for discovering which blameworthy act was, and which goal was. It then asks for information about variables that can affect the intensity of anger. Since these do not match a general pattern for fury, it reasons that one explanation for this might be the greater weight of the principle about stealing, and asks Elliott about this. After confirmation, it updates his internal representation of what is important to Elliott. Later, it draws on this information to ask Elliott an intelligent question about what might happen if their friendship relationship was at odds with a strongly held principle.

As we can observe in the dialogue, although it seems quite real, the agent uses some cues in the dialogue in natural language with the user to infer his appraisal and, consequently, his emotions. It is a rule-based framework to build agents that respond emotionally and that could also be used to model user's affect. As our model (see Section 6.1), the Affective Reasoner is also based on the OCC theory of emotions, but relies on rules to model the appraisal, differently from our work which we use a mentalistic approach (see Section 7.1). Another major difference is that in the Affective Reasoner, the information used to infer student's appraisal (for example, goals, events, agent's actions) should be provided by the user directly in the dialogue with the agent. In our work, we infer this information from student's observable behaviour.

[27] From http://condor.depaul.edu/~elliott/drea.html.

Table 4.2: Dialogue between Elliot and Sam (ELLIOTT, 1994)

Elliott: I am really furious at Joe.
Sam: Boy what a blameworthy thing he must have done! What do you call such an action?
Elliott: Joe was stealing.
Sam: When Joe was stealing, he must have caused you distress. What is the name of the thing you wanted, or wanted to preserve?
Elliott: My sandwich.
Sam: How important was your sandwich to you, Clark?
Elliott: Not very important.
Sam: How surprising was it that Joe was stealing and caused you distress about your sandwich?
Elliott: It was not surprising.
Sam: How bad was it that Joe was stealing?
Elliott: It was not very bad, actually.
Sam: How important is your principle about stealing?
Elliott: Quite important.
Sam: Hmmm. I would think that you are only somewhat annoyed at Joe. I do not understand that you are furious at Joe. After all, what Joe did was not that bad. Your sandwich is not that important to you. It is not very surprising that Joe was stealing. Perhaps your principle about stealing is very important to you. Is this correct?
Elliott: Yes.
Sam: I will remember that about you.
... later ...
Sam: Clark, if I was stealing and it affected your sandwich, would you still be my friend?

4.8 Affectivity in Intelligent Educational Systems

Some studies have given attention to the generation of emotion in pedagogical environments (emotion expression and emotion synthesis – see Sections 4.7.2 and 4.7.3)(ABOU-JAOUDE; FRASSON, 1998) and to the emotion recognition (see Section 4.7.1) (DE VICENTE; PAIN, 1998) (BERCHT; VICCARI, 2000), pointing out the richness presented in affective interaction between student and tutor.

Good teachers are always good motivators. The motivation has an important role in education and is directly influenced by emotions (VYGOTSKY, 1962). The emotional perturbations interfere in the mental life. Bad-humoured, anxious and depressed students have greater difficulties when studying (GOLEMAN, 1995). Therefore, researchers in education believe that the pedagogical agents would be more effective if they had mechanisms to show and recognise students' emotions (ELLIOT; RICKEL; LESTER, 1999).

An emotive pedagogical agent, which shows that it cares about the student's progress, can encourage the student to give more attention to his own progress. Besides, the use of emotions makes it possible to transmit more enthusiasm to the subject to be learned and, so, foster the enthusiasm into the learning (ELLIOT; RICKEL; LESTER, 1999)[28].

According to Johnson and colleagues (JOHNSON; RICKEL; LESTER, 2000b), the modelling of emotions is also important in educational environments which consider interpersonal relations, including environments for group training. The virtual students must show and react to students' emotions. For example, if a simulation represents a war, it is important that the participants react in a real way to the situation in order to increase the scenario's realism. In this specific case, the artificial characters must have

[28] For more details, see the persona effect of animated pedagogical agents in Section 2.5.8.

an architecture which allows them to react emotionally to situations, which are known as “emotion synthesis” (see Section 4.7.3).

People tend to see emotions and attitudes in animated characters and expect that these characters react emotionally, in the same way humans do. So, it is essential to take into account the representation of an animated behaviour by the lifelike agent, as Section 4.7.2 shows. Otherwise, the agent seems monotonous and robotic.

Besides, the agents that are represented as animated characters must be able to represent different types of emotions. As it happens in real-life characters, the agents must show emotions as happiness, sadness, fear, jealousy, shame and others. However, as the animated pedagogical agents are projected to further positive learning experiences, a set of behaviours that are appropriate to the learning must be chosen (LESTER; TOWNS; FITZGERALD, 1999). It is necessary to identify which behaviours are better at letting the student in a positive mood, which will make him study better.

To respond to the student, the agent must interpret the student’s emotions rightly. For example, we suppose that the student finds it difficult to accomplish the exercises because he is very anxious. If the agent misinterprets the student’s emotional state, it can generate an action that will let the student more anxious, instead of helping him. This way, it is necessary that the agent have**, besides a cognitive model of the student, an emotional one that takes into account his affective states**.

A first work that proposes the integration of affective modelling in pedagogical agents is the Elliot and colleagues’ work (ELLIOT; RICKEL; LESTER, 1999). The model discuss how to use the Affective Reasoner (that like our model is based on the OCC theory - see section 4.7.5) in the environment Design a Plant of the Herman agent (LESTER; STONE, 1997) in order to model student’s emotions. But this model was not implemented yet and it does not show how to identify the student’s goals in order to infer his emotions. The authors assume that the user’s goals and preferences necessary to define the outcome of the appraisal are known. In Section 4.7.1 we describe other works.

Due to the human psycho-social trend to anthropomorphize software, recent studies had shown that ITSs that have animated agents are more effective pedagogically (LESTER et al., 1997c), besides having a strong motivational effect for students (LESTER et al., 1997b). Besides, as some cartoon designers’ works show, the dramatic impact in the communication, as the quality, can be increased through the creation of emotive movements that communicate the affective content of the message (JOHNSON; RICKEL; LESTER, 2000b) (The affective and cognitive impact of animated pedagogical agents is further explored in Section 2.5.8).

According to Elliot and colleagues (ELLIOTT, 1997), the use of affective behaviour in ITSs will considerably increase the complexity of these systems. Thus, the authors indicate some **advantages in using emotions in education systems** that show that this complexity can be compensated.

- A pedagogical agent, which cares about student’s progress, can make the student believe that they are together and so encourage him to pay more attention in his own progress;
- An animated pedagogical agent that is sensitive with the student’s emotions can intercede when the student shows to be disappointed or loses the interest, giving him encouragement and assistance;

- An animated pedagogical agent can transmit enthusiasm to the subject and, so, promote greater enthusiasm in the student. As the enthusiasm is a human emotion, it is better represented by a program if it has an emotional structure;
- A way of making the student engage in the study is interacting with him by his social tendencies.
- Finally, the authors state that the animated pedagogical agent, due to its appearance with life and personality, can make learning funnier. A student who likes to interact with the agent will have a more positive perception of learning. Besides, if the student appreciates the educational environment, he will use it for a longer time, and so will learn more.

Faivre and colleagues (FAIVRE; NKAMBOU; FRASSON, 2002) propose the integration of two emotional agents in an ITS. The first agent, SAEA, is responsible for inferring the student's emotions. It detects the student's emotions by his actions in the ITS interface. This emotion-recognition process is modelled through a collection of rules that match specified external situations with emotions and that were specified according to the OCC model. The affective model is formed by two types of temporal modules: (1) the Short Term Mood Memory that stores the emotions detected in a session; and (2) the Long Term Mood Memory that maintains information about the student's mood average profile on several learning sessions. It also uses rules for choosing the adequate pedagogical tactic according to the student's emotions. The tutor is represented by a 3-D embodied agent that shows emotional expressions and gestures, but is does not have any kind of verbal communication. Its model of emotion is also made according to the OCC model and implemented as "if-then" rules. In this work, the student's emotional states are used to adapt the pedagogical tactics. Although the character has an emotional model that allows it to express emotions, it doesn't present some behaviour that can contribute to student learning. Differently from our work that proposes a character that presents emotional behaviours that have the function of engaging and promote positive moods in the student. Another limitation that we see is that as the character has an emotional architecture to possess emotions, it will react emotionally by showing expressions of, for example, sadness and disappointment that can be bad for the student's emotions and can interfere negatively in his learning.

4.8.1 Pedagogical Point of View: Affectivity in Learning

Some pedagogues, such as Piaget (1989), Vygotsky (1962), Goleman (1995), Vail (1994) and Mahn and John-Steiner (MAHN; JOHN-STEINER, 2000) (MAHN; JOHN-STEINER, 2002) (JOHN-STEINER, 2000), **point to the importance of motivation and affectivity in learning**. For Piaget (1989), the accelerating or disturbing role of the affectivity in learning is incontestable. For instance, a considerable part of the students that is weak in mathematics fails due to an affective blockage. According to Piaget (1989), there is not cognitive mechanism without affective element. Affectivity motivates the intellectual activity. There is an intrinsic or extrinsic interest, a necessity. It is through the interest that we select our activities.

Goleman (1995) has pointed out the way in which emotional disturbances affect mental life. He recalls the well-known idea that depressed, ill-humoured and anxious students find greater difficulty in learning.

Coles (1998) points to some links between learning and emotions. For example, poor learning can produce negative emotions; negative emotions can impair learning; and positive emotions can contribute to learning achievement and vice versa. Izard's

work (1984) shows that induced negative emotions damage performance on cognitive tasks, and positive emotions have an opposite effect. Coles shows other studies made by Masters, Barden and Ford which found that inducing a sad mood in very young children increased the time it took them to learn to respond to a task, and also increased their number of errors; opposite results were achieved by inducing happiness. Tanis and Bryan *apud* (COLES, 1998) showed that young identified as at risk in school completed math problems significantly more accurately under induced positive-mood conditions.

The interest and the pleasure in the action are considered the elements that will strongly influence the development of affectivity in the student. According to Piaget (1989), feelings associated to the actions or activities are always remembered. Children are attracted by activities that are successful and pleasant. We can associate this premise to the use of computational environments. Although some failures can become challenges and activate the interest and persistence of the students, we all will keep interested in activities where we got success.

Another basic factor to learning is motivation; therefore without motivation there is no learning. Motivated, students search responses to their problems and to satisfy their needs. For Vygotsky (1962), motivation is the reason of the action. It stimulates needs, interests, desires and particular attitudes of the citizens:

> "the thought has its origin in the sphere of consciousness, a sphere that includes our inclinations and needs, our interests and impulses, and our affect and emotions. The affective and volitional tendency stands behind thought. Only here do we find the answer to the final “why” in the analisys of thinking.” (VYGOTSKY, 1962, p. 282)

As to the role of affectivity in learning, Vygotsky considers the unit between the intellectual, evolutionary and affective processes. Vygotsky considers that the affect can not be separated from cognition.

> “When we approach the problem of the interrelation between thought and language and other aspects of mind, the first question that arises is that of intellect and affect. Their separation as subjects of study is a major weakness of traditional psychology, since it makes the thought process appear as an autonomous flow of 'thoughts thinking themselves' segregated from the fullness of life, from personal needs and interests, the inclinations and impulses of the thinker.” (VYGOTSKY, 1962, p. 10)

In one of his last publications (VYGOTSKY, 1994), Vygotsky presents a new important concept introducing affectivity in learning: *perezhivanie*. The development of a child depends on the way that the child experiences a situation of the environment, it means “how a child becomes aware of, interprets, and emotionally relates to a certain event” (VYGOTSKY, 1994, p. 341), which Vygotsky called *perizhivanie*. In this work, Vygotsky pointed out the important role of emotions in the child’s development (see Section 5.1 for more details about Vygotsky sociocultural approach and *perezhivanie* meaning).

Coles (1998) considers that as a teacher can contribute to the development of the student’s cognitive abilities, he can also assist the emotional development of the child through guidance and support. As Coles points to:

> “Fear of failure may be changed to feelings of self-confidence; motivation may change from low to high; intellectual insecurity may become confidence in one's intelligence. These transformations can occur through a teacher's "scaffolding" and guidance in the formation of new emotional states a learner can achieve and sustain by him- or herself.” (COLES, 1998, p. 4)

As we can see in the works mentioned above, emotions play an important role in learning. This way, they can not be neglected by teachers and computational educational systems.

4.8.2 Empathy in Intelligent Educational Systems

Cooper and colleagues (COOPER; BRNA; MARTINS, 2000) (COOPER; BRNA, 2002a) (COOPER; BRNA, 2002b) have explored the role of empathy in intelligent educational systems through animated pedagogical agents. Empathy concerns "*the ability to imagine oneself in the position of another person, and so to share and understand that person's feelings*" (SUMMERS, 1987, p. 333). Communication is an important key to learning (VYGOTSKY, 1978) and empathy is central to ensuring the quality of human communication and personal development (COOPER; BRNA; MARTINS, 2000).

An artificial tutor represented by an animated agent (as Cosmo, Adele, Steve, Vincent presented in Section 2.5), cannot really empathise with or understand the student, but it can demonstrate empathic characteristics that empathic teachers show. These empathic characteristics can improve the learning atmosphere and help to meet the individual learning needs (COOPER; BRNA; MARTINS, 2000).

In some works presented in this text, we verify some empathic characteristics pointed out by Cooper:

- positive affirmation and understanding;
- motivating aspects of facial expression, voice tone and understanding, as we can see in the agents Cosmo (see Section 2.5.4) and Vincent (see Section 2.5.1);
- creation of a persona with empathic responses in combination with knowledge-based learning environments, as Adele (see Section 2.5.2), Vincent (see Section 2.5.1), Cosmo (see Section 2.5.4) and Steve (see Section 2.5.3).
- Besides, Cooper and colleagues (2000) present some characteristics of an empathic teacher, which were identified in a study in which students and empathic teachers were interviewed and observed. These characteristics are described in Table 4.3.

Table 4.3: Characteristics of an Empathic Teacher
(COOPER; BRNA; MARTINS, 2000)

Attitudes Open, warm; relaxed, good-humoured; fair; ensure fairness; models and expect common courtesy; explains how children should work or behave in an understanding way rather than criticizing their present work or behaviour.
Facial characteristics Frequent smiles; lots of eye contact; generally positive demeanour; expressive face which shows emotions and can switch emotion quite quickly; tends to reflect students emotions but also leads and influence them e.g. if the teacher wants to encourage thinking/reflecting, she models a thinking face.
Voice Positive; encouraging; expressive; clear directions when necessary; supportive; varied; reflects accurately the meanings of the word.
Body language Uses gesture; animated; tactile; moves around; uses body for emphasis and explanation
Positioning Generally gets closer to child; less distance; less formality in a large classroom provides one to one support when possible; moves around quite a lot; sits down with students; lowers whole body, often down below student's level.
Responses Knows and uses student names frequently; listens carefully to students; gives them sole concentration when possible; elicits understanding from them; echoes and affirms their comments; tries to give a positive response but asks them to elaborate or develop response if weak; prompts and helps them when necessary; constructs answerable questions to build success and self-confidence; frequent use of the 'cloze' technique to build confidence

Content or teaching Frequently initiates a session with some aspect of topic that relates directly to child's own experience; personal interest, humour and discussion of non academic issues interspersed at appropriate moments through lesson; the personal used as vehicle into the subject matter
Method of teaching Varied teaching strategies; relaxed but vigorous; involves changes of pace and style; adaptable and flexible; sessions well-structured; individualized and personalized wherever possible; use of differentiation – matches task to child; explains problem issues; takes time over any issues; prepares individual material for children who needs it
Other features Uses humour; 'not like a teacher'; in touch with students interests; forms personal relationships with each child; considers the informal significant; very aware of individual social and emotional aspects; puts time and effort into relationships; concerned with out-of-school life of child; maintain a long-term vie of the child's well-being.

The teachers listened in the research consider empathy essential to their teaching (COOPER; BRNA, 2002b). Empathy was central to high quality, effective teaching and learning, enable greater understanding, better assessment and better academic support.

We believe that the empathic characteristics provided by Cooper and presented in this section, can be very useful to implement a more powerful affective agent and to improve the communication between tutor and student through a more careful feedback. The characteristics presented in Table 4.3 were for the design of the appearance of the life-like character as well as for the definition of the affective actions of the tutor.

II THE STUDIED EDUCATIONAL ENVIRONMENT

5 MACES: THE STUDIED COLLABORATIVE EDUCATIONAL ENVIRONMENT

The proposed agent, Mediating Agent, is part of the multi-agent architecture of the educational collaborative system MACES (Multi-agent Architecture for a Collaborative Educational System). We intend to present in this chapter an overview about MACES and the multi-agent architecture that compose it, since we believe that this knowledge is necessary to better understand the work of this thesis.

MACES is based on the sociocultural pedagogical approach of Vygotsky (ANDRADE; JAQUES; VICCARI; BORDINI; JUNG, 2001) (JAQUES et al., 2002). This system is formed by five types of artificial agents – Diagnostic Agent, Mediating Agent, Collaboration Agent, Social Agent and Semiotic Agent and by human agents – teacher and students. This research uses the technology of Distributed Artificial Intelligence (DAI), in particular multi-agent systems, for implementing this social model for distance learning. The features of autonomy, collaboration and learning can assist in the construction of a student model and assist in the interaction among students, stimulating their socio-cognitive development.

The social model implemented by the proposed system is strongly inspired by Sociocultural Vygotsky's Theory (VYGOTSKY, 1978) (VYGOTSKY, 1962). Sociocultural approaches originate from Vygotsky and his collaborator's works and are based on the concept that human activities take place in cultural contexts, are mediated by language and other symbols systems, and can be best understood when investigated in their historical development (JOHN-STEINER; MAHN, 1996). The sociocultural approach is suitable to our computational model for offering a pedagogical theory that explores the role of interaction and collaboration in learning.

The proposed computational educational environment is domain-independent and can be employed as a distance educational system in any domain of knowledge. In this architecture, the artificial agents have the function of monitoring and assisting the human agents in their collaborative activities. Although the general multi-agent architecture is previously defined, each agent of the society is being developed as a separated work of a master or PhD student and some agents are still in definition and development. This way, the general architecture of the system may undergo modifications due to a more detailed specification that is being made in each agent.

In Section 5.1 we present basic concepts on the Vygotsky's sociocultural theory, which are necessary for a better understanding of the proposed educational environment. In Section 5.2 we describe the computational model of the environment; and in Section 5.3 we describe each agent which is part of the multi-agent system of the collaborative educational environment.

5.1 Vygotsky's Sociocultural Theory

Vygotsky emphasizes in his work the importance of the society and culture in the individual's process of learning. Learning enables the awakening of the internal process of developing which is possible only with the contact with certain cultural environments. For example, if a person lives in an isolated cultural group which does not count on a writing system, he will never be alphabetized while living in this community. But if he decides to live in a literate group, he could be alphabetized and his developing process would be changed (OLIVEIRA, 1997). This conception, that learning enables the awakening of individual's internal process of developing, links the person's development with his relation with the sociocultural environment where he lives and shows that a person doesn't develop entirely without other individuals' support.

There are two types of cognitive development according to Vygotsky: *biological* which comprises the development of the central nervous system, physical growth and maturation; and *socio-historical* which begun with the invention and use of culturally based psychological tools in primitive humans. Functions happen primarily in a social level and after in an individual level. First among people (interpersonal) and after into the person (intrapersonal).

According to Vygotsky (VYGOTSKY, 1978), the mental functions are divided in *elementary* and *higher* mental functions. The elementary (or natural) functions are those that are genetically inherited, as for example the elementary memory, perceptions and attention. The higher mental functions (HMF) emerge dynamically through transformations of the lower ones. Thinking, reflecting, reasoning, problem solving and logical memory are examples of higher mental functions.

In elementary functions there is a direct link between a stimulus in the environment and a response from the organism (S→R).

The higher mental functions are mediated by a psychological tool (sign) as Figure 5.1 shows. For HMF to occur, the elements of symbolic **mediation** (tools and signs) and social interaction are necessary.

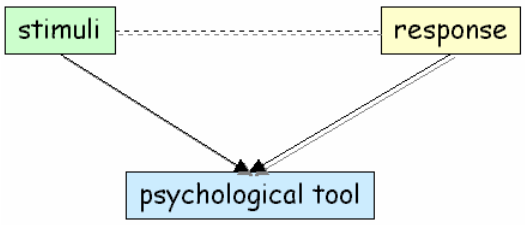


Figure 5.1: The organisation of higher psychological process (VYGOTSKY, 1978)

The mediation is an important concept in Vygotsky's theory. According to him, mental activities are based on social relationships between the individual and the environment in a historical process and that this relationship is mediated by symbolic systems, through *instruments and signs*.

The function of an *instrument* is to serve as tool between the worker (in the case of this research, the student) and the object of his work, seeking help with some activity. The instruments are guided externally. The *signs* are artificial incentives with the purpose of mnemonic aid; they work as middle ground for adaptation, driven by the individual's own control. The signs act as instruments of the psychological activity.

They are auxiliary means to solve a given problem. Sign functions as internally oriented, since they transform natural human abilities and skills into higher mental functions. Actions conducted with these psychological tools, create thoughts (LINDBLOM; ZIEMKE, 2002). An important and powerful sign is the language. The main function of the language, in the form of speech, is a device for social contact. In a distance education environment, we can cite as example of signs and instruments: chat tools, graphical resources, e-mail and forum services, video-conference tools and other tools that make the role of mediation.

Vygotsky called the process of transforming an interpersonal process (human-to-human interaction) into an intrapersonal *internalisation.* The internalisation is mediated by signs. During an internalisation process, the individual is able to do mental associations in the absence of the object. To do this representation, the individual needs to use internal signs for representing objects, events and situations.

For Vygotsky, learning and development are related one to each other since child birth. Although the development is in part based on process of biological maturing, the learning enables to arouse internal process of development.

An important concept of Vygotsky study of learning is the *Zone of Proximal Development (ZPD)*. It is firstly necessary to understand the Level of Real Development and Level of Potential Development concepts. When the child is able to do an activity independently and alone, he is using psychological functions of the *Level of Real Development* which are result of a complete and consolidated developing process.

There are tasks which the children are not able to do alone, but that he can do with instruction or demonstration of another person. The capacity of the children to accomplish a task with the help of another person is denominated *Level of Potential Development*.

The child can just benefit from the help of another person if he is in a certain level of development. It means that the capacity of obtaining benefit from the help of other person happens just in a determined level of development, not before. The Level of Potential Development is an important concept of Vygotsky's theory because it considers the important role of the social interaction in the construction process of human psychological functions (OLIVEIRA, 1997).

From these two levels of development (real and potential), Vygotsky defines the Zone of Proximal Development (ZPD) as:

> "It is the distance between the actual development level as determined by independent problem solving [without guided instruction] and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (VYGOTSKY, 1978, p. 86).

Thus, the ZPD is the path that the individual will make for developing functions which are in process of maturing and which will become consolidate functions, functions established in the Level of Real Development (OLIVEIRA, 1997).

In another of his last publications (VYGOTSKY, 1994), Vygotsky presents a new important concept introducing the affectivity in learning: *perezhivanie*.

In this paper (VYGOTSKY, 1994) Vygotsky discusses the role of the environment in child development. He showed examples of children that had different picture of developments, caused by the same situation. He received three children of the same family, so each external situation in this family is the same for all three children. The children's mother drinks and, as a result, she apparently suffered from several nervous and psychological disorders. "The children find themselves in a very difficult situation" (p. 340). When drunk, the mother regularly beat them or threw them to the floor. Each

child reacted in a different way to that situation. The youngest reacted to the situation by developing a number of neurotic symptoms of a defensive nature. He developed attacks of error and a stammer. The child was in a state of complete depression and helplessness. The second child was in a state of inner conflict, since the mother represented for him an object of painful attachment and also a source of all kinds of terrors and terrible emotional experiences. The oldest child had a limited mental ability but, at the same time, showed signs of some precocious maturity, seriousness and solicitude. He already understood the situation. He understood that their mother was ill and he pitied her. So, as we can see, the same environmental condition (a drunk mother who beats her children) exerted three different types of influence on these three different children. It can be explained because each of the children had a different attitude to the situation. Each of the children experienced the situation in a different way. It is the way that the child "becomes aware of, interprets, and emotionally relates to a certain event" (p. 341), the child's emotional experience (his *perezhivanie*), that determines the influence of the environment on the course of child's development. Vygotsky asserts that:

> "The emotional experience [*perezhivanie*] arising from any situation or from any aspect of his environment, determines what kind of influence this situation or this environment will have on the child. Therefore, it is not any of the factors themselves (if take without the reference of the child) which determines how they will influence the future course of his development, but the same factors refracted through the prism of the child's emotional experience [*perizhivanie*]" (VYGOTSKY, 1994, p. 339).

Perezhivanie is a Russian term and there is no adequate term in English that can be used as translation of Perezhivanie. According the Vygotsky translator's article (VYGOTSKY, 1994), this Russian term serves to express the idea that one objective situation may be interpreted, experienced or lived through by different children in different ways. Neither 'emotional experience' (which is used as a translation, but which only covers the affective aspect of the meaning the perezhivanie), nor 'interpretation' (which is too exclusively rational) are fully adequate translations of the name.

Vygotsky's choice of the term *perezhivanie,* which expresses emotional experience and interpretation (a cognitive process), to express this sort of emotional experience can be an evidence of his view of emotion as dependent of cognitive process. This way, we can consider that Vygotsky's view of the emotion is closer to the cognitive psychologists' view (which is explained in Section 4.5).

Although Vygotsky's works, mainly the ZPD notion, are largely known by pedagogues and educator's community, little attention has been paid to his writings about the role of emotion in learning (VYGOTSKY, 1999) (VYGOTSKY, 1962). This can be explained by the fact that Vygotsky's works about emotions ("Teaching about Emotions") were published only in 1999 with the Volume 6 of Vygotsky's Collected Works (VYGOTSKY, 1999).

Mahn and John-Steiner (2002) have worked about the perezhivanie in classroom. They assert that "the *perezhivanie* describes the ways in which the participants perceive, experience, and process the emotional aspects of social interaction". According them, there is great relation between the ZPD and the *perezhivanie* (affectivity). In a certain stage of the development (in ZPD), children can solve a certain range of problems **only when they are interacting** with people and in cooperation with peers. In this case, the interaction is fundamental and the way the student perceives the emotional aspects of this interaction (perezhivanie) will interfere in his learning. As Mahn and John-Steiner

(2002) argue, there is a great relation between the ZPD and the student's experience of his interaction (perezhivanie), and "when there is a breach in this relation because the cognitive demands are too far beyond the learner's ability or because negative affective factors such as fear or anxiety are present, the zone (ZPD) in which effective teaching/learning occurs is diminished." Thus, "**affective factors play a substantial role in the construction of the ZPD**" (MAHN; JOHN-STEINER, 2002).

The teacher is an important person in the student's learning process, since he will offer support to the student when he achieves the ZPD zone. A teacher aware of student's ways of perceiving, processing and reacting to classrooms interactions – their *perezhivanija* - will engage more significantly the student in his learning (MAHN; JOHN-STEINER, 2000) (MAHN; JOHN-STEINER, 2002).

Mahn and John-Steiner (MAHN; JOHN-STEINER, 2002) carried out a study, with adult learners in an English as second language classroom, which aimed at exploring the role of affectivity in learning. The experience consisted of students and teacher writing collaboratively a journal in English for 15 minutes at the beginning of class on whatever topic they choose. In this study they showed that **teachers could instil the student's confidence by offering caring support**:

> "careful listening, intense dialogue and emotional support sustain the cooperative construction of understanding (MAHN; JOHN-STEINER, 2002)".

The students reported that the responses from the teacher played an important role in motivating them and giving them the confidence to take risks with their writings. In the same way, without understanding the student's *perezhivanija* and the ways that their ZPD is affected by their responses to the interactions in the classroom, it is difficult for teachers to offer the support that will motivate the continuing development of learning. The students revealed that when they were anxious by the fear of making mistakes, they were less fluent in writing. As the experience showed positive results with adult learners, the authors also believe that the ZPD and *perezhivanie* notions are not limited to children or other novice learners.

These important concepts of Vygotsky's theory presented in this section (ZPD, mediation, interaction, perezhivanija) are implemented in the computational model of the educational environment proposed. In the next sections, we describe this computational model and each agent which is part of this educational environment.

5.2 The Computational Model of the Educational Environment

The system initially proposed (ANDRADE; JAQUES; VICCARI; BORDINI; JUNG, 2000) (ANDRADE; JAQUES; VICCARI; BORDINI; JUNG, 2001) was formed by four classes of artificial agents – the ZDP agent, the Mediating Agent, the Social Agent and the Semiotic Agent – and the human agents (learners and tutors). The current system has evolved so that, now, it is composed of human agents (students and tutors) and by five classes of artificial agents: the *Diagnostic Agent* has the function of describing the cognitive diagnosis, modelling the group and suggesting pedagogical tactics; the *Mediating Agent* is an animated pedagogical agent responsible for the interface of the environment with the student and for applying (1) support tactics in accordance to student's cognitive profile (sent by the Diagnostic Agent) and (2) affective tactics in accordance to student's affective state (determined by the Mediating Agent); the *Collaboration Agent* is responsible for mediating/monitoring the interaction among students' groups in synchronous tools of communication among the students (for

example, chat); the *Social Agent* that should establish the integration of the society forming students' groups for study and creating a Collaboration Agent for each formed group; and the *Semiotic Agent* responsible for the use of signs, concepts and language sent to the Mediating Agent or Collaboration Agent and, consequently, presented to the student. Further details of the system may be found in (ANDRADE; JAQUES; VICCARI; BORDINI; JUNG, 2000) (ANDRADE; JAQUES; VICCARI; BORDINI; JUNG, 2001) and (JAQUES et al., 2002). The tutoring system may function as an individual tutor, where the Mediating Agent presents pedagogical contents to the student in accordance to his profile and cognitive style, or as a facilitating system of collaboration, where the Collaboration Agent monitors and mediates the interaction among the students with collaborative tools.

Each student connected to the system will interact directly with the **Mediating Agent**. The Mediating Agent is an animated agent responsible for the interface of the environment with the student and for applying the scaffold tactics suggested by the Diagnostic Agent. Its role is to assist the student in the process of internalisation due to contact with the social environment of distance learning. As the Mediating Agent is the interface of the student with the system, it will gather all the actions made by the user[29]. The Mediating Agent will consider the affective aspect of the interaction with the student. It will gather the user actions and store the affective information in the affective student model. At the same time, it will send all the user actions to the Diagnostic Agent, which is responsible for the cognitive evaluation of the student.

The **Diagnostic Agent** has the function of describing the cognitive diagnosis, modelling and suggesting "scaffold tactics" both for an individual student and for students group. The cognitive diagnosis is based on the notions of the (1) Zone of Proximal Development (ZDP) of the Vygotskian theory (VYGOTSKY, 1978) and (2) Core (LEWIS, 2000). If the Diagnostic Agent verifies that it's necessary to offer a support to the student, it sends a message to the Mediating Agent. If this tactic is, for example, the presentation of an instructional content, the Mediating Agent makes a request to the **Semiotic Agent** which is responsible for searching a determined instructional material in the database.

One of the important concepts of the Vygotsky socio-interactionist theory (VYGOTSKY, 1978) (VYGOTSKY, 1962) is that the relationship man-environment is a relationship mediated by symbolic systems, through instruments and signs. According to Vygotsky, the signs are artificial incentives with the purpose of mnemonic aid; they work as middle ground for adaptation, driven by the individual's own control. The function of an instrument is to serve as tool between the worker (in the case of this research, the student) and the object of his work, seeking help with some activity.

In order to fulfil this function, the system is composed of the Semiotic Agent, which has the role of looking for the instruments and signs to be presented to the student as external stimulation. These signs and instruments (such as pictures, sounds, texts and others) compose the instructional material in the database.

When the Diagnostic Agent considers it would be necessary that more capable students interferes (because some skill is in the ZDP region) or it is interesting to perform an activity in group, it will make a request to the Social Agent. The **Social Agent** looks for more able learners to form a study group and creates a **Collaboration**

[29] In this paper, we employ the term user as synonym for student, since the users of our system are potentially the students. We also consider the term learner as synonym for student.

Agent to assist the interaction among that group of students in a collaborative dialogue tool, such as a chat.

There are a Diagnostic Agent and a Mediating Agent for each student, a Semiotic and Collaboration Agent for the whole society, and a Collaboration Agent for each group of students that has been formed.

Note that the tutoring system may function as an individual tutor, where the Mediating Agent presents pedagogical contents to the student in accordance to his profile and cognitive style, or as a facilitating system of collaboration, where the Collaboration Agent monitors and mediates the interaction among the students in a collaborative dialogue tool. The general architecture of the system can be seen in Figure 5.2.

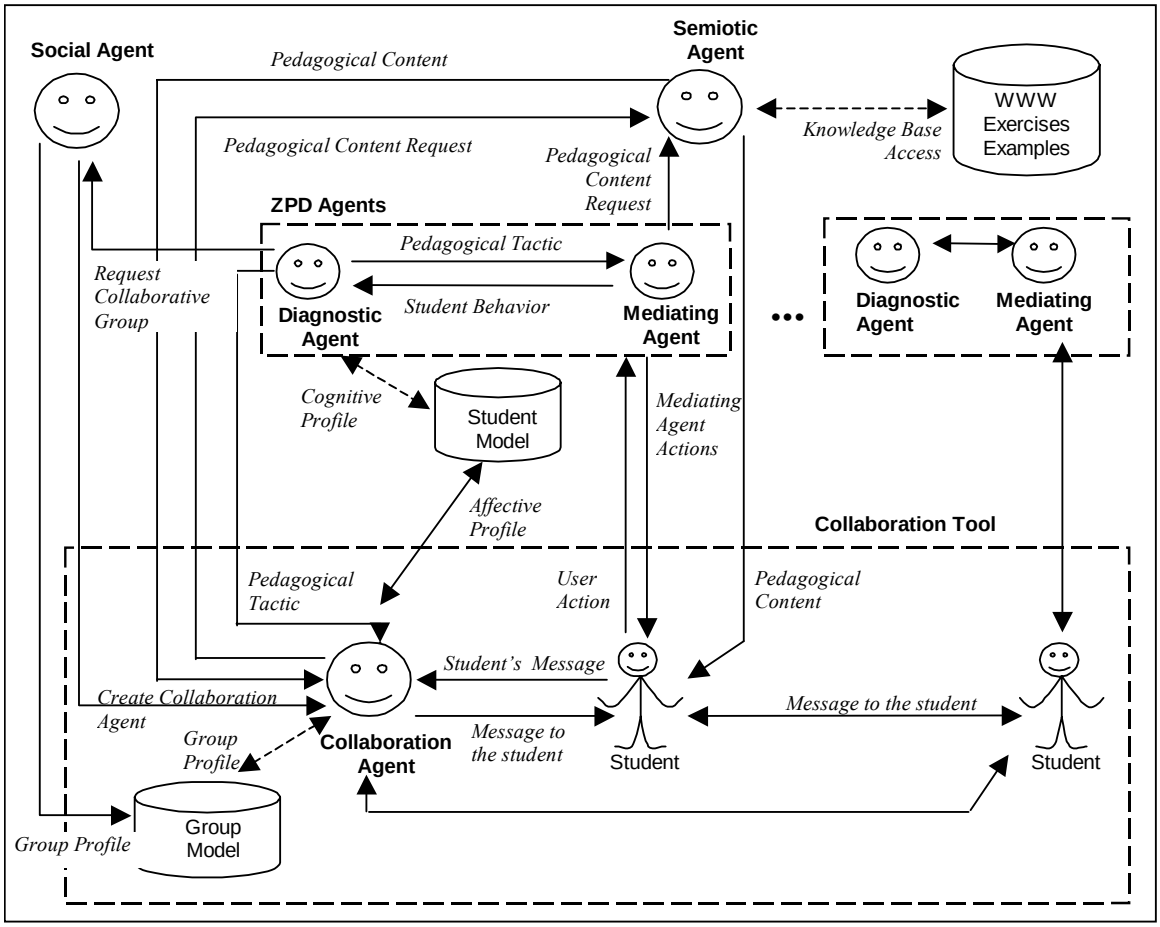


Figure 5.2: A society of Social Agents for a Learning Environment (JAQUES et al., 2002)

When the system functions as a collaborative tool, the Collaboration Agent has an essential role; its function is to promote and to mediate the interactions of groups of students using communication tools (for example chat, discussion list, and distribution list). In such a way, it attends the students during the interactions, stimulating them when they look unmotivated, presenting new ideas and correcting wrong ones.

5.3 The Society of Agents

The computational environment is formed by a society of artificial and human agents. The artificial agents have the function of monitoring and assisting the human agents in their collaborative activities. The human agents are represented by the learners and teachers that use the system.

In this section, we describe the functionalities and internal architecture of each agent that is part of the multi-agent architecture of the system.

5.3.1 The Semiotic Agent

The Semiotic Agent (JUNG, 2001) is based on Vygotsky's notion of mediation and, therefore, it has the function of looking for signs and instruments in the database, when requested by the Mediating Agent, to help the student's cognitive activity, building dynamically the page to be introduced to the student and showing more specific contents as the student is going deeper in the detail of the subject. With this objective, the agent uses several signs, expressed in a variety of ways, for example: the drawing, the writing (presenting the domain in form of paragraphs, examples, citations, tables, keywords, and exercises), systems of numbers, illustrations and multimedia resources, propitiating, thus, the presentation of the instructional material according to teaching tactics specified by the Diagnostic Agent.

The presentation of this instructional material is based on Semiotic Engineering. According to the Semiotic Engineering (PEIRCE, 2000), (ECO, 1976), (SOUZA, 1993), for the communication designer-user to be possible, it is necessary to consider that software applications (that comprehend interfaces) are signs, formed by signs, and that generate and interpret signs. The Semiotic Agent has the role of designer of interfaces. It decides which signs will be used to present a determined subject to the student. The Semiotic Agent constructs a HTML page (HyperText Markup Language) with this pedagogical content and sends it to the Mediating Agent, which will present it in the browser running on the student's computer.

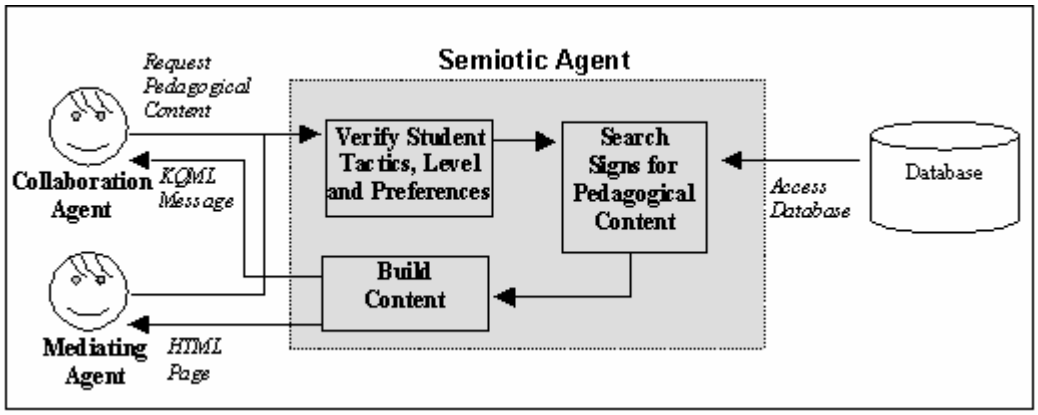


Figure 5.3: Internal Architecture of Semiotic Agent (JUNG, 2001)

Figure 5.3 shows the internal architecture of the Semiotic Agent. We observe that the Semiotic Agent, starting from the solicitation of incoming pedagogical content of the Collaboration Agent or Mediating Agent, verifies which are the tactics, preferences and the student's level, seeking in the database which are the ideal signs to be used for the pedagogical content, dynamically generating a HTML page (as an answer for the

Mediating Agent) to be presented to the student. It can still send a message to the Collaboration Agent, in KQML, saying if the pattern found by the Collaboration Agent during the changes of messages among the students is part of certain content to be treated in the teaching-learning process (JUNG, 2001).

The Semiotic Agent was developed by the master student Joao Luiz Jung who finished his dissertation in December, 2001. It was implemented in Java and a database which contains the signs and instruments that constitute the pedagogical content of the system was also modelled. More details about the Semiotic Agent can be found in Jung's thesis dissertation (JUNG, 2001) and in the papers (JUNG et al., 2001) (JUNG; VICCARI, 2002) (JUNG et al., 2002).

5.3.2 The Diagnostic Agent

The **Diagnostic Agent** (ANDRADE; BRNA; VICCARI, 2002) has the function of describing the cognitive diagnosis, modelling the students, and suggesting "scaffold tactics", both for an individual student and for students' group. The cognitive diagnosis is based on the notions of the (1) Zone of Proximal Development (ZPD) of the Vygotskian theory (VYGOTSKY, 1978) and (2) Core (LEWIS, 2000).

In the system, the ZPD is a subset of domain that describes skills that are not internalised, i.e., skills that the learner does not have yet, but he can perform with some support or scaffold (ANDRADE; BRNA; VICCARI, 2002). The notion of core is defined by Lewis (LEWIS, 2000) as "the knowledge of an individual has a central core that is owned by the individual who is able to use that knowledge in the autonomous performance of tasks". The core is implemented as a subset of the domain, which represents the knowledge internalised (learned) by the learner. In order for the student to execute some task that is in the ZPD level, a kind of assistance, named support (or scaffold), is offered. This support is applied according to the level of the learner with relation to a given domain knowledge and it is associated with the user's actions and activities.

In order to assist the student in the learning process, the Diagnostic Agent must have a learner model, identifying his abilities and deficiencies, which is constructed by the observation of the learner's interaction with other learners and with instructional contents. This way, it is able to indicate how to expand the learner's cognitive abilities; it does so by having access and modifying this model.

Figure 5.4 shows the internal architecture of the Diagnostic Agent. Below, we describe each module of this architecture based on (ANDRADE; BRNA; VICCARI, 2002).

The *Sensor Module* is an internal part of the diagnostic agent. It has the role of communicating with mediator/collaboration agents. This module has the objective of interpreting the message that arrives from the mediating and collaboration agents. The messages are described in ACL format (FIPA, 1997).

The *Effector Module* is responsible for sending messages with "scaffold tactics" to Mediating and Collaboration agents. Besides, this module informs the diagnostic of learners for the other agents so that they can facilitate learning.

The *Open Learner Model* is formed by the cognitive and emotional profile of the learner. The cognitive profile stores the information about beliefs, skills, difficulties and assistance. The emotional profile contains information about the personality of the learner, like introvert, extrovert, if he likes to work in group, and his level of motivation. These parameters are used as first reference, however they can change

during the interaction. This model is considered an open learner model because it is inspectable by the learner, he can analyse and agree or disagree about his diagnosis.

The *Group Model* is formed during the evaluation of the learner's ZPD. When the diagnostic agent discovers that the learner has some skill in ZPD, he suggests forming a group with some expert that has knowledge in that domain area and can help that student. It maintains not only a cognitive status but also an affective profile of the group sent by the collaboration agent. The *Knowledge Update Module* updates the agent beliefs about the learner's performance, goals and skills.

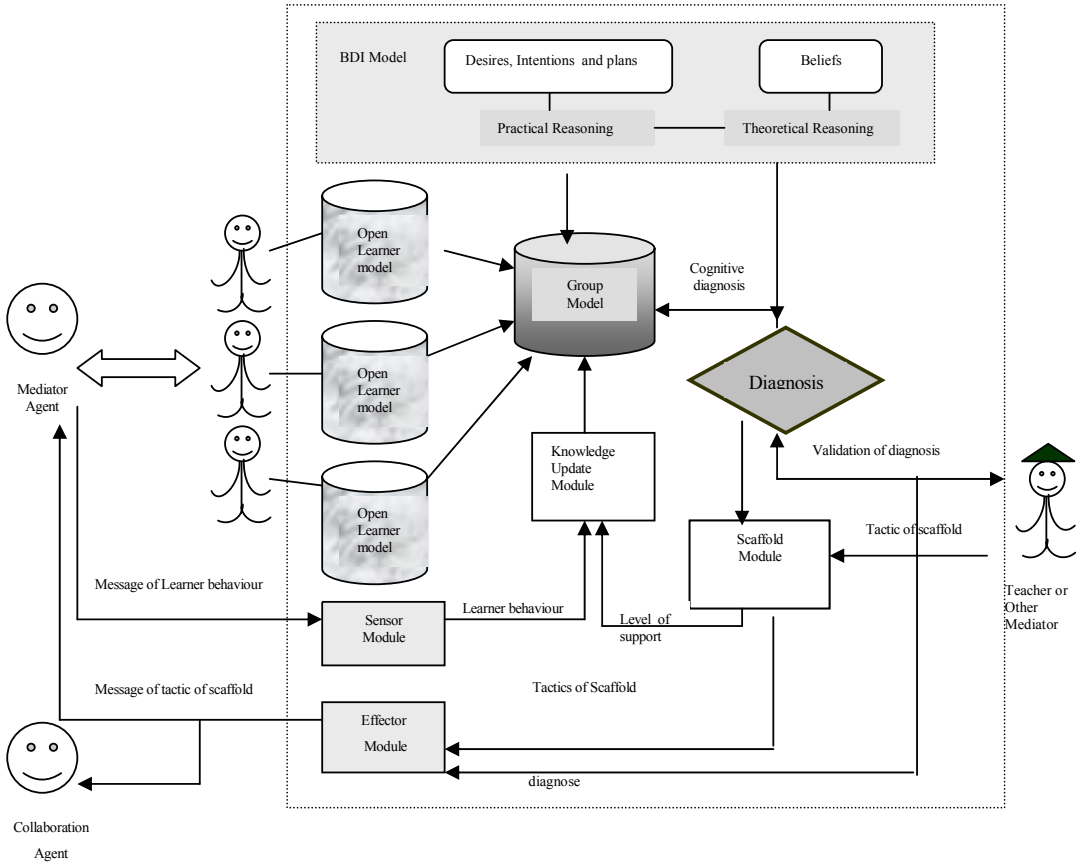


Figure 5.4: The Internal Architecture of the Diagnostic Agent
(ANDRADE; BRNA; VICCARI, 2002)

The *Scaffold Module* is formed by the description of tasks, list of skill in ZPD, level of support (low, moderate, advanced) and the suggested tactics. The learner's knowledge level must be observed before the scaffold tactics (for instance modelling, start solution, give clues) are applied. The tactics have the role of helping the students to perform some task whose skills are in ZPD level. These tactics are sent through the diagnostic agent to the mediator agent and the collaboration agent that interacts directly with the learner.

Diagnosis is the main module of the architecture. Its function is to diagnose what is in ZPD or Core level. The diagnosis starts when the diagnostic agent suggests some task to be performed by the group without any support. After the group accomplished this task, the agent assesses the task performance model and self-confidence model, which describe the level of knowledge and confidence of the learner to realise the given task.

In function of this analysis the agent determines the ZPD_skills, in other words, the skills that the learner can not carry out alone and needs some "tactics of support". For the pedagogical validation of the diagnosis, the agent must communicate with the teacher. The diagnosis must also be updated in the group model.

The *Theoretical-Reasoning Module* represents the agent's beliefs. These beliefs model the knowledge about the domain (based on the BDI description to be described in the next section). However, Beliefs and desires are not enough to implement the agent's behaviour. They need a "plan of actions" to achieve the goal and desires. The *Practical Reasoning Module* represents the planning module, in other words, this module describes the agent's reasoning about what it should do.

The Diagnostic Agent was developed with a BDI architecture by the PhD student Adja Ferreira de Andrade in PGIE- Federal University of Rio Grande do Sul (UFRGS). For the implementation of the cognitive part of the agent, she used the modelling and developing system X-BDI (MÓRA, 1999). More about her work can be found in (ANDRADE; BRNA; VICCARI, 2002) (ANDRADE; VICCARI, 2003).

5.3.3 The Collaboration and Social Agents

Talk and discourse have long been seen as critical components in the learning process (OLIVEIRA, 1997). According to Vygotsky (VYGOTSKY, 1978), learning is frequently achieved through interactions among the individuals that lead to the development of higher order learning, which is obtained when there are cognitive conflicts in the activities. The talk and language allow this kind of cognitive activity because they are means by which the student can justify, explain and acquire new abilities of reasoning (OLIVEIRA, 1997).

The conversational communication tools based in text can promote deeper contributions than the face-to-face interaction; and the absence of visual presence can encourage participants who normally would not contribute (PILKINGTON, 2001). This sort of software is a good mechanism of conversation among students, but it does not provide any guidance or direction for the student during or after the dialogue sessions (SOLLER, 2001).

Our system privileges the social interaction encouraging the students to interact in collaborative tools. This way, the system has two agents with the ability of encouraging the interaction among students: Social and Collaboration Agents. The Social Agent searches for peers that are capable of assisting a student in his learning process and creates a Collaboration Agent to mediate the interaction among the students. The Collaboration Agent will monitor and mediate the interaction between students in collaborative communication tools (for example, chat, discussion list and bulletin boards). It attends the students during the interactions, stimulating them when they look unmotivated, presenting new ideas and correcting wrong ones.

When the Diagnostic Agent considers that it would be interesting to have the intervention of facilitators or other more capable colleagues and/or teachers (because some skill is in the ZDP region), it makes a request to the Social Agent. Then, the Social Agent will invite certain students with a suitable profile to participate in an interaction by means of a collaborative tool, which can be, for example, a chat, a discussion list, or a bulletin board; and creates a Collaboration Agent for mediating the interaction among the students. The Collaboration Agent will monitor the discussions among the students, stimulating them when they look unmotivated, presenting new ideas and correcting wrong ones.

This agent will be connected to the collaborative tool of the system (chat), just as any another user of the system, which gives greater realism to it. From now on, the students can visualise the animated character which represents the collaboration agent, as well as the messages it sends. All the messages sent for the tool can be visualised by all the online users.

The collaboration agent receives the messages of the students. For each received message, the collaboration agent carries out an internal processing in order to respond in an appropriate way to the student. We can see the internal architecture of the Social Agent in Figure 5.5.

We can see in the Figure 5.5, that during the interaction with the students in the collaborative tool, the Collaboration Agent interacts with the Diagnostic Agent to obtain new tactics to be used. In such a way, it must send the actions of the user, in this case, sent messages, so that the Diagnostic Agent decides which tactics must be carried out.

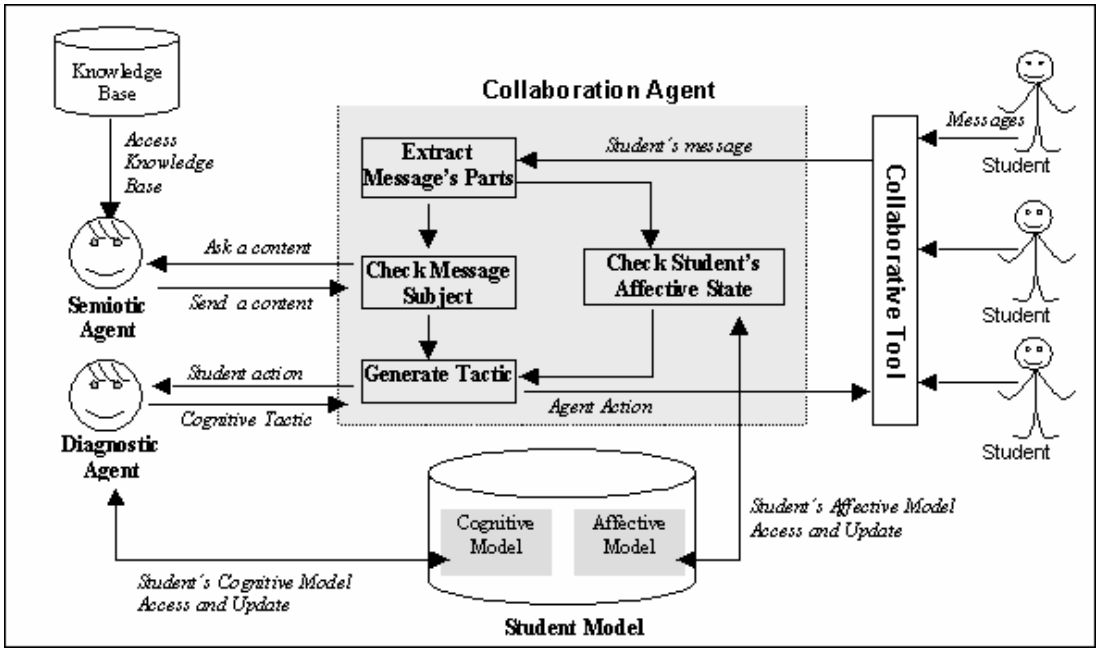


Figure 5.5: The Internal Architecture of the Collaboration Agent (JUNG et al., 2002)

The Collaboration Agent interacts with the Semiotic Agent to get the pedagogical content. For example, the Collaboration Agent can check, in accordance with statistical analyses of the students' message, which students presented incorrect ideas. As the interactions progress, the Diagnostic Agent can decide if a more difficult subject can be presented. In that case, the Collaboration Agent requests that the Semiotic Agent sends certain contents at a more difficult level.

The Collaboration Agent updates the affective model of the student. It is responsible for obtaining the affective state of the student and updating the student model, in order to reply to the student with an appropriate emotional behaviour.

In collaborative learning, the group is an active entity; therefore, the system must contain information that refers to it as a whole. This information generates a group model, which is constructed and stored by the Collaboration Agent.

Due to its social function – to communicate with students, to promote and monitor the interaction among students – it would be interesting for the Collaboration Agent to have an interface that would allow it to exploit students' social nature. In fact, one of

our main concerns is to better exploit the social potential of the students to improve their learning, since studies demonstrate that people interacting with animated characters learn to interact with other humans (HUARD, 1998). Therefore, we chose to represent it as an animated character who has a personality and which interacts with the student through messages in natural language.

The Collaboration Agent will carry out the analysis of the student's dialogue based on statistical methods, such as pattern matching, message categorisation and information retrieval (SOLLER, 2001). The messages will be generated in natural language, using dialogue models and frames.

Prola (2003) in her master dissertation identified, in chat interaction of some virtual classes, some social factors that aim at indicating the *participation*, *collaboration* and *interest* of the students in collaborative classes. This work provided a case study to support the future implementation of the online recognition of these factors in the social agent.

The Collaboration and Social agent will be developed by future PhD students of the Group of Artificial Intelligence of UFRGS (Brazil).

5.3.4 The Proposed Agent: The Mediating Agent

One of the central ideas of Vygotsky's theory, the ZPD (see Section 5.1), is created when two or more people form a collaborative learning partnership in which the most skilled members enable the least ones to achieve their goal. In a real class, the teacher (or other more able colleague) provides support for the student who needs help. In a computational system, it is necessary to offer a more able partner to the learner. It must provide challenging activities and the right quantity and quality of assistance.

This role of a more able partner for the student is accomplished by the Mediating agent in our system. In order to offer appropriate scaffolding, the educational system must model the student's knowledge, based on ZPD, and decide which cognitive tactics it must apply for the student. The cognitive learning model and the cognitive tactics planner are supported by the Diagnostic Agent. This way, the Mediating Agent interacts with the Diagnostic Agent in order to send the student's information (as student's actions which are used by the Diagnostic Agent for student modelling) and to receive cognitive tactics and apply them to the student.

As we saw in Section 5.1, the affectivity has a central role in the ZPD and the teacher who is aware about student's *perezhivanija* (emotions) can engage more effectively the student in learning.

We see two important scenarios to consider the student's emotions in MACES: (1) considering the student's emotions when interacting with the instructional content and his personal partner - the Mediating Agent; and (2) considering the student's emotions when he interacts with other colleagues in the chat tool or in other collaborative tools. For this thesis, we are working with the student's emotions in the first situation. We see that this is not the only possibility and we foresee that the system will handle with student's emotions in the second situation (more specifically this will be handled by the Collaboration Agent). But, due to great differences in the approaches and in implementation technology, we opted to deal with only one scenario. Besides, we see that much study and implementation made for this one could be employed also in the second situation.

In order to accomplish its function of handling the student's affectivity, the Mediating Agent catches the student's affective state by his observable behaviour and

applies tactics in accordance to student's affective state, i. e. promote actions that aims at adapting the system to the student's affective state. This affective tactics can be (1) domain-based tactics to motivate and encourage the student or (2) emotional behaviour to promote a student's positive mood. Therefore, we chose to represent it as an animated character who has a personality and which interacts with the student through speeches. In order to interact in an effective way with the student, the Mediating Agent must interpret the student's affective states correctly and must have an affective model to store this affective information. Due to the dynamic nature of the students' affective information, we adopted a BDI (BRATMAN, 1990) (RAO; GEORGEFF, 1995) approach to implement the affective user model.

The proposal of this work is to model and implement the Mediating Agent, which will be described in detail in chapter 6.

III TOWARDS AN AFFECTIVE AND PEDAGOGICAL AGENT

6 MODELLING AN AFFECTIVE PEDAGOGICAL AGENT

This work proposes an animated pedagogical agent that applies affective pedagogical tactics that aim at promoting a positive mood in the student, which fosters learning process (Section 4.8.1), as well as providing an emotional support to the student, motivating and encouraging him. As a case study, the proposed agent is implemented as the Mediating Agent of the multi-agent architecture of the educational environment MACES, which was described in Chapter 5.

In order to choose the adequate affective tactics for the student's affectivity, the agent should also recognise the student's emotions. With this purpose, the Mediating Agent recognizes the student's joy/distress, satisfaction/disappointment, anger/gratitude, and shame emotions[30]. The student's emotions are inferred from student's observable behaviour, i. e. the student's actions in the interface of the educational system. We grounded the inference of emotions in the cognitive theory of emotions, more specifically, in the OCC model which is based on the cognitive theory of emotions and is also possible to be implemented computationally.

Due to dynamic nature of the student's affective information, we adopted a BDI approach to implement the affective user model. This and other aspects relative to implementation are described in Chapter 7.

In this chapter we describe the process of emotions inference and the affective diagnostic. In Section 6.1 to Section 6.6, we describe the mechanism that the Mediating Agent uses for recognising the student's emotions and how it infers these emotions. In Section 6.7 the affective tactics applied by the Mediating Agent.

6.1 Inferring the Student's Emotions from his Observable Behaviour

In order to accomplish its function, i. e. provide emotional support for the student and to promote positive emotions in him, the Mediating Agent should recognise the student's affective states to respond appropriately. For example, when the student is disappointed with his performance, he will probably give up the task. The agent needs to know when the student is disappointed in order to encourage him to carry on studying and accomplishing the task. Therefore, the Mediating Agent has a sensor component (software) responsible for identifying the student's emotions and an affective model to store this information.

[30] Although we use the terms "emotion" and "affective state" when we refer to the student's emotions that are inferred by the Mediating Agent, affective state is a more wide-ranging term and it comprises the emotions and other states such as moods and sentiments (FRIDJA, 1994). Thus, it is not incorrect to use the term affective state also to denote the emotions, although it is not so accurate. See Section 4.1.

As we showed in Section 4.7.1, the student's emotional states can be inferred from several mechanisms that are able to detect emotion by voice (prosody); facial expressions; and by physiological signs such as blood volume pulse, electromyogram – muscle tension, skin conductivity and respiration.

The Mediating Agent catches the student's affective state from his observable behaviour[31], i. e. the student's actions in the system's interface. So, the agent obtains information about the student's emotions by analysing his actions. There are some examples of observable behaviour: execution time of an activity, success or failure in the execution of an exercise and frequency of assistance required. The student's emotion recognition by his observable behaviour has been adopted by other researchers, as in the works of Bercht (BERCHT; VICCARI, 2000), de Vicent (DE VICENTE; PAIN, 2002) and Martinho (MARTINHO; MACHADO; PAIVA, 2000). More details about these works can be found in Sections 3.3 and 4.7.1.

However, we recognise the existence of other mechanisms to infer the student's affective states, which are presented in Section 4.7.1, and, this way, the agent's architecture foresees the insertion of these other sensors.

Currently, the sensor responsible for inferring student's emotions by his observable behaviour is implemented as a software module of the agent which detects all actions of the student and sends the information to the agent's Mind that is responsible for inferring the student's emotions. Some other emotion recognition mechanisms, such as emotions recognition by user's facial expressions, are composed of a hardware equipment which detects the physiological signs, and a software component which is responsible for decoding the information sent by the equipment. For example, Wehrle and Kaiser (2000) videotape user's facial expressions playing a game with a video-camera and use the software FEAT for analyzing automatically the recorded facial behaviour. The date detected by these sensors allows to infer more accurately the student's emotions. For example (CONATI, 2002) (PICARD, 1997):

- Frowning eyebrows (that can be detected by using software to perceive facial expression) are a good indicator of anger and reproach emotions.
- Skin conductivity is a very good indicator of the level of arousal.
- Heartbeat (measured from a heart rate monitor) increases more in the presence of emotion with negative valence.

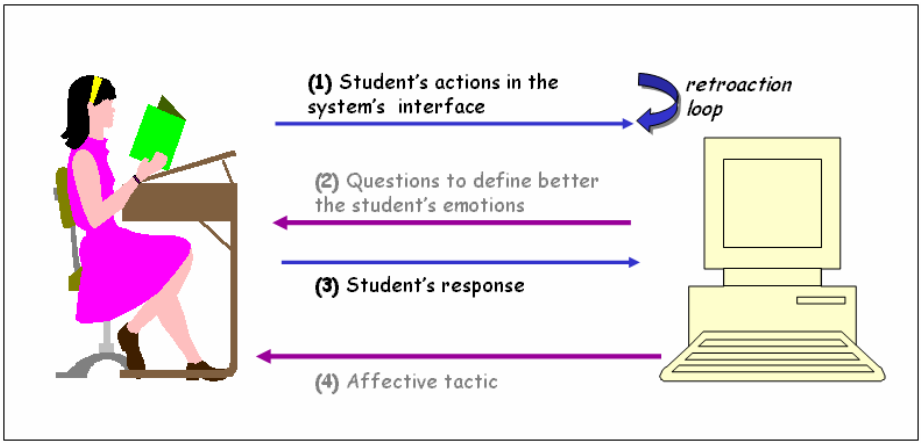


Figure 6.1: Student's Emotion Recognition Scheme

[31] This and other forms to recognize user's affective states are described in Section 4.7.1.

We verified that some actions (or a set of actions) could indicate more than one emotion. In this case, it was necessary to resolve this ambiguity. In order to better define the student's emotions, the system makes questions to the student. The student's emotion recognition is represented by the scheme presented in Figure 6.1 and by the following steps:

- The agent catches the student's actions in the system interface. In some cases, a set of actions is necessary to deduce a student's emotion. In this case the system keeps locked in a retroaction loop.
- Each action (or a set of actions) can indicate more than one affective state. Then the system makes questions to the student in order to define more accurately the student's emotional states or even when the system is not sure about a determined affective state. The questions can be of two types:
  - Direct: "Are you disappointed with your performance on the exercise?"
  - Indirect: "Do you think that you can not resolve the task?"
- The student answers the agent's question.
- Finally, the agent infers the student's emotional states from this information and chooses the affective tactics to present to the student.

In relation to the questions that the agent asks to the student during the interaction, we intend to bypass the lack of natural language processing of the interface by limiting the learning input to a set of standard expressions accessed by menus. Although the communication with the learner is limited, the possible answers offer less ambiguous interpretation to the tutor about the student's emotional states. This was originally suggested by del Soldato and de Boulay (1995).

The system can also apply a **questionnaire** to the student in the beginning of the interaction, for example, to know the student's goals and preferences, which will help the system to better determine the student's emotions in the future. It is important to underline that the questionnaire can be just used as an auxiliary tool (and can not be used as an isolated mechanism to recognise the student's emotions) because it is static, while the emotions have a dynamic nature, i. e. we can fell happy in a specific moment and sad in the next. In our work, we use a questionnaire for determining the student's goal (that is used to infer the student's emotions - see Section 6.3), which is an information less dynamic about the student.

The student's self-evaluation can also be another mechanism that helps us to increase the efficacy on the determination of student's emotional states. The use of questionnaires and self-evaluation was proposed by del Soldato (del SOLDATO; de BOULAY, 1995). We do not use self-evaluation because it is a static mechanism for determine student's emotions.

6.2 Which Student's Affective States to Recognise?

According to Conati (CARBERRY et al., 2002, p. 649), the user's affective states that should be modelled in a computational system are "the ones that significantly influence the user's behaviour in the task that the system is designed to support and these emotions are generally task-dependent".

Thus, the question is "Which affective states are important to be modelled in a situation of teaching and learning with an artificial pedagogical agent?"

According to Lisetti (CARBERRY et al., 2002), emotions such as surprise, confusion, frustration, and satisfaction, for example, can help to monitor the user's

learning process, and teachers generally rely on these cues from their students to pace a lecture.

In our work we recognise the **joy** and **distress**, **satisfaction** and **disappointment**[32] emotions, as well as **gratitude** and **anger** emotions, and **shame** emotions.

As we infer these student's emotions from his observable behaviour (his actions in the computational system interface), we need a psychological theory that grounds it. The **cognitive theory of emotions** (see Section 4.5) is adequate, because it considers that emotions are elicited by a cognitive evaluation (which is called appraisal) made based on stimulus of the world and user's behaviour. Specially, we are going to use the OCC model (see Section 4.6), which is based on the cognitive theory of emotion and is possible to be implemented computationally. The OCC model provides information on how to build an interpretation of a situation from the user's point of view and to which emotion this interpretation leads. This approach is also used by (MARTINHO; MACHADO; PAIVA, 2000) and (CONATI; ZHOU, 2002) for educational games.

According to the OCC model, **joy** and **distress** emotions arise when a person focus on the desirability of an event in relation to his goals. For example, for a determined student which has the goal of pleasing the teacher and his parents, obtaining a good grade is a desirable event. The OCC model defines joy as a person pleased about a desirable event, and distress as a person displeased about an undesirable event. Figure 6.2 illustrates the appraisal for joy and distress emotions according to the OCC model.

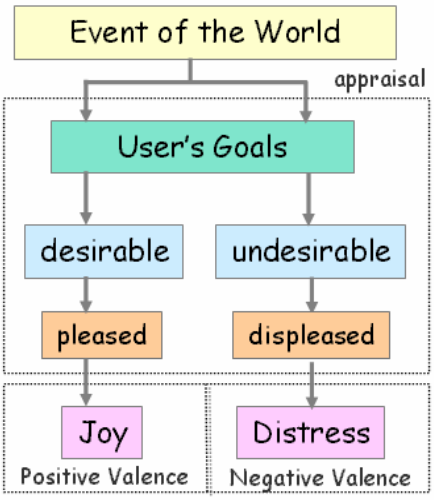


Figure 6.2: Scheme Representing Appraisal for Joy and Distress Emotions

The OCC model considers that emotions of **satisfaction** and **disappointment** are elicited when a person has a confirmation or disconfirmation of the prospect of a desirable event (ORTONY; CLORE; COLLINS, 1988). It means that the student knows that an event that was expected because it is desirable will or will not happen. The satisfaction emotion arises when one is *pleased* about the confirmation of the prospect of a desirable event and disappointment when one is *displeased* about the disconfirmation of the prospect of a desirable event. Figure 6.3 presents a scheme that illustrates the appraisal for Satisfaction and Disappointment emotions. Knowing the student's satisfaction and disappointment emotions can help the agent to detect the

[32] According to Ortony, Clore and Collins (1988), frustration has the same lexical meaning of disappointment.

student's engagement, since, generally, when the student is satisfied, he is more engaged in the course than when he is disappointed.

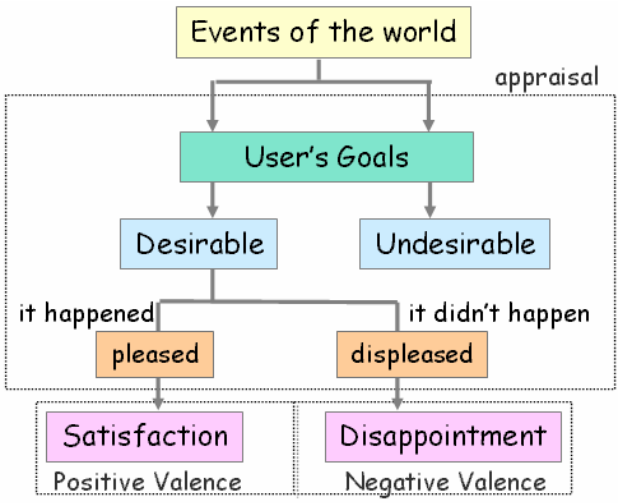


Figure 6.3: Scheme Representing Appraisal for Satisfaction and Disappointment Emotions

Besides, according to the OCC model (ORTONY; CLORE; COLLINS, 1988), emotions of **gratitude** and **anger** are elicited when actions of agents are evaluated according to their interference in the achievement of one's goals. The OCC model defines the gratitude emotion as approving of someone else's praiseworthy action and being pleased about the related desirable event. Anger arises when one disapproves someone else's blameworthy action and is displeased about the related desirable event. In our educational system, the emotion of anger arises when the student evaluates that an action of the Mediating Agent interferes with his goals, and gratitude arises when an action of the Mediating Agent promotes his goals. Figure 6.4 shows a scheme representing the appraisal for gratitude and anger emotions according to the OCC model.

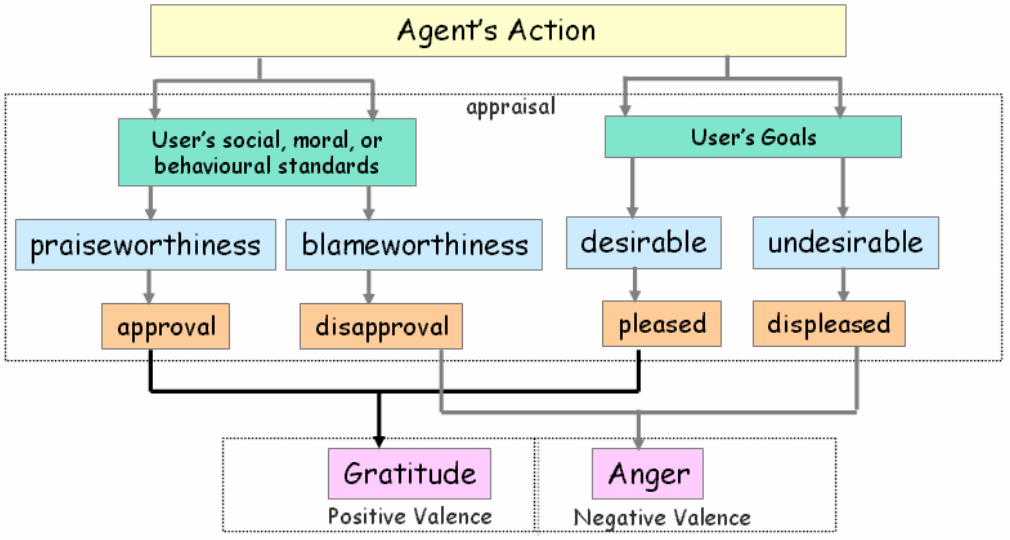


Figure 6.4: Scheme Representing Appraisal for Gratitude and Anger Emotions

If the action that is evaluated is a student's own action (the student is the agent of the action), the **shame** or **pride** emotions can be elicited. Pride arises when a person approves his praiseworthy action and shame when this person disapproves his own blameworthy action. Figure 6.5 represents the appraisal for the pride and shame emotions.

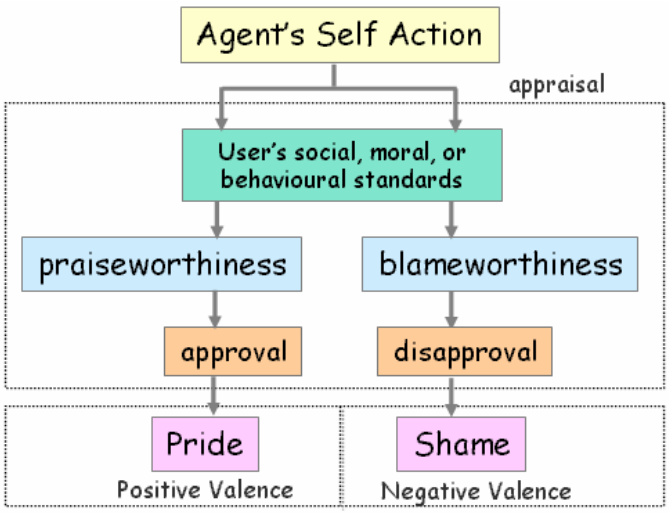


Figure 6.5: Scheme Representing Appraisal for Pride and Shame Emotions

The Longman Dictionary (SUMMERS, 1987) defines joy as "great happiness and pleasure" and distress as "a feeling of extreme worry and unhappiness". According to the same dictionary, the satisfaction emotion is "a feeling of happiness or pleasure because you have achieved something or got what you wanted"; and disappointment is to be "sad because something you hoped for did not happen, or because someone or something was not as good as you expected". Anger is "a strong feeling of wanting to harm, hurt or criticize someone because they have done something unfair, cruel, and offensive" and gratitude is defined as "the feeling of being grateful". Shame is described as "the uncomfortable feeling of being guilty and embarrassed that you have when you have done something wrong". These definitions are somewhat close to the definitions of the OCC model.

When the student has emotions as pride/shame and gratitude/anger, the emotions are towards the Mediating Agent, which is an inanimate object. Although it seems unreasonable that the student has emotions towards a computer program, it is what happens in real-life, as show the works of Reeves and Nass (1996). They assert that people interact with machines as if they were social actors and, in this way, feel emotions that they feel when interact with other humans.

According to the OCC model, emotions are always valenced reactions. Joy and distress emotions are opposite valenced reactions for the evaluation of events, satisfaction and disappointment for the prospect of events, as well as gratitude, anger and shame for the actions of an agent.

The emotion that is elicited depends mainly on the person's interpretation of a situation and on which aspects of a situation this person focuses.

For example, let's suppose a person learns that his neighbour is a merciless child-beater. If such a person focuses only on the neighbour's role as the *agent* of child-beating, he will probably have reproach emotion. The person can focus on the aspects of

the child-beating *event* and if it focuses only on its undesirability he will probably feel distress. He could also focus on his neighbour's children and experience pity. Finally, the person can focus on his neighbour and feels hatred. In reality, according to the OCC, it is more probable that "a person will experience a mixture of emotions resulting from considering the situation from different perspectives at different moments so that some of the resulting emotions may co-occur and some will occur in sequences" (ORTONY; CLORE; COLLINS, 1988, p. 21).

This is the case of satisfaction/disappointment and joy/distress emotions. For example, because satisfaction results from the confirmation of a desirable event, the eliciting conditions for joy emotions will be satisfied by virtue of that desirable event. The OCC model asserts that, for the cases when two emotions co-occur that are compatible in this way (i.e., the elicitation of one entails the elicitation of the other), the most intense emotion presents itself to conscious awareness more insistently than the least intense one. In general, satisfaction is more likely to be available in consciousness when the desirability of the event in question is not very high. We consider in our work that all events that are expected elicit a mixture of satisfaction and joy emotions (when they have positive valence), or disappointment and distress (when they have negative valence). If the event is not expected, it elicits only joy or distress emotions, since satisfaction and disappointment are valenced reactions for the prospect of an event.

The case is different for gratitude and anger emotions, which are compound emotions. Although these emotions are elicited when the eliciting conditions for joy/ distress, and admiration/reproach are satisfied, they are not a mixture of these emotions. For example, despite the fact that gratitude is elicited when is also elicited the conditions for admiration and joy emotions, gratitude is not a mixture of admiration and joy, but the resulting emotion when one focuses on *both* the blameworthiness of the agent's action (the eliciting condition for admiration emotion) *and* on the desirable event (the eliciting condition for joy emotion). A person can also focus on the constituents individually, and then the associated emotions are likely to be experienced along with gratitude. In this work, we consider that the student focuses on both eliciting conditions and so the student experiences gratitude or anger emotions individually, since the agent's actions that elicit these emotions are not highly undesirable events and because they are viewed as caused by the Mediating Agent.

So, the emotion that is elicited is the effect of focusing on different aspects of an emotion-inducing situation. But, identifying each emotion disconnectedly seems to be the first step to identify this mixture of emotions that happens in real life.

Another important point is the words that are used to characterize the emotions. There is an abundance of lexical gaps when we use words for referring emotions. In a determined culture, the same word can be used for two distinct emotions, according to a cognitive psychology theory. But, at the same time, in order to specify a domain of a theory of emotions, it is difficult to avoid using natural language words or expressions that refer to emotions. Besides, for some categories of emotions, a language like English provides a relatively large number of tokens. In such cases, it becomes necessary to identify one of the words in the category as the category label. It is what the OCC model does. For example, fear has lexical realizations that mark special cases such as very strong fear ("terrified"), very weak fear ("worried"), and so on. Thus, we need to think of the word "fear" as a relatively neutral word for an emotion type, fear. In other words, we can view the word "fear" as designating a distinct emotion type (whereas the word "terrified" does not). This is the same for the OCC emotions considered in this work. We need to think of the emotions words of this work, as emotion labels for

determined type of emotions. In this work, when we say that we infer the student's satisfaction emotion, we refer to the emotion's type satisfaction according to OCC model. We do not have available computational resources that allow us to precisely infer the emotion's intensity and, in this way, to use an appropriate token for designating a determined emotion with a determined intensity.

We recognise that the inference of other emotions will enhance the accuracy of our affective model, but we think that with the recognition of the emotions cited above we can already obtain relevant results and in this way validate our proposal. Besides, this thesis is one of the first experiences of the group (the first work is Bercht's thesis, which is described in Section 3.3) in an affective modelling, and we had some restrictions of time to accomplish this work. But we believe that the recognition of these seven emotions gave us good insights that will help in a future work to infer other student's emotions.

To detect the student's joy/distress, satisfaction/disappointment emotions, all the events of the educational system will be evaluated in the light of their desirability in respect of the user's goals. So, to determine the student's emotions, first, it is necessary to **define the student's goals** (see Section 6.3). Afterwards, we need to define the **events that can happen** (see Section 6.4); their **desirability according to student's goals**. To detect the student's gratitude and anger emotions, the event should be caused by an agent, in the case of our work, by the Mediating Agent. Shame arises when the event is caused by the own student. These steps are described in detail in the next sections.

6.3 Defining Student's Goals

So, to determine the student's emotions, first we have to determine the student's goals in order to determine if the events of the world are desirable according to these goals and when the student is pleased/displeased with the occurrence or not of these events. Ortony and colleagues (1988) define a goal as the kinds of things that can be pursued and the kinds of things for which one believes that one can develop a plan for them to be realized. According to the authors, there are three kinds of goals: *Active-pursuit* goals (A-goals), *Interest* goals (I-goals) and *Replenishment* goals (R-goals). The A-goals represent the kind of things that one wants to happen, because he/she wants to achieve them, either to satisfy certain biological needs, to enjoy certain things, or to preserve some state of affairs. Either these goals are necessary to achieve other goals, or to handle crises. While the *A-goals* represent things that one wants to get done, the *I-goals* represent the kind of things that one wishes to see happen. They are generally those goals that a person does not believe that he or she can exert a great deal of influence over them. For example, the interest of a friend prospering, of one's favourite sport team be successful, and of preserving the health of another person. The *R-goals* are those achievement goals that are not abandoned when they are achieved. They represent those goals that have a cyclical nature, such as feeding oneself, filling one's car with gasoline, receiving one's regular pay check.

And in an educational situation, what goals does the student have?

According to Ames (AMES, 1990), students can have *mastery* or *performance* goals[33] that are the reasons for which students to engage.

[33] The term achievement goal is also used as synonym of goal orientation.

Students who have a *learning/mastery goal* are oriented toward developing new skills and abilities, trying to understand their work, improving their level of competence and learning new things (AMES, 1990). “They resolve an activity for its own sake, for the enjoyment it provides, for the learning it allows, or for the feeling of accomplishment it evokes” (LEPPER *apud* AMES, 1990). These individuals make more effort to learn something new or when they confront challenging tasks. When they experience difficulty, they increase their efforts because they believe that effort is necessary for success or improvement (MEECE; MCCOLSKEY, 2001). They are also called *intrinsically motivated*.

When students have *performance goal* they believe that performance is important and want to demonstrate that they have abilities (AMES, 1990). They feel successful when they please the teacher or do better than other students, rather than when they learn something new. When these students experience difficulty, they are not likely to increase their effort because this shows lack of ability according to their point of view. As these students are primarily motivated by extrinsic factors (grades, parent approval, etc), they are also called *extrinsically motivated*.

Learning or performance goals can be classified as *Active-pursuit* goals, according to Ortony and colleagues classification (ORTONY; CLORE; COLLINS, 1988).

In Figure 6.6 we can see an imaginary structure of goals for students that have performance goal. This scheme was made based on the macro-structure proposed by (ORTONY; CLORE; COLLINS, 1988).

This scheme aims at offering a simplified view of the student’s goals. As Ortony and colleagues state, indeed, it seems that this structure is more complex than a tree, as they propose; even though its overall shape is probably treelike. The high-level nodes represent fairly abstract goals that might be characterized as aspirations or general concerns, while the nodes at the lowest level are the more concrete immediate goals. The nodes have connections with the other goal nodes. Incoming connections represent those goals whose achievement can be affected by the achievement of lower-level goals from which the links come. For example, in order to achieve the “*please the teacher and parents*” goal (Figure 6.6), the student must obtain “*good grade*”. This same connection is an outgoing one for the “*good grade*” goal.

When a goal has multiple outgoing connections, it means that the achievement of that goal can directly affect other goals. So, for example, attaining the “*good grade*” might affect not only a “*please the teacher and parents*” goal, but also a “*do better than other colleagues*” goal, and “*show that has a high level of competence*” goal.

While outgoing links are usually conjunctive, i. e. a goal can have many consequences, incoming links can be conjunctive or disjunctive. Disjunctive incoming links represent alternative ways for achieving the goal. The conjunctive links represent those links that must be achieved together for the accomplishment of the goal in question. To represent conjunctive and disjunctive goals, we use the nomenclature proposed by Ortony and Colleagues. According to them, the links can be classified as sufficiency, or necessary, or facilitative, or inhibitory links. *Sufficiency* (marked with an **S** in the Figure 6.6) links are those that can be considered in some degree sufficient to achieve the goal. No particular one of the *sufficiency* links is necessary, but it is necessary that one of them succeed. In the conjunctive case, the links are all to some degree *necessary* (marked with an **N**), none of them alone being sufficient. Besides, a link can also be *facilitative* (marked with an **F**), which means that it is neither necessary, nor sufficient, but when achieved, it increases the probability that a higher level goal will be achieved even though it does not guarantee it. Furthermore, a link can also be

inhibitory (marked with an **I**), which means that the sub-goal reduces the probability of attaining the high-level goal.

As Figure 6.6 shows, a performance oriented student have as high-level goals "please the teacher and parents", "do better than other colleagues", and "show that he has a high level of competence". In order to "please the teacher and his parents" it is sufficient that the student has good grades. To achieve the goal "do better than his colleagues" it is necessary that he obtains good grades, but he should also obtain better grades than his colleagues. But in this work we do not consider the affective aspects of the collaborative learning. In order for the student to "show that he has a high level of competence" it is necessary that he obtains "good grades", makes "low effort" and "does not ask for help" (since he believes that make high effort and ask for help mean lack of ability). "Provide a correct response for the exercises" is sufficient to "have success in the activities", which is sufficient to have "good grade". In order to "have success in the activities", the student must "finish the proposed activities". "Receives appropriate help" from the Mediating Agent can facilitate his goal of "having success in the activities".

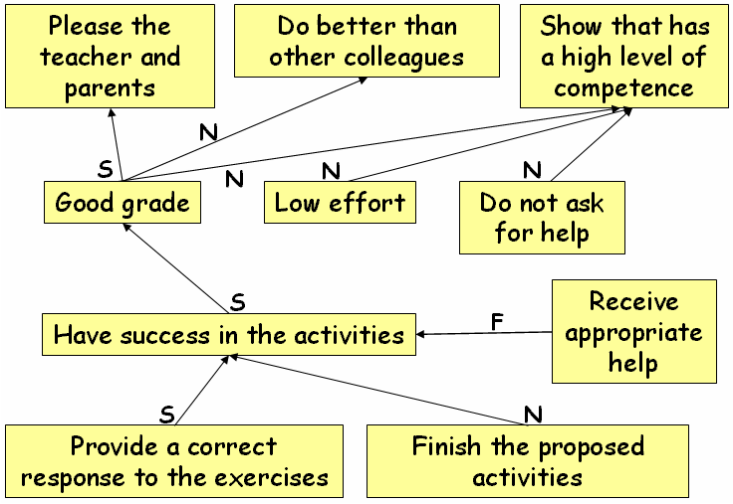


Figure 6.6: Virtual Goal Structure of a Performance Oriented Student

Figure 6.7 shows the virtual goal structure for the students that are mastery oriented, which is also based on the Structure of Virtual Goals proposed by (ORTONY; CLORE; COLLINS, 1988, p. 36). The intrinsic student has the goals of "developing new skills", "improving his level of competence", and "learning new things". The goals of making "high effort" and "receive appropriate help" of the Mediating Agent are necessary to achieve the other goals. To "ask for help" when having difficulties and to "finish the proposed activities" can facilitate the achievement of the high-level goals. The mastery student believes that to "have success in the activities" can facilitate his high-level goals, since it shows that the student learned the taught subject. To the student "have success in the activities" is sufficient to "provide a correct response for the exercises".

In order to identify the student's goal orientation we use the *Motivated Strategies for Learning Questionnaire (MSLQ)* (PINTRICH, 1991). The MSLQ is a self-report instrument which allows to determine students' motivational orientation and learning strategies. It is based on a cognitive view of motivation and learning. MSLQ was developed by a group of researchers from the National Center for Research to Improve

Postsecondary Teaching and Learning and the School of Education at University of Michigan.

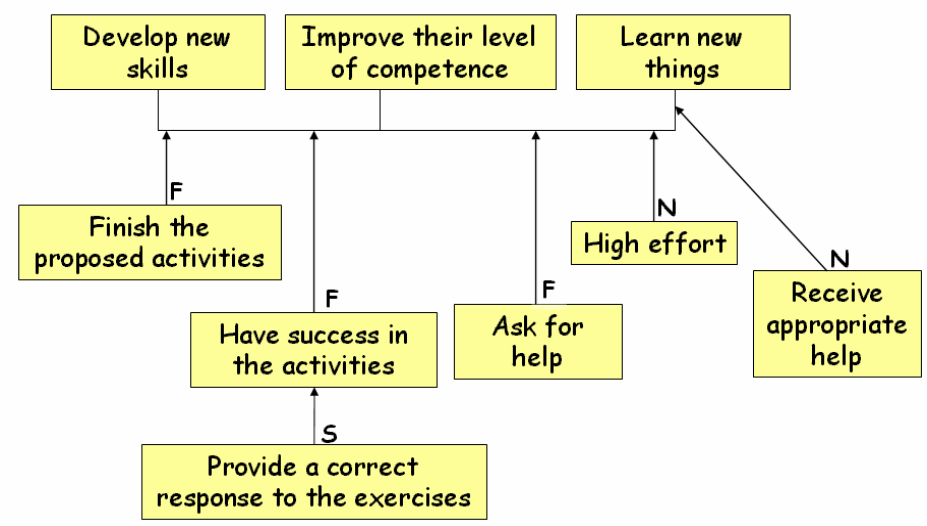


Figure 6.7: Virtual Goal Structure of a Mastery Oriented Student

To determine students' motivational orientation, the questionnaire has 8 items (questions). For each question, the student must provide a response that can be a number between 1 and 7 which means how true is the item for the student (1 = "Not at all true for me" and 5 = "Very true for me."). For example, the following item is part of the Mastery goal orientation section of the questionnaire: "In a class like this, I prefer course material that really challenges me so that I can learn new things". As example of an item of the Performance goal orientation section, we can cite: "Getting a good grade in the class is the most satisfying thing for me right now". The Mediating Agent presents this questionnaire to the student in the first time he uses the educational environment. The questionnaire MSLQ is showed in Appendix I.

6.4 Events in the Educational Environment

In order to accomplish the next step which is to determine the desirability/undesirability of events, we need to know what events can happen in the educational environment. Events are the way people perceive things that happen. "They are people's construals about things that happen, considered independently of any beliefs they may have about actual or possible causes" (ORTONY; CLORE; COLLINS, 1988, p. 18). In our educational environment the events can be caused by either a student's action or the Mediating Agent's action. In a computational environment for learning a great number of events can arise. For our study and prototype's implementation, we chose a limited number of events due to time restriction. But, we believe that these events are sufficient to validate this thesis proposal. Table 6.1 shows some events that can happen in our educational environment and which are analysed in this work. Some of these events can be viewed as an action of the student and, in this case, can elicit shame emotion.

Table 6.1: Events in the Educational Environment that Elicit Satisfaction/Disappointment and Joy/Distress Emotions

SECTION	Student begins section (login)				
	Pedagogical Subject	Begins a pedagogical subject (can be formed by many chapters)			
		New chapter	Content		
			Examples		Correct
			Exercises	Responses	Not correct
					Student did not accomplish it
		Finish chapter	Student did not begin it		
			Student accomplished it		
			Student did not finish it		
	Finish Pedagogical Subject	Student did not begin it Student accomplished it Student did not finish it			
	Finish Section (logout)				

The pedagogical scheme is formed by different pedagogical items, for example, a chapter or a section. Each chapter (or another item) is composed of a pedagogical subject, examples and exercises. They are chosen by the Diagnostic Agent. At each chapter, the student asks the agent to go to the next chapter or to return to the previous section.

Table 6.2 shows the events in the educational environment which were caused by the Mediating Agent. When these events (that are the Mediating Agent's actions) are evaluated by the student, they can elicit emotions of gratitude or anger in relation to the agent that causes them, in this case, the Mediating Agent.

Table 6.2: Events in the Educational Environment that Elicit Gratitude and Anger Emotions

AGENT'S ACTIONS	**Help**	Agent offers help	Student denies agent's help	
			Student accepts	Specific Help
				Generic Help
		Student asks for help	Specific Help	
			Generic Help	
	Message	Agent present a message of encouragement and motivation to the student		
	Behaviour	Agent presents a sequence of animations that aims to encourage, motivate and create a positive mood in the student. This behaviour is usually followed by a message.		

The student can ask for help or the agent diagnostic can decide to offer some help to the student. This help can be specific or generic. A generic help provides examples, formulas and explanations for an exercise or pedagogical subject. The specific help

shows how to accomplish the exercise. The student can deny the help offered by the agent, but the agent always accept the help asked by the student.

As the agent is a lifelike agent with artificial voice, it can present animations and messages of motivation and encouragement to the student. The system is available on the Internet. This way, the student must logon each time he desires to use the system.

In the next section, we present the variables that interfere in the intensity of the emotions.

6.5 Intensity of the Emotions

The intensity of the **joy/distress** emotions depends mainly on the degree to which the event is *desirable* or not. The intensity of emotions **satisfaction/disappointment** also depends on the *desirability* of the event, on the *effort* made for the accomplishment of the event, and on the *realization* of the event (the degree to which the confirmed or disconfirmed event is realized).

The intensity of the shame emotion depends on the degree of judged *praiseworthiness*/*blameworthiness* of the agent's action, and on the *deviation of the agent's action from person/role-base expectations*. The intensity of **gratitude** and **anger** emotions depends on these variables and also on the *desirability* of the event.

Besides, the OCC theory considers that other global factors (that affect all OCC model's emotions) must also be considered: *sense of reality* (the degree to which the event that underlies the affective reaction seems real to the person experiencing the emotion), the *proximity* in time of the event, the event's *unexpectedness* (unexpected positive things are evaluated more positively than expected ones), and the level of *arousal* (the physiological response of the organism).

In this work, we do not consider the *arousal* variable, since we do not have the appropriate physiological sensors to identify this kind of information. We also believe that the *sense of reality* variable can also be disregarded, since it is used to explain when emotions are elicited by an imaginary event. In the same way, as the event generally already happened, the variable *proximity* can also be ignored.

The degree of *desirability* of an event can be measured through the information that we have about performance and mastery oriented students. For example, we know that mastery oriented students desire more strongly to obtain a high grade. We use Bercht's model of effort (section 3.3) in order to measure the student's *effort* that can be minimal, little, medium, big and maximal. This variable is considered for all emotions recognised in this work. The *realization* variable can also be considered. For example, when an extrinsic student wants to obtain an excellent grade to please the teacher, if he just obtains a good grade, he achieves his goal partially. For the performance oriented student who usually receives average grade, to receive the maximal grade is an event with high *unexpectedness* and, so elicits the satisfaction emotion with a higher intensity. In the Section 6.6, we describe how these variables will be considered. The *praiseworthiness* of an agent's action is related to the degree that people do things that appear to us to uphold valued standards and blameworthiness to the extent that violate them. Praise can arise when the agent accomplishes well its role of an effective and empathic tutor, and blame in opposite situations, such as when the agent disturbs the students or in other situations in which the student thinks that the agent's action is impairing his performance and his study. By the moment, it is very difficult to know the blameworthiness/praiseworthiness of the agent's actions. If the agent asks questions for the student, it can disturb more the student and it becomes a more blame action. But we

hope that when we use other instruments for recognising the student's emotions, we can infer more accurately the intensity of this variable. Finally, the *expectation-deviation* variable is manifested in terms of deviations from expectations about what could normally be expected of a person. As the Mediating Agent always acts in order to help the student and shows empathy, we think that there is not deviation of its role in its actions.

In the next section we describe how the Mediating Agent infers the student's emotions from the events and the student's goals.

6.6 The Student's Emotions

Table 6.3 shows the emotions that are elicited, for each event, for students who have mastery goal orientation and Table 6.4 presents the emotions that are elicited when the student has performance goal orientation. In the column "*Events*" we present the events that can happen. Once we know the student's goals and the events that can arise in our educational system, we can determine the event's desirability according to the student's goals. This process is necessary to infer the student's appraisal, i. e. the cognitive evaluation that elicits emotions. Each event is classified as *desirable* (marked with a **D** in the table), *undesirable* (marked with a **U**), or with *no valenced reaction* to the situation (marked with an **N**) in the column "*Event's Desirability*". Sometimes, in order to determine if an event is desirable or not, the agent needs to make questions to the student or access other kind of information (for example, the student's effort). These questions are presented in column "Agent's Question". In the column "Student's Response", possible responses given by the student[34] are presented. The column "Intensity Variables" describes the variables that affect the intensity of each emotion, and, finally, the column "Emotions" presents the elicited emotions of the student. The emotions can be Distress or Joy, Disappointment (marked with **Disap**) or Satisfaction (marked with **Satisf**), Gratitude or Anger, and Shame.

When an event is desirable, it elicits the **joy** emotion, and when it is undesirable it elicits the **distress** emotion. For example, for a performance oriented student who has the goal of pleasing his parents, to provide a correct response for an exercise is a desirable event because it promotes his goal, and for the same reason, not to provide a correct response is an undesirable event.

For the **satisfaction** and **disappointment** emotions, it is necessary to know when the event is expected and if it happened or not. The majority of educational events can elicit satisfaction and disappointment emotions because they have a degree of expectedness. When the student is pleased, in sufficient intensity, because a desirable and expected event happened, he feels the satisfaction emotion. When he is displeased because the event did not arise, he has the disappointment emotion. Sometimes, the student can see an undesirable event as an expected desirable event that did not happen. This is the case of the event "the student did not provide a correct response for an exercise". If the event "to provide a correct response for the exercise" is a very desirable and expected event, the student can interpret the event "the student did not provide a correct response for an exercise" as a desirable event that did not happen and so elicit disappointment emotion. The emotions of the student that are elicited for each event are shown in the column "**Student's Emotions**".

[34] Standard expressions available through menus, as section 6.1 explains.

The satisfaction and disappointment, joy and distress, and anger and gratitude emotions have opposite valence. The student can not experiment disappointment and satisfaction at the same time. This way, when the student has a disappointment emotion, the satisfaction emotion dies. Since the Mediating Agent aims at promoting a positive mood in the student, it acts in order to cancel the student's negative emotions. So, we consider that the Mediating Agent's interventions always annul the student's negative emotions.

6.6.1 Elicited Emotions when a Student Has Mastery Goal Orientation

The events 1, 2 and 3, showed in Table 6.3, concern the accomplishment of the tasks by students who have mastery goal orientation.

If the student accomplished the task incorrectly or did not finish it (events 1 and 3), it is necessary to know if it was important to him to learn about the pedagogical subject relative to the task, since the mastery oriented students are motivated to learn those subjects that they think are interesting. If he has the goal of learning that subject, it is an undesirable event; otherwise not. When the event is undesirable, the elicited emotions are Distress and Disappointment. The intensity of these emotions depends on the degree of *realization* of the event, on the event's *unexpectedness*, and also on the event's desirability. The realization variable can be determined by the grade obtained by the student in the exercise. The degree of *realization* is higher, if the response is 70% incorrect than when the response 50% incorrect and, so, the student is more disappointed in the former situation. We consider that the degree of realization is stronger for the responses in which the degree of incorrectness is superior to 50%. The degree of *unexpectedness* can be measured by the actual performance of the student. The event "not provide a correct response for an exercise" is less unexpected when the student is having an excellent performance. We consider that when one or more of these variables have a higher degree, an emotion with a higher intensity arises (marked with a ++).

If he accomplished the task correctly, which is a desirable event, it is important to know if he made a high effort (event 2). Students with mastery orientation become more satisfied with good results obtained in tasks which they made more effort. The degree of realization and unexpectedness also interferes. It is necessary to verify the grade obtained (if higher, higher is the intensity of satisfaction/joy emotion) and the unexpectedness (if the student always obtains good grades).

A pedagogical subject is composed of chapters (sections of study). If the student finishes the chapter (event 5), when he made all tasks and followed all the content presented, the event is desirable and elicits satisfaction/joy emotions. If he gave up or did not obtain a good grade (event 4), the event is undesirable. In this case it is also necessary to verify the degree of *realization* (grade) and the *unexpectedness* of the event. The degree of desirability can also be measured by the interference of this event in the final grade of the course.

When the student asks for help (event 7), it is important to know if the help is adequate for the student, so that we have a desirable event, otherwise the event is undesirable. The act of asking for help (event 6) is a non affective event for the mastery student.

If the student accepts the agent's help (event 9), the proposal is a desirable event and the student has gratitude emotion. When the student denies the agent's help proposal (event 8), there is no valenced reaction. But, if the agent offers help many times and the

student does not need it, the help can be disturbing to the student. So, this event becomes an undesirable event and the student experiences anger emotion.

If the student disables the PAT character (event 10), it means that the presence of the character is undesirable and that the student is anger at the agent. When the student enables the character (event 11), the agent's actions are desirable because the student thinks that the agent is useful and that it can help him. In this last case, the student feels gratitude emotion. Note that in these last situations (events 6 to 11) the student focuses on the character as an agent and in this case he has emotions related to the judgment of a person's actions (anger and gratitude).

Table 6.3: Elicited Emotions when a Student Has Mastery Goal Orientation

Student has Mastery Goal orientation Student's Goal: learn the content.						
Event		**Agent's Question**	**Stud. Resp.**	**Event's Desirab.**	**Intensity Variables**	**Student's Emotions**
1	**Student provided an incorrect task answer**	ask the student if it is important to him to know the subject of the task	yes	U	realization unexpectedness	Distress/Disap
			no	N		NE
2	**Student provided a correct task answer**	effort	high	D	realization unexpectedness	Joy/Satisf++
			low	D		Joy/Satisf
3	**Student did not accomplish the task**	ask the student if it is important to him to know the subject of the task	yes	U	realization unexpectedness	Distress/Disap
			no	N		NE
4	**Student gave up the chapter**	ask the student if it is important to him to know the subject of the task	yes	U	realization unexpectedness	Distress/Disap
			no	N		NE
5	**Student finished the chapter**			D	realization unexpectedness	Joy/Satisf
6	**Student asked for help**			N		NE
7	**After agent's help**	ask the student if "help was adequate"	yes	D		Gratitude
			no	U		Anger
8	**Student denied agent's help**	ask if the student thinks that the agent is disturbing him	yes	U		Anger
			no	N		NE
9	**Student accepted agent's help**			D		Gratitude
10	**Student disabled agent**			U		Anger
11	**Student enabled agent**			D		Gratitude

6.6.2 Elicited Emotions when a Student Has Performance Goal Orientation

Table 6.4 deals with elicited emotions for students who have performance goal orientation.

For a performance goal orientated student, the event "did not accomplish the task correctly or did not finish it" is undesirable (events 1 and 3) and elicits distress and disappointment emotions. These events are even more undesirable if the student made greater effort and so elicits these emotions with higher intensity. If he accomplished the task correctly, it is important to know if he made effort (event 2). Students with performance orientation become more satisfied by good results obtained in tasks in which they made less effort because it implies high ability (MEECE; MCCOLSKEY, 2001). But, if he made efforts, he expects more strongly to have success and, then, the event elicit a high intensity emotion.

If the student finished the chapter with success (event 5), the event is desirable and the student experiences joy/satisfaction emotion.

If the student finished the chapter without success or gave up (event 4), the event is undesirable and elicits distress/disappointment emotions.

The intensity of the emotion above depends on the *reality* variable. The higher the grade, the higher the level of realization and consequently (the higher) the intensity of the positive emotion. Differently, if the emotion is a negative one, the intensity is higher when the student obtains a worse grade. The *effort* variable also affects the emotion intensity. High effort implies that the emotion's intensity is higher.

The *unexpectedness* variable also interferes on the emotion's intensity. The degree of unexpectedness can be measured by the actual performance of the student. The event "student provided an incorrect response for an exercise" is less unexpected when the student is having an excellent performance. We consider that when one or more of these variables have a higher degree, an emotion with a higher intensity arises.

When the student asks for help (event 6), it is important to ask the student if he feels uncomfortable doing so. Asking for help may mean for the student that he is not able to accomplish the task alone. If the student answers that he feels comfortable, he does not have any affective reaction. If he feels uncomfortable, it means that he disapproves his attitude of showing to the Mediating Agent that he is not able to accomplish the activities alone, and feels shame. If the help was not appropriate (event 7), the student is displeased since the goal of receiving appropriate help by the agent was not achieved. In this case the student feels angry.

When the student does not accept the agent's help (event 8), it is also important to know if the student is comfortable with the help and if the agent is disturbing the student. If he feels comfortable, it does not elicit any emotion, but if he feels uncomfortable, the event is undesirable and the student becomes angry with the agent since the agent suggests that the student is not able to accomplish the task alone. If the agent is disturbing the student, the student also becomes angry with the agent.

If the student accepts the agent's help (event 9), the student feels gratitude because the agent's help has been useful for him. If the student disables the PAT character (event 10), it means he is angry with the character, because he does not trust it and he is afraid about what the character feels about his performance. When the student enables the character (event 11), he feels gratitude about the agent's actions, and he thinks he can trust it, that it is funny and can help him.

Table 6.4: Elicited emotions when a student has performance goal orientation

Student has Performance Goal Orientation **Student's Goal: have success in tasks and exercises and obtain rewards**						
Event		**Agent's question**	**Stud. Resp.**	**Event Desir.**	**Intensity Variables**	**Student's Emotions**
1	**Student provided an incorrect task answer**			U	realization/ effort unexpectedness undesirability	Distress/Disap
2	**Student provided a correct task answer**			D	realization/ effort unexpectedness desirability	Joy/Satisf
3	**Student did not accomplish the task**			U	realization/ effort unexpectedness undesirability	Distress/Disap
4	**Student gave up the chapter**		yes	N		NE
			no	U	realization/ effort unexpectedness undesirability	Distress/Disap
5	**Student finished the chapter**		yes	D	realization/ effort unexpectedness undesirability	Joy/Satisf
6	**Student asked for help**	the student feels uncomfortable for asking help	yes	U	blameworthiness	Shame
			no	N		NE
7	**After agent's help**	the help was appropriate	yes	N		NE
			no	U	undesirability blameworthiness	Anger
8	**Student denied agent's help**	student feels uncomfortable by the agent's help offer and if the agent is disturbing the student	yes	U	undesirability blameworthiness	Anger
			no	N		NE
9	**Student accepted agent's help**			D	desirability praiseworthiness	Gratitude
10	**Student disabled agent**			U	undesirability blameworthiness	Anger
11	**Student enabled agent**			D	desirability praiseworthiness	Gratitude

6.7 Affective Learning Tactics

The pedagogical tactics applied by the Mediating Agent are divided in **affective tactics** and **tactics for performance and competence**[35]. The tactics for performance and competence promote actions that give support to the student in the learning of concepts and the domain (BERCHT; VICCARI, 2000). The affective tactics promote actions that aim to adapt the system to the affective state of the student, to promote a positive mood in the student and providing emotional support to the student.

The cognitive diagnostic is made by the Diagnostic Agent. As the Mediating Agent is an interface agent, it catches all the actions of the student and sends them to the Diagnostic Agent. The Diagnostic Agent does the Cognitive Diagnostic - based on the notion of Zone of Proximal Development of Vygotsky (ANDRADE; BRNA; VICCARI, 2002) - and sends, when necessary, a scaffolding tactic to be employed by the Mediating Agent. At the same time, the Mediating Agent does the affective diagnostic to decide the affective tactic to be presented to the student. In some cases, a conflict can arrive between the affective tactic (proposed by the Mediating Agent) and the tactics for performance and competence (decided by the Diagnostic Agent). In this case, the Mediating Agent will carry out a new reasoning in a way that it reaches an affective pedagogical tactic that does not conflict with the tactic for performance and competence. If it verifies that the tactics for performance and competence is not adapted to the actual affective state of the student, it negotiates with the Diagnostic Agent until a convergence for a tactic that should be effective in the intellectual and affective point of view. As this work implicate the study of negotiation and interaction among agents, this negotiation will not be handled in this thesis and it will probably be subject of work of another master dissertation.

As a facilitator companion, the Mediating Agent applies the cognitive tactics suggested by the Diagnostic Agent. But, what we propose in this work is to improve the communication of the user and agent by considering the affective aspect of the interaction with the student.

The agent promotes positive emotions in the student by presenting emotional behaviours and messages, which we call affective tactics, that will be applied according to student's emotional states. These tactics also have the goal of providing emotional support to the student: encourage and motivate him when necessary, make him believe in his self-ability, etc. Domain-based tactics can also be applied as affective tactics. For example, the agent can decide to present an easier exercise when the student is having difficulties, in order to increase the student's confidence and show him that he is able to resolve the problem. But **which affective tactics will the agent apply**? We found in psychology and pedagogy literature some insights.

Aspects related to the tasks can be used to motivate the student. Ideally, tasks should be challenging but achievable (LUMSDEN, 1994). It is also important to conceptualise learning, to show the student how the subject can be applied in the real world. It is also important to define tasks in terms of specific, short-term goals to the students to associate effort with success.

Brophy (1986) believes that it is important: (1) to concentrate on the tasks rather than to become distracted by fear of failure; (2) to respond to frustration by retracing the

[35] This separation has been adopted by the Group of Artificial Intelligence in the University of Rio Grande do Sul (BERCHT; VICCARI, 2000). Other synonymous used in this thesis for "tactics for performance and competence" are "domain-based tactics" and "cognitive tactics".

steps to find mistakes or to figure out alternative ways to approach a problem instead of giving up; and (3) to attribute their failures to insufficient effort, lack of information, or reliance on ineffective strategies rather than to lack of ability.

Some researches suggested that better learning occurs when intrinsic motivation (learning because it is interesting and useful) is emphasised over extrinsic motivators (learn because it will be on the quiz) (MEECE; MCCOLSKEY, 2001). When intrinsically motivated, students tend to employ strategies that demand more effort and that enable them to process information more deeply (LEPPER *apud* LUMSDEN, 1994). Besides, students who are more intrinsically oriented tend to take on more challenging tasks, persist longer on a task, handle failure better, and use better learning strategies (MEECE; MCCOLSKEY, 2001). Many researchers believed that rewards (a type of extrinsic motivator), in general, reduce intrinsic motivation. However, recent studies (CAMERON; BANKO, 2001) show that rewards are not harmful to motivation to perform a task and do not have negative effects on intrinsic motivation. These studies also showed that rewards given for low-interest tasks enhance free-choice motivation (time that student spend on task when rewards are removed) and self-reported task interest (task liking, enjoyment, satisfaction), both are used as measures for intrinsic motivation. Verbal rewards (e.g., praise, approval, positive feedback) showed to significantly enhance both free-choice intrinsic motivation and self-reported task interest. Tangible rewards (e.g., money, candy, gold stars) showed insignificantly effects. They believe that rewards can be used to shape performance progressively, to establish interest in activities that lack initial interest, and to maintain or enhance effort and persistence at a task. In relation to rewards, (MEECE; MCCOLSKEY, 2001) recommends that:

- Threats, punishments and other aversive incentives should be avoided because they generate fear and anger, which undermine intrinsic interest in learning.
- Incentives should be given for all students, not just for high achievers. This can be reached by rewarding students by their improvement. Students then continue to make progress in order to receive additional rewards.
- Avoid rewarding students on a competitive basis, since they focus their attention on who will win or lose, rather than the content of what they are learning.
- Rewards should be used in ways that help students see the connection between their behaviour and the reward. When they are long time delays, teachers should encourage them.

Praise is a verbal type of reward. Hirtz and Driscoll (1989) state that not all kind of praise can be effective to motivate students. He calls “encouragement” the positive type of praise. *Praise* is related to express approval or admiration. *Encouragement*, on the other hand, refers to a positive acknowledgment response that focuses on student efforts or specific attributes of work completed. Unlike praise, encouragement does not place judgment on student work or give information regarding its value or implications of student status. Statements such as "You draw beautifully, Marc," or "Terrific job, Stephanie," are examples of praise. They are non-specific, place a judgment on the student, and give some indication of the student's status in the group.

Hirtz and Driscoll (1989) cite the characteristics of encouragement:

- Offer specific feedback rather than general comments. For example, instead of saying, "Terrific job," teachers can comment on specific behaviours that they wish to acknowledge.

- It is teacher-initiated and private. Privacy increases the potential for an honest exchange of ideas and an opportunity for the student to talk about his or her work.
- Focus on improvement and efforts rather than evaluation of a finished product.
- Use sincere, direct comments delivered with a natural voice.
- Do not set students up for failure. Labels such as "nice" or "terrific" set students up for failure because they cannot always be "nice" or "terrific".
- Help students to develop an appreciation of their behaviours and achievements.
- Avoid competition or comparisons with others.
- Work toward self-satisfaction from a task or product.

According to Hirtz and Driscoll (1989), the ineffective praise can restrain natural curiosity and desire to learn by focusing their attention on extrinsic rewards rather than the intrinsic rewards that come from the task itself. On the other hand, "teachers who encourage students, create an environment where students do not have to fear continuous evaluation, where they can make mistakes and learn from them, and where they do not always need to strive to meet someone else's standard of excellence" (HITZ; DRISCOLL, 1989). Most students have more success in encouraging environments where they receive specific feedback and have the opportunity to evaluate their own behaviour and work. Encouragement fosters autonomy, positive self-esteem, a willingness to explore, and acceptance of self and others.

Ames (1990) also points to some strategies for motivating students:

- "Reinforcing children's work even if it involves some small aspect of the total effort should be a step in the direction of giving child more confidence".
- Rewards can increase the students' self-efficacy[36] (self-ability), which can positively influence student's motivation.
- "Give children choice and thus a sense of personal control in the classroom. Choice of tasks is viewed as fostering belief in personal control and increasing interest and involvement in learning".
- Persuade students to work harder on occasions of failure or poor performance. The goal is to make the student perceive that positive outcomes are result of efforts. But, it is important to verify if the student thinks that he is already trying hard. Telling this child that he didn't work hard may decrease his self-efficacy.

Based on studies cited at this section, we defined the affective tactics to be employed by the Mediating Agent. As the student disappointment/satisfaction emotions were determined by his achievement goals (mastery or performance), we opted to apply affective tactics that consider the student goal orientation, besides student's emotions. Table 6.5 shows the affective tactics that we defined. Each affective tactic is presented by an agent's physical (marked with **PB**) and verbal (marked with **VB**) behaviour. These behaviours are presented in Table 7.1.

[36] According to Bandura (1994, pp. 391), self-efficacy "is concerned not with the skills one has but with judgments of what once can do with whatever skills one possesses". Researchers believe that student's motivation and effort is related to a positive self-efficacy. We use self-ability as synonymous of self-efficacy in this document.

Table 6.5: Affective Tactics

Event	Intrinsic Motivation (Mastery Goals)	Extrinsic Motivation (Performance Goals)
1) Not correct task answer	***Distress/Disappointment:***	***Distress/Disappointment:***
	1) Recognise-student-effort VB: Recognise-student-effort PB: Empathic **2) Offer-help** VB: Offer-help PB: Speak	**1) Increase-student-self-ability** VB: Increase-student-self-ability PB: Encouragement **2) Increase-student-effort** VB: Increase-student-effort PB: Speak **3) Offer-help** VB: Offer-help PB: Give-help
	NE:	
	Agent applies tactic "for performance" suggested by Diagnostic Agent.	
2) Correct task answer	***Joy/Satisfaction:***	***Joy/Satisfaction:***
	1) Congratulate-student PB: Congratulation (moderate) VB: Congratulation (moderate) **2) Show-students-new-skills** VB: New-skill PB: New-skill	**1) Congratulate-student** PB: Congratulation VB: Congratulation
3) Not accomplished task	***Distress/Disappointment:***	***Distress/Disappointment:***
	1) Encourage-student VB: Encouragement PB: Encouragement **2) Offer-help** VB: Offer-help PB: Give-help	**1) Increase-student-self-ability** VB: Increase-student-self-ability PB: Encouragement **2) Increase-student-effort** VB: Increase-student-effort PB: Speak
	NE:	
	1) Show-students-new-skills VB: New-skill PB: New-skill **2) Offer-help** VB: Offer-help PB: Give-help	
4) Gave up the chapter	***NE:***	***NE:***

	1) Show-curiosity-about-subject
	VB: Show-curiosity
	PB: Show-curiosity
		If (student-effort != high)
		1) Increase-student-effort
		VB: Increase-student-effort
		PB: Encouragement.
		Else
		1) Encourage-student
		VB: Encouragement
		PB: Encouragement

	Distress/Disappointment:	***Distress/Disappointment:***
	1) Encourage-student VB: Encouragement PB: Speak **2) Offer-help** VB: Offer-help PB: Give-help	*if (student-effort != high)* **1) Increase-student-self-ability** VB: Increase-student-self-ability PB: Encouragement **2) Increase-student-effort** VB: Increase-student-effort PB: Speak *else if (student-effort == high)* **1) Increase-student-self-ability** VB: Increase-student-self-ability PB: Encouragement **2) Encourage-student** VB: Encouragement PB: Speak

5) Finish the chapter	***Joy/Satisfaction:***	***Joy/Satisfaction:***
	1) Congratulate-student PB: Congratulation VB: Congratulation	**1) Congratulate-student** PB: Congratulation VB: Congratulation
6) Student asks for help	***NE:***	***Shame:***
	1) Give-help VB: Give-help PV: Give-help	**1) Explain-help-importance** VB: Explain-help-importance PV: Empathic **2) Give-help** VB: Give-help PV: Give-help
		NE:
		1) Give-help VB: Give-help PV: Give-help
7) After agent's help	***Anger:***	***Anger:***
	1) Agent-is-sorry-for-not-helping VB: Sorry-for-not-helping. PV: Sorry. **2) Informs the Diagnostic Agent that the help was not appropriate**	**1) Agent-is-sorry-for-not-helping** VB: Sorry-for-not-helping. PV: Sorry. 2**) Informs the Diagnostic Agent that the help was not appropriate**
	Gratitude:	***NE:***
	1) Agent-is-happy-for-helping-student VB: Happy-for-helping PV: Happy-for	**1) Agent-is-happy-for-helping-student** VB: Happy-for-helping PV: Happy-for
8) Student denies agent's help	***Anger:***	***Anger:***
	if (agent_is_disturbing) **1) Sorry-for-disturbing** VB: Sorry-for-disturbing PV: Sorry	*if (agent_is_disturbing)* **1) Sorry-for-disturbing** VB: Sorry-for-disturbing PV: Sorry *else if (student_feels_uncomfortable)* **1) Explain-help-importance** VB: Explain-help-importance PV: Empathic **2) Offer-help** VB: Offer-help PB: Give-help
9) Student accepts agent's help	***Gratitude:***	***Gratitude:***
	1) Give-help VB: Give-help PV: Give-help	**1) Give-help** VB: Give-help PV: Give-help
10) Student disables the agent	***Anger:***	***Anger:***
	1) Student-disable-agent VB: Student-disable-agent PV: Sorry	**1) Student-disable-agent** VB: Student-disable-agent PV: Sorry
11) Student enables the agent	***Gratitude:***	***Gratitude:***
	1) Student-enables-agent VB: Student-enables-agent PV: Happy-for	**1) Student-enables-agent** VB: Student-enables-agent PV: Happy-for
12) While student is accomplishing a task	**1) Agent-observes-student** VB: Agent-observes-student PV: Agent-observes-student **2) Show-curiosity-about-subject** VB: Show-curiosity PB: Show-curiosity	**1) Agent-observes-student** VB : Agent-observes-student PV : Agent-observes-student **2) Encourage-student** VB: Encouragement PB: Speak

13) Student makes greater effort for a task	**1) Recognise-student-effort** VB: Recognise-student-effort PB: Empathic	**1) Recognise-student-effort** VB: Recognise-student-effort PV: Recognise-student-effort **2) Encourage-student** VB: Encouragement PB: Speak
14) Student is idle	**1) Student-idle** VB: Idle. PV: Idle. **2) Show-curiosity-about-subject** VB: Show-curiosity PB: Show-curiosity	**1) Student-idle** VB: Idle PV: Idle **2) Increase-student-effort** VB: Increase-student-effort PB: Speak

When the student who has **intrinsic orientation** feels disappointed and distressed because he **did not accomplish the task correctly (Event 1)**, the agent presents an empathic gesture showing that it understands the difficulties that the student is experiencing. As an intrinsic student already makes great efforts, the agent does not ask him to try harder, just offers help[37] in order to assist him accomplishing the exercise. A **student who has extrinsic motivation** feels that he is not able to accomplish the task when he fails. And he usually does not make greater effort when he has difficulties, because he thinks that it means lack of ability (MEECE; MCCOLSKEY, 2001). In this way, the agent presents a message[38] to increase the student's beliefs about his self-ability and says to the student that he is able to carry out the task with a little more effort. The idea is to show the student who has performance goals that when he did not achieve success in a task, it does not mean lack of ability, but that he can achieve better results with more effort.

When the student who has **intrinsic motivation** is satisfied and glad because he **accomplished a task with success (Event 2)**, the agent shows him the new ability he acquired, since the student is motivated to learn new things**,** to improve. If the event is indifferent to him, the agent shows the new abilities the student acquired to foster his motivation and congratulate the student so that he notices the new ability he acquired. The student who has **extrinsic motivation** is always satisfied and happy with success in tasks, because it means a proof of ability for him. In these cases, the agent congratulates his performance strongly to maintain his motivation since this student appreciates to receive agent's praises.

Since the student who has **intrinsic motivation** usually makes great effort (MEECE; MCCOLSKEY, 2001) when he **"does not accomplish the proposed task" (Event 3)**, it does not mean lack of effort, but difficulties to carry it out. Then, the agent presents an encouragement message so that to keep the student making efforts, and shows a generic help in order to assist the student in overcoming his difficulties. When the **intrinsic motivated student** is emotionally indifferent to this event (he is not satisfied or disappointed/distressed because he thinks that the subject is not important or interesting), the agent presents to him the new ability he can acquire with this subject and gives a specific help too. The **performance oriented student** feels very disappointed when he does not finish a task, because it means lack of ability. This way, the agent presents a message that aims at increasing his self-ability since his beliefs about his ability are diminished due to failure experience. The agent also aims at

[37] We believe that the choice of the help's type (specific or generic) should be decided by the Diagnostic Agent. We also think that in order to apply this tactic the Mediating Agent should negotiate with the Diagnostic Agent. This negotiation is not subject of study of this thesis.

[38] According to (AMES, 1990), praise can be used to increase students' self-ability.

increasing the student's efforts for accomplishing the task, considering that performance oriented students make fewer efforts because this means lack of ability for them.

Students can also "**give up studying a chapter" (Event 4)**. If the **student is mastery goal oriented** and is experiencing disappointment and distress, it means that he made efforts for a task that was interesting for him, even if he was not able to accomplish the task. The agent shows a specific help and also presents an encouragement message so that the student keeps his efforts in the task. If he was not disappointed, it means that he does not think that the subject is interesting and so the agent shows some curiosities about the subject. Brewster and Fager (2000) suggest that showing curiosities about a subject, relating it to the student's life, is an efficient tactic to motivate him. If the student is **performance goal oriented,** he usually wants to achieve the minimal grade required by the class (usually 70%). If he achieves this grade, he does not experience disappointment, and so the agent aims at increasing the student's effort for the next tasks. If the student is disappointed/distressed because he did not achieve the minimal grade, his self-ability decreases. In this case, the agent shows a behaviour that aims at increasing student's self-ability and also the student's efforts. According to Ames (1990), the tutor should persuade students to work harder on occasions of failure or poor performance in order to make the student perceive that positive outcomes are the result of efforts. But, in these cases, it is important to verify if the student thinks that he is already trying hard. Telling this child that he did not work hard may decrease his self-efficacy (AMES, 1990). If the child is already accomplishing hard efforts, the agent presents an encouragement message in order for the student to maintain his efforts.

When a student who has **mastery orientation finishes a chapter (Event 5)**, he feels satisfied and glad. The agent congratulates his efforts in accomplishing the proposed task. As suggested Meece and Mccolskey (2001), it is important to connect the student's success to his behaviour. The agent uses the same tactic for the **performance goal student** who is also satisfied. Otherwise, if this student is disappointed and distressed, because he did not achieve the required minimal grade, the agent presents an encouragement behaviour stimulating him to make more efforts.

The student can also **ask for help (Event 6).** If this action is required by an **intrinsic motivated student**, the agent presents a help for the student. If the **extrinsic motivated student** feels shame because asking for help means lack of ability, the agent shows a message that aims at clarifying this misconception and gives him help. The kind of help (specific or generic) is determined by the Diagnostic Agent.

The student can also have affective reactions **after agent's help (Event 7)** because the help can be not appropriate. If the student **(mastery or performance oriented)** is anger with the agent's help, it shows an "agent-is-sorry-for-not-helping" behaviour and informs the Diagnostic Agent that the help was not appropriate. Otherwise, the agent presents a "happy-for-helping" behaviour which shows that it is happy for helping the student. This behaviour aims at getting student's empathy.

The agent can also offer help to the student**.** It is the diagnostic agent that decides when to offer help to the student and what kind of help. **When the student turns the agent's help down (event 8)**, if he is **performance oriented,** he will get angry because he feels uncomfortable by receiving help. The agent then explains the importance of the help and then offers it again. Besides, the student can feel anger because the agent is disturbing him and he thinks that he can resolve the task alone. In this occasion, the Mediating Agent presents the behaviour "sorry-for-disturbing". Otherwise, if the student is emotionally indifferent, it does nothing. Presenting a behaviour (as "agent-is-

sorry-for-not-helping") can disturb more than become empathic. If the student **accepts (Event 9) the help proposal**, the agent gives the help.

If the **student disables the agent (Event 10)**, he is angry with the agent actions. In this case, the agent presents apologies.

If the **student enables the agent (Event 11)**, the agent presents a behaviour showing that it is very happy for being with the student again. This aims at obtaining student's empathy (see Section 4.8.2 about empathy in intelligent educational systems).

When the student is **accomplishing a task (Event 12),** the agent observes him. It can show curiosity about the subject in order to motivate the mastery goal oriented student and also present encouragement messages for the performance goal oriented students keeping their efforts.

When **students make great effort for a task (Event 13),** the agent shows behaviour recognizing this effort. For a performance goal oriented student, it shows an encouragement message in order to keep the student making efforts.

When the **student is idle (Event 14)**, the agent presents a behaviour that aims at encouraging him to go back to work. If the student is mastery oriented it also shows some curiosity about the taught subject in order to motivate the student. If the student is performance oriented, it shows the tactic of increasing the student's effort, since these students usually do not make great effort.

Each affective tactic is represented by an agent's physical and verbal behaviour. The attitudes that compose these tactics, the implementation of the emotions inference and the process of choosing the affective tactics are discussed in the next chapter.

7 THE ARCHITECTURE AND IMPLEMENTATION OF THE PROPOSED AFFECTIVE PEDAGOGICAL AGENT

This chapter describes the implementation of the Mediating Agent. First, we describe the Mediating Agent's deliberative process in BDI for the emotion inference and for the choice of the affective tactics. The emotion inference and the affective diagnosis are made by the cognitive Kernel of the agent that represents its Mind. In Section 7.2 we describe the reasons that lead us to implement the Mediating Agent as a lifelike character. Section 7.3 presents the general architecture of the Mediating Agent. Section 7.4 describes with more details the modules that compose the agent's body and which are responsible for selecting the character's behaviours and messages to be shown. Finally, Section 7.5 presents the architecture of interaction of the Mediating Agent with other agents of MACES and the protocols of communication that are used in the information exchanges.

7.1 Emotion Recognition and Affective Diagnosis through Mental States

In our system, we use a mental states approach for implementing the affective student model and the affective diagnosis. The proposed agent will be implemented as a BDI (Belief, Desire and Intention) agent (BRATMAN, 1990) (RAO; GEORGEFF, 1995). The BDI approach is based on description of the internal processing of the agent through mental states (belief, desire and intention) and definition of the control architecture that rationally selects the agent's course of actions (see Section 2.6 for more details about the BDI approach). For the implementation of the cognitive agent, we use the modelling and developing system of BDI agents, named X-BDI (MÓRA et al., 1998), which makes it possible to implement the cognitive structure of a BDI agent, called "cognitive kernel".

The agent beliefs are the information the agent has about the environment, about itself, about other agents and the relationship among the beliefs. In our system, the information about the student (student model), possible strategies and behaviour of the agent are represented as beliefs. The desires represent a situation the agent wants to achieve. The fact that the agent has a desire does not mean that the agent will do it. The agent carries out a deliberative process in which it confronts its desires and beliefs and chooses a set of desires that can be satisfied. The intention is a desire that was chosen to be executed by a plan, because it can be carried out according to the beliefs of the agent (because it is not rational that the agent carry out something that it does not believe). The desires can be contradictory, but the intentions cannot.

In our system, the strategies and behaviours of the agent are described as the agent's beliefs. The decision of what to do and when to do it are the desires and intentions of the agent. This way, a determined strategy (belief) of the agent is activated if a desire of the agent becomes an intention.

In our work, the X-BDI was used as tool for the implementation of the agent's cognitive kernel because it makes the developer's work easier since it allows to specify the behaviour of the agent in a high level of abstraction. But we believe that other approaches could also be used as, for example, rules (RUSSEL; NORVIG, 1995).

The choice of the mental states approach for the implementation of an affective pedagogical agent is based on the cognitive approach of emotion (CLORE; ORTONY, 1999) (SCHERER, 1999) that considers that the emotions are elicited by a cognitive evaluation of the personal significance of an agent, object or action (appraisal). For example, a person feels fear of being bitten by a snake because he evaluates that this event (the bite) can have an undesirable consequence for him (he can die or be seriously hurt). This way, the agent can also deduce the affective state of the student through a BDI reasoning which aims at discovering the cognitive evaluation made by the student.

Besides, the affective model must be dynamic enough to consider the changes in the emotional states (BERCHT, 2001). Since the motivation and the affectivity of the student may vary in a very dynamic way (the student may not feel self confident at some determined instants and feel more confident in another instant), the use of the BDI approach for the implementation of the student model is very convenient, because it allows simple revisions and frequent modifications of the information about the student (BERCHT, 2001). The student model is built dynamically from each interaction in real-time (GIRAFFA, 1999).

For example, let us see how the X-BDI cognitive kernel selects the affective tactics for the following scenario: the student has performance goal (extrinsic motivation) and he is disappointed because he provided an incorrect response for the exercise. The *cognitive kernel* receives the following information from the agent's sensors:

```
[current_time(2),sense(student_goal(performance),1)].
[current_time(3),sense(event(not_correct_answer),2),sense(effort(high),2)].
```

The sensors notify the BDI cognitive kernel that the student has performance goals and his effort was high, and that an event happened - the student provided an incorrect response for the exercise.

So, the agent activates the desires "*apply_tactics*" and "*emotion_sent*" as intentions. The desire "*emotion_sent*" aims at sending to the Diagnostic Agent the student's emotions. It uses this information for helping the Mediating Agent to choose the pedagogical tactics that are adequate in the cognitive and affective point of view (in the process of negotiation which is not handled in this thesis). The desire "*apply_tactics*" is responsible for choosing the affective tactics that will be applied.

```
/* ************ The agent's desires to apply an affective tactic ********** */
   des(mediador,apply_tactics(Tactic),Tf,[0.6]) if
       bel(mediador,choose_tactics(Tactic)).

   act(mediador,send_tactic(Tactic)) causes
       bel(mediador,apply_tactics(Tactic))
       if  bel(mediador,choose_tactics(Tactic)).
```

```
/*  The  Mediating  Agent's  desires  to  send  the  student's  emotions  to  the
Diagnostic Agent */
   des(mediador, emotion_sent(Emotion, Intensity), Tf, [0.8])
       if bel(mediador, student_emotion(Emotion)),
          bel(mediador, emotion_intensity(Emotion,Intensity)).
   act(mediador, send_emotion(Emotion,Intensity))
       causes bel(mediador, emotion_sent(Emotion, Intensity))
       if bel(mediador,student_emotion(Emotion)),
          bel(mediador, emotion_intensity(Emotion,Intensity)).
```

In order for the agent to satisfy its intention of applying an affective tactic, it must accomplish the action of sending this tactic to the agent's actuator ("*send_tactic"* predicate). To satisfy the intention "*emotion_sent*" it needs to send the emotion to the Diagnostic Agent ("*send_emotion"* predicate).

In order to send the emotions to the Diagnostic Agent, the Mediating Agent must know the student's emotions. It infers the student's emotions from the following beliefs:

```
/* The student is displeased with the event */
   bel(mediador,event_pleasantness(not_correct_answer,displeased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(not_correct_answer)).

/* It is a prospect of an event */
   bel(mediador,is_prospect_event(not_correct_answer)) if
       bel(mediador,event(not_correct_answer)).


/* When the student is displeased, disappointment (when the student has an
expectation of the event) and distress emotions arises */
   bel(mediador,student_emotion(disappointment))if
       bel(mediador,event_pleasantness(Event,displeased)),
       bel(mediador,-is_mediador_action),
       bel(mediador,is_prospect_event(Event)).

   bel(mediador,student_emotion(distress))if
       bel(mediador,event_pleasantness(Event,displeased)),
       bel(mediador,-is_mediador_action).
```

The student is displeased with the event, because the event is undesirable, or it is desirable but it did not happen. When the student is displeased, it experiences distress emotion, and disappointment if it is the prospect of an event that was confirmed (*"is_prospect_event"* predicate). It is the case of the event "not_correct_task_answer", since when the student accomplishes a task he has an expectation that this event would happen. To elicit disappointment and distress emotions the event should not be caused by the Mediating Agent. The agent's actions elicit emotions as anger and gratitude.

It is also important to verify the value of the variables that affect the emotion's intensity:

```
   bel(mediador,emotion_intensity(disappointment, high)) if
       bel(mediador, effort(high)),
       bel(mediador, student_emotion(disappointment)).

   bel(mediador,emotion_intensity(disappointment,high)) if
       bel(mediador, realization(high)),
       bel(mediador, student_emotion(disappointment)).

   bel(mediador,emotion_intensity(disappointment,high)) if
       bel(mediador, unexpectdness(high)),
```

```
    bel(mediador, student_emotion(disappointment)).

bel(mediador,emotion_intensity(disappointment,high)) if
    bel(mediador, undesirability(high)),
    bel(mediador, student_emotion(disappointment)).
bel(mediador,emotion_intensity(disappointment,medium)) if
    bel(mediador, -unexpectdness(high)),
    bel(mediador, -realization(high)),
    bel(mediador, -effort(high)),
    bel(mediador, -undesirability(high)),
    bel(mediador, student_emotion(disappointment)).


bel(mediador,emotion_intensity(distress,high)) if
    bel(mediador, undesirability(high)),
    bel(mediador, student_emotion(distress)).

bel(mediador,emotion_intensity(distress, medium)) if
    bel(mediador, -undesirability(high)),
    bel(mediador, student_emotion(distress)).
```

According to the beliefs above, the variables that affect the emotion's intensity are effort, realization, unexpectedness and undesirability for disappointment, and undesirability for distress. If one of these variables has a higher value (marked with high) the student experiences the specific emotion with high intensity, otherwise he experiences emotions with medium intensity. The values of the variables that affect the emotion's intensity are sent by the sensor of the body module. It is responsible for identifying the value of these variables with questionnaires and student's observable behaviour.

Finally, the agent chooses the tactics through the beliefs showed below. The affective tactics are: (1) to increase the student's self-ability, (2) to increase the student's effort; and (3) to offer help to the student. Once it chose the affective tactic, it can accomplish the action of sending the tactic to the Body module. As this action is the restriction for the elected intention to be satisfied, the agent's intention of applying an affective tactic is accomplished.

```
bel  (agent, choose_tactics(increase_student_self_ability))
       if    bel (agent,student_emotion(disappointment)),
             bel (agent,event(not_correct_answer)),
             bel (agent,student_goal(performance)).

bel  (agent, choose_tactics(increase_student_effort))
       if    bel (agent,student_emotion(disappointment)),
             bel (agent,event(not_correct_answer)),
             bel (agent,student_goal(performance)).

bel  (agent, choose_tactics(offer_help))
       if    bel (agent,student_emotion(disappointment)),
             bel (agent,event(not_correct_answer)),
             bel (agent,student_goal(performance)).
```

The inference of the student's emotions and the choice of the affective tactics by the X-BDI kernel can be visualized in the interface of the Sicstus Prolog that is shown in Figure 7.1. In the example shown in this figure, we are using the "coreografia" execution mode, as explained in Section 3.2.2. In order for the cognitive kernel (Mind module) to communicate with the Body module, the "*normal*" execution mode is used, which allows this two modules to exchange information by sockets (see Section 3.2.2 for more details). The set of intentions chosen by the Mediating Agent's Mind for the

example previously described are represented by the predicates *int_that* (according to X-BDI model explained in Section 3.2.1) inside the shaded square in Figure 7.1.

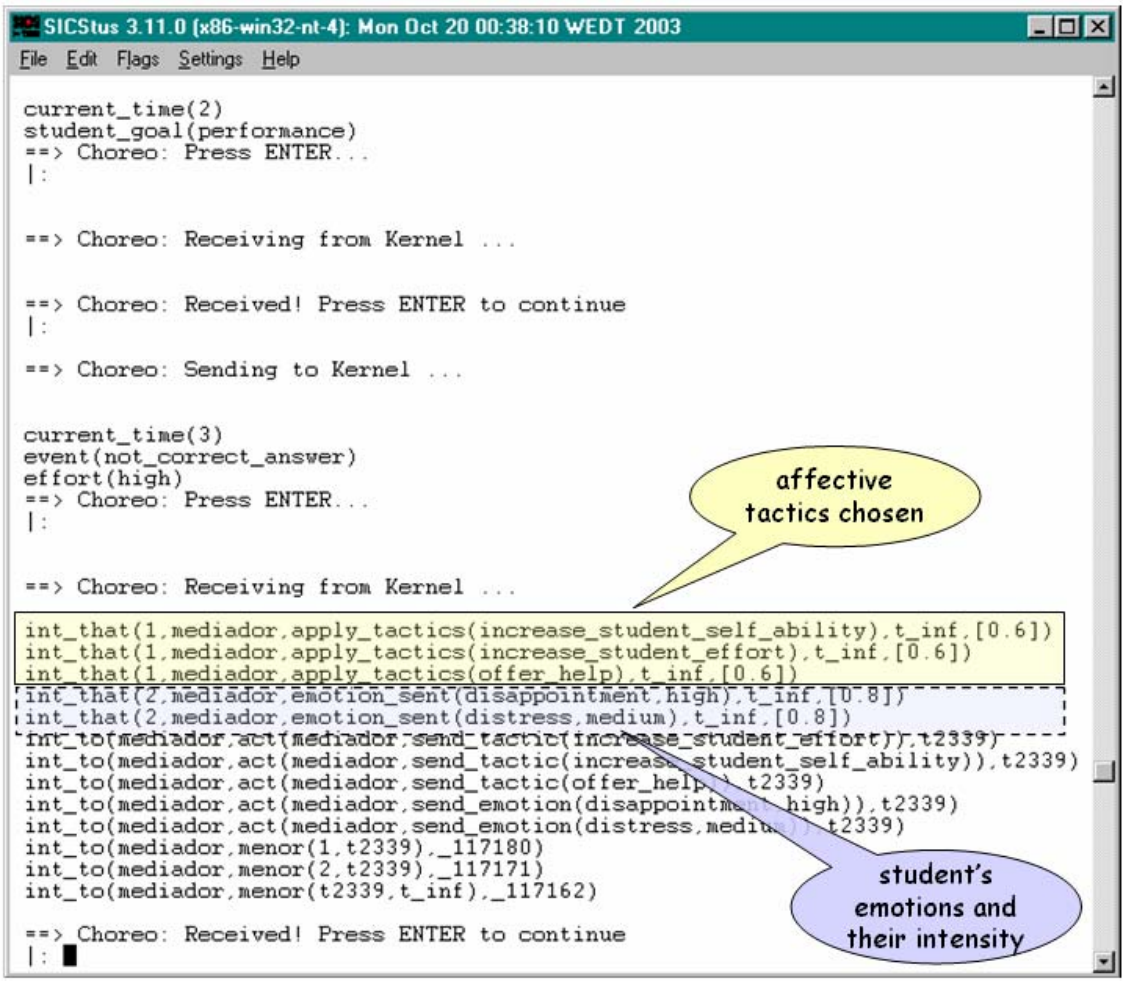


Figure 7.1: The choice of the affective tactics by the X-BDI cognitive kernel.

A complete list of the BDI beliefs and desires of the Mediating Agent can be found in Appendix B.

The BDI approach for the implementation of the student's cognitive and affective model of pedagogical agents has been used by the Group of Artificial Intelligence at Federal University of Rio Grande do Sul (GIA-UFRGS), more respectively in the works of Bercht (2001) and Giraffa (1999).

Although Giraffa's (1999) work showed us great advantages in relation to student modelling that can be applied also for affective modelling, her work uses BDI only for the student's cognitive modelling and diagnosis, while in this work we use BDI for student's affective modelling and diagnosis.

Bercht (see Section 3.3) used the BDI for affective student modelling and diagnosis. She modelled the behavioural factors (effort, confidence and independence) for the detection of the student's motivation and also of the displeased emotional state. Our work differs from Bercht's work in the methodology used to recognise the student's emotion. The emotional state "displeased" in the Bercht's work is inferred by rules, inserted in the BDI agent as beliefs, generated according to the OCC model. Basically,

Bercht used the OCC model for constructing the rules that infer the student's emotions from the user's actions. The inference of the student's appraisal was made by an expert that inserted the rules in the system. In our idealisation the inference of student's appraisal is made by the agent itself. So, in our work, we benefit from the reasoning capacity of the BDI to infer the student's affective states according to the OCC model. An advantage of our proposal is that it is not necessary for an expert to determine all the rules for the student's affective state inference, to implement them in the agent in advance. The system deduces the student's affective state by reasoning about his appraisal.

The use of a cognitive kernel (based on the BDI architecture) allows the tutor to process information referring to the student without the need of using a traditional model for Intelligent Tutoring Systems (ITS), such as overlay, stereotypes and buggy. Thus, it is possible to extend the student model just through the insertion of the mental states (desire and beliefs). This way, we have already implemented the system, although we do not have all the affective tactics defined yet. They will be added to the system after its implementation.

7.2 Why an Animated Agent?

Kato and colleagues (2001) accomplished a study that analysed the affective states of students after receiving emails. This study showed that when the individuals interpret their companion's (email sender) affective states as positive they feel positive emotions; and when they interpreted the companions' emotions as negatives, they usually felt negative emotions.

The works of Izard (1984) show that induced negative emotions damage performance on cognitive tasks, and positive emotions have an opposite effect. Coles (1998) shows other studies made by Masters, Barden and Ford which found that inducing a sad mood in very young children increased the time they took to learn and to respond to a task, and also increased their number of errors; opposite results were achieved by inducing happiness.

As these studies show, positive emotions increase the learning and the negative emotions have the opposite effect. At the same time, these positive emotions can be induced by a careful support and encouragement by the teacher, colleagues and the artificial pedagogical agent, the Mediating Agent in our computational system.

Due to its affective function – to provide emotional support for the student and to promote a positive mood in him more appropriate to learning – it would be interesting for the Mediating Agent to have an interface that would allow it to exploit students' social nature. Due to psycho-social human tendency of anthropomorphizing software (REEVES; NASS, 1996), recent studies have shown that tutorial systems that have animated agents can be more effective pedagogically (LESTER et al., 1997c), besides having a stronger motivational effect in the students (LESTER et al., 1997b). Therefore, we chose to represent it as an animated character that has a personality and interacts with the student through messages and emotional behaviour.

The representation of the agent as a character allows it to show emotional behaviour that can promote a positive mood in the student. Studies demonstrate that there is a relation between emotions and intellectual processes. According to Goleman (1995), laugh, as euphoria, seem to help people to think with more largeness and to make free-form associations and promote creativity. This way, represented as a character, the

agent can carry out affective behaviours that promote emotions in the student, propitious to the accomplishment of determined activities.

But there is another question: Can a computer represented by a lifelike character accomplish this kind of function which is highly related to human social relationship? The response is: Yes, it can! As Reeves and Nass (1996) states, although we think that we do not react socially to computer, in reality we do. In their book they presented a lot of interesting experiences that show that people react socially to computer, although they think that they do not do it. In one of these experiments, Reeves and Nass showed that people react to praise or criticism of computers in the same way that they react to praise and criticism of other people. They like to receive praise (being it true or not), they believe in the computers' praise and they think that the computers that praise are more likeable. Otherwise, they believe that the computers that criticize are more intelligent, although they think they are less likeable. In this way, computers can be used to accomplish the role of motivating and engaging the student as teachers do in real class.

The definition of the character appearance was made based on interviews with psycho-pedagogues, pedagogues and psychologists. The animated character, called PAT (Pedagogical and Affective Tutor), is a female woman with entire body and with height in proportion to the monitor size. She has brown eyes and long hair, she wears jeans pants and a coloured shirt and she is approximately 30 years old, because the objective is to represent a young, extrovert and informal character. The Figure 7.2 shows the final appearance of PAT.

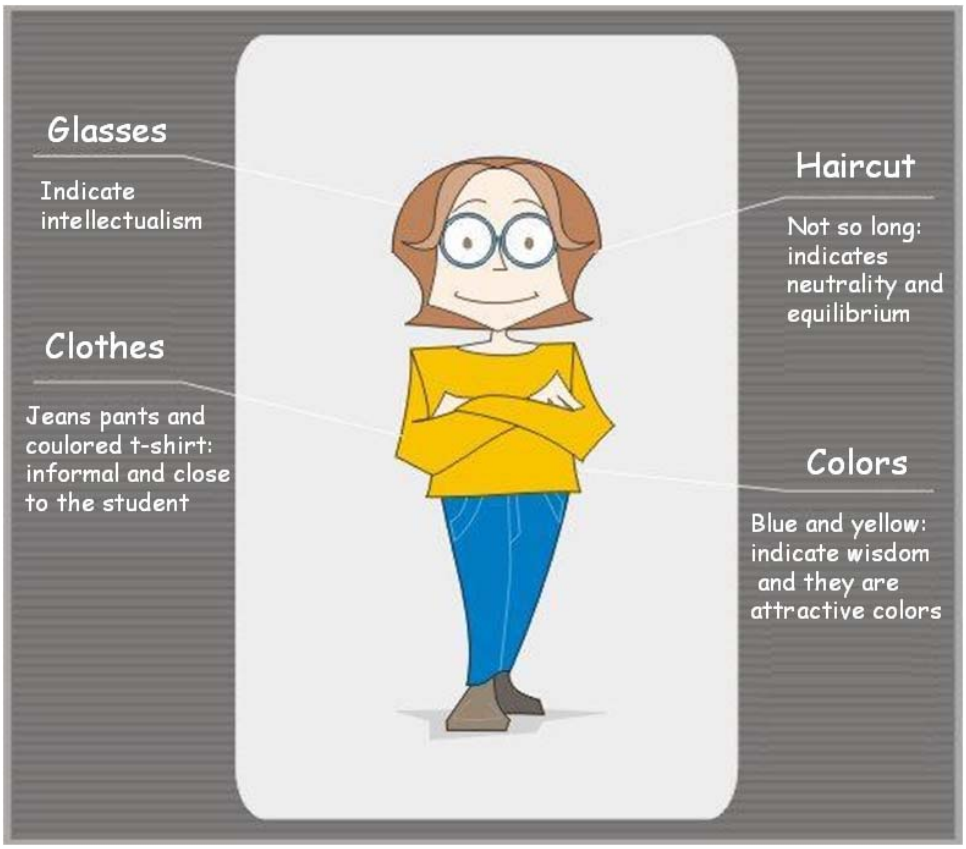


Figure 7.2: Pat's appearance (BOCCA, 2003)

Besides, empathy is a very important factor to ensure the quality of human communication and personal development. This way, we are also considering the empathic characteristics proposed by Cooper (see Section 4.8.2 for more details) for animated pedagogical agents in the definition of the appearance of the agent's character as well as the affective tactics applied by it.

The definition of the appearance of the character and its implementation were developed by the Master Student Everton Bocca (BOCCA, 2003) of the Programa de Pós-Graduação em Computação of the Federal University of Rio Grande do Sul.

7.3 The General Architecture of the Mediating Agent

Figure 7.3 shows the architecture of the Mediating Agent. The agent's architecture is divided in two main parts: the agent's Body and the agent's Mind.

The agent's Body is responsible for catching the student's actions in the system interface, performing the communication with other agents and showing the behaviour and messages selected by the Mind module.

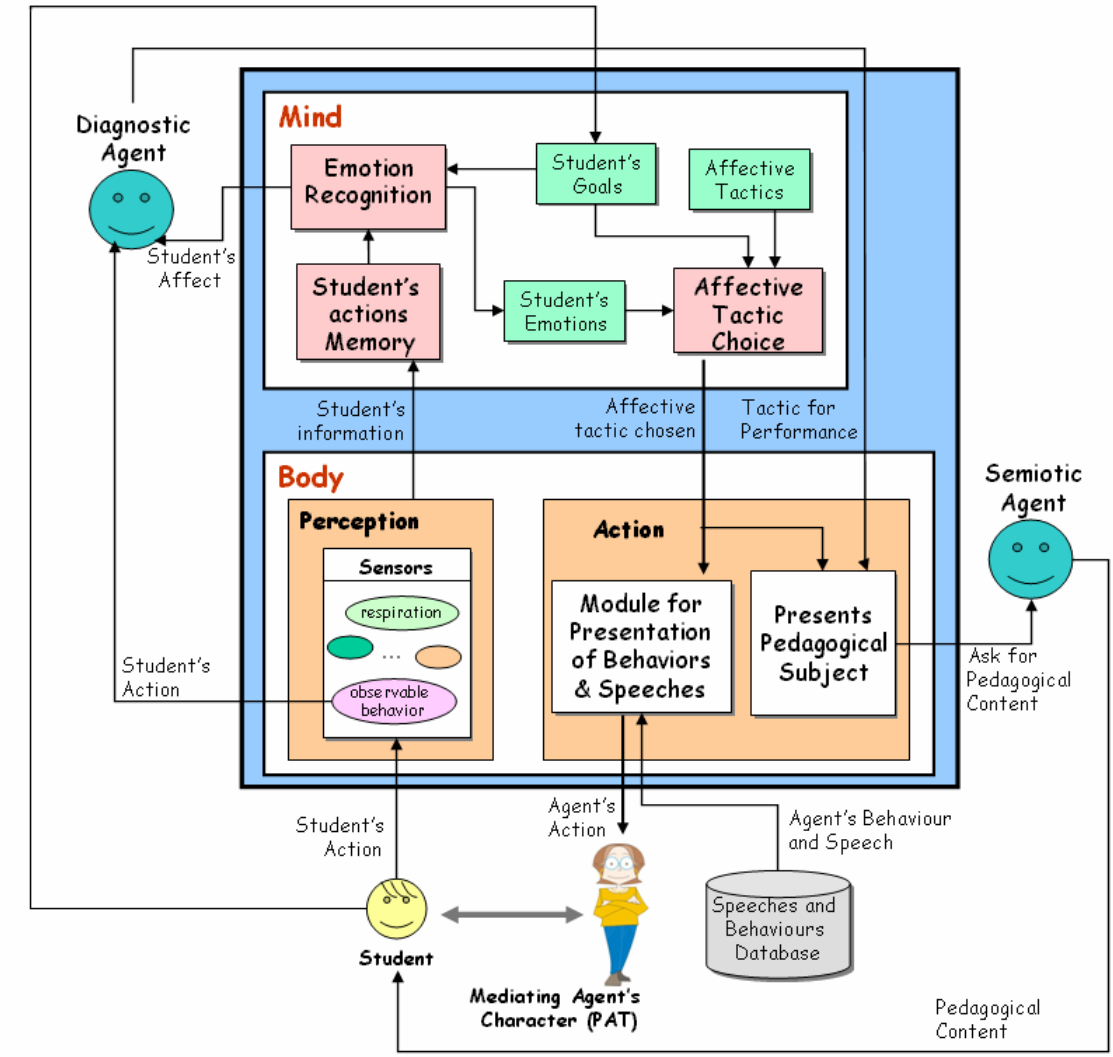


Figure 7.3: The Architecture of the Mediating Agent

The agent's Mind is responsible for recognizing the student's affective states by his observable behaviour and choosing the adequate affective and pedagogical tactic according to his affective model.

During all the time, the Mediating agent catches the student's data that will be used to infer his affective states. These data are taken by sensors that compose the Perception Module. There are some examples of sensors: the device to take the student's respiration, the device to monitor the student's cardiac rhythm and so on (other examples are cited at section 6.1). In our prototype, we catch the student's affective states by his actions in the system interface (observable behaviour). In this case, the sensor is a software program responsible for catching the student's actions.

The student's information taken by the Perception Module is sent to the Diagnostic Agent (to do the cognitive diagnostic) and to the Mind of the Mediating Agent[39]. The agent mind is implemented as a BDI kernel that recognises the student's emotions and updates the student model, and also chooses the affective tactics to be applied.

First, when the mind receives a student observable behaviour, it stores the information in the Student's Actions Memory and starts the process of emotion recognition. Sometimes, the emotion is inferred from a determined pattern that is composed of a sequential set of actions. This way, it is necessary that past actions be also stored in the system by the Student's Actions Memory for future recovery.

The process of emotion recognition verifies if it can infer a student's affective state from the information received (with or without past actions). The information received is analysed according to the student's goals following the OCC model. If any emotion is detected, it is stored in the student's affective model and it starts the process of choosing the affective tactics. The student's affective state is also sent to the Diagnostic Agent that will use this information for better defining the abilities of the student that are in the ZPD (ANDRADE; BRNA; VICCARI, 2002). It is important that the agent knows the student's goals to understand how the emotion of the student was elicited and how to act. The tactic is sent to the Action Module. The emotion recognition by a BDI reasoning using the OCC model to detect the student's emotions is described in Section 7.1.

If the affective tactic is the presentation of an emotional behaviour (for example, to congratulate the student on the success in the exercise), the Module for Selection of Behaviour and Speeches searches on the database the behaviour to be presented according to the chosen tactic.

The Mediating Agent is also responsible for receiving the tactics for performance and competence from the Diagnostic Agent. If the tactic is the presentation of a pedagogical content, it makes a request to the Semiotic Agent and exhibits the content to the student.

The interface of communication of the Mediating Agent with another agent is not represented in Figure 7.3. In the next section we present the communication architecture of the Mediating Agent and the communicative acts also exchanged between the Mediating Agent and other agents.

[39] First, this information is sent to the Sensor Module of the Communication Architecture that encapsulates the data in ACL messages before sending them. The communication architecture is presented in Section 7.5.

7.4 The Architecture for the Presentation of Emotive and Animated Behaviours and Speeches

The affective tactics are emotive behaviours and speeches presented by a lifelike character called PAT (Pedagogical and Affective Tutor).

The presentation of these emotive attitudes is accomplished by the **Action** component that is part of the Mediating Agent's Body module presented in Figure 7.3. The Mind module, based on the student's emotion, decides an affective tactic (in this case a behaviour and/or a speech) to be presented by the **Module for the Presentation of Behaviour and Speeches**. The architecture of this module is shown in Figure 7.4. It was implemented by Everton Bocca's dissertation (BOCCA, 2003).

In our system, the animated behaviours of the character are stored in a database of speeches and behaviours. The agent chooses a behaviour, that can be verbal or physic or both, to be presented from this database. This implementation is very similar to the "Space Behaviours" used for the generation of animated behaviour in the Cosmo Agent (see Section 2.5.4 for more details). As in Cosmo, the animated behaviour of the agent is not generated dynamically by 3D graphical algorithms (like Steve – see Section 2.5.3), but it is selected from a database of behaviour. The behaviours' database is shown in Table 7.1.

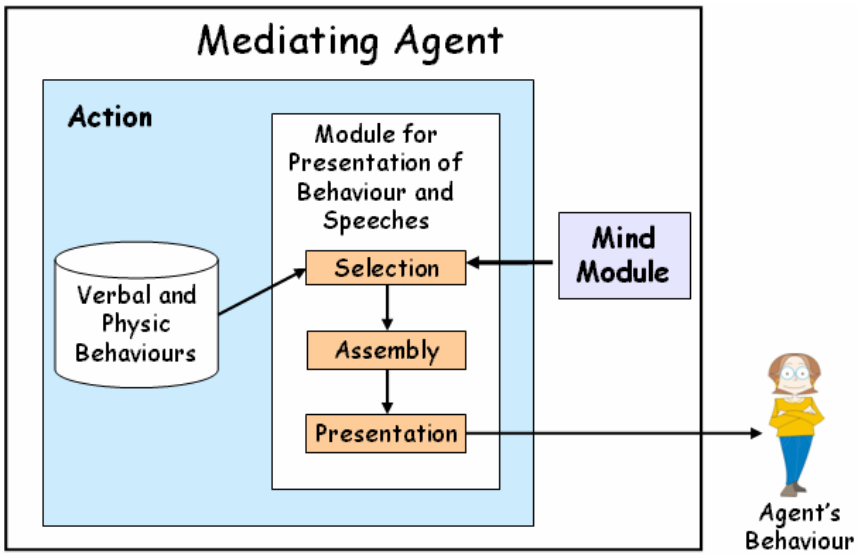


Figure 7.4: The Module for the Presentation of Behaviour and Speeches Architecture (BOCCA, 2003)

The Mind module sends a message to the Action Module that contains the affective tactic to be accomplished. The Mind module communicates with the Body Module via sockets, since the Mind (X-BDI) was implemented in *Sicstus Prolog* and the Body in Java. Let us imagine that the Mind module desires to present the affective tactic of "Increasing the student's effort". This message has the form "*tactic1, tactic2 ...*", where *tactic1* and *tactic2* represent the chosen affective tactics separated by comma, and so on. The tactics are presented in the order that they are received by the Body Module.

First, the message is sent to **Selection Component** in the **Module for Presentation of the Behaviours and Speeches**. The Selection Component chooses randomly a physical and a verbal behaviour type for each affective tactic (*VB* for verbal behaviours,

and *PB* for physical behaviours in the Action field of Table 7.1). For the "*increase student effort tactic*", it knows that it should choose a verbal behaviour of "*increase-student-effort*" type and a physical behaviour of "e*ncouragement*" type. This way, it can use a behaviour for a determined type for more than one tactic. For example, the "*encouragement*" type behaviour can be used for the "*increase-student-effort*" and "*encouragement*" tactics.

For example, if the behaviours' database was formed by the behaviours presented in Table 7.1, for the "increase-student-effort" physical behaviour the agent could choose among the behaviours identified by the 47, 47 and 49 values in the ID field of the table. To choose the behaviours arbitrarily, the agent stores the time that each behaviour was accessed for the last time on the database. Thus, the agent can choose the least recently used behaviours to be shown.

When the behaviour is a physical behaviour (for example, the agent chooses the encouragement behaviour - ID=48), the agent looks for what it must say (in the **Speech field)** while it presents the physical behaviour. If value of the **Speech field** is *null*, the agent will not speak. The **Description field** of the database contains the behaviour's description. Besides, this speech, which is closely related to the physical behaviour, the agent also speaks the sentences of the verbal behaviour.

After the agent has chosen a behaviour, it composes the JavaScript code that will make the Microsoft Agent move the agent. This Javascript code is listed in the **Optional field**. This process is accomplished by the **Assembly component**.

The code is sent to the **Presentation component** that generates an HTML page with the Javascript code for the agent's movements and presents it in the student's browser. The browser reads the HTML page and sends the code to the Microsoft Agent (MICROSOFT CORPORATION, 2002) that presents the behaviour determined in the code.

The Microsoft Agent has already some characters to be used like Merlin and others. After a study with psychologists (see Section 7.2 for more details), we opted to design the desired character, since we didn't find a character that matched the specified characteristics. For the agent's speeches we use the Microsoft Speech API as voice synthesiser. Although the Microsoft technologies used in the character's implementation depend on the operational system, we opted for this software because it offers a package to develop animated agents easy to implement, with good aspects of interface and besides, graphical implementation of the lifelike character is not part of the work's scope. But the system supports the character implementation in other implementation languages. For characters that work in a similar way with the Microsoft Agent, it is only necessary to replace the JavaScript of the Optional Field of the Database by the code of the language used. For characters in 3D environments (like Steve), it is necessary to create a component of communication between the Mediating Agent's Action Module and the environment responsible for generating the movements of the character.

Due to restrictions of Microsoft Agent for the design of the character, the agent can not speak at the same time that it shows a physical behaviour. As Microsoft Agent imposes, the agent has a special physical behaviour that is shown when it speaks (see behaviour of type "Speak" in Table 7.1).

Table 7.1: Emotive Behaviours and Speeches Database

Verbal Behaviour						
Id	**Action**	**Type**	**Description**	**Speech**	**Optional**	**Time**
1	VB	Congratulation	Pat congratulates the student	Uauuuuu! Você arrasou! Parabéns pelos esforços que você fez!		12
2	VB	Congratulation	Pat congratulates the student	Parabéns! Você conseguiu um ótimo resultado! Continue assim!		13
3	VB	Congratulation	Pat congratulates the student	Parabéns! Você conseguiu! A sua performance foi estupenda!		8
4	VB	Congratulation	Pat congratulates the student	Parabéns pelos seus esforços! Você se saiu muito bem!		11
5	VB	Congratulation	Pat congratulates the student	Parabéns! Você atingiu um bom resultado!		14
6	VB	Encouragement	Pat encourages the student to keep performance	Juntos vamos superar! O importante é continuar tentando!		11
7	VB	Encouragement		Vamos em frente! Você conseguirá!		14
8	VB	Explain-help-importance	Pat shows the student that asks for helping does not mean lack of ability	Heiii. Pedir ajuda não significa que você não seja capaz de realizar. Ninguém nasce sabeno e, por isso, precisamos de ajuda para aprender e ultrapassar as dificuldades!		0
9	VB	Explain-help-importance	Pat shows the student that asks for helping does not mean lack of ability	Ganhar ajuda não significa que você não saiba fazer. Todo mundo precisa de ajuda!		0
10	VB	Give-help	Pat says that it will help the student	Vou te dar umas informações úteis que vão te ajudar!		0
11	VB	Give-help	Pat says that it will help the student	Deixa eu ver no que eu posso te ajudar...		0
12	VB	Give-help	Pat says that it will help the student	Boa hora para ter dúvida. Este conteúdo não é fácil mesmo!		1
13	VB	Give-help	Pat says that it will help the student	Vou te mostrar outra alternativa.		0
14	VB	Greeting	Greeting Behaviour	Olá!		75
15	VB	Greeting	Greeting Behaviour	Bom dia!	if (hour>00:00 && hour≤12:00)	79
16	VB	Greeting	Greeting Behaviour	Boa tarde!	if (hour>12:00 && hour≤18:00)	78
17	VB	Greeting	Greeting Behaviour	Boa noite!	if (hour>18:00 && hour≤24:00)	80
18	VB	Greeting	Greeting Behaviour	Alôzinho!		81
19	VB	Happy-for-helping	Pat says that it is happy for helping the student	Estou feliz em poder te ajudar!		0
20	VB	Happy-for-helping	Pat says that it is happy for helping the student	Iupppi. Gosto de ser útil a você!		0
21	VB	Idle	Student is idle	Hei! Esta na hora de começar a trabalhar.		13

22	VB	Increase-student-effort	Pat presents a message that aims to foster the student to make more efforts	É apenas necessário fazer um pouco mais de esforço! Vamos tentar mais uma vez?	if (effort!=high)	24
23	VB	Increase-student-effort	Pat presents a message that aims to foster the student to make more efforts	Não desista! Vamos em frente! Para ter bons resultados é necessário ser persistente e se esforçar!		25
24	VB	Increase-student-effort	Pat presents a message that aims to foster the student to make more efforts	Continue com os seus esforços que o sucesso está a caminho.		26
25	VB	Increase-student-self-ability	Pat presents a message that aims to increase the student's self-ability	Eu sei que você é capaz de acertar!		20
26	VB	Increase-student-self-ability	Pat presents a message that aims to increase the student's self-ability	Você é um vencedor! Lembre de tudo que voce ja conseguiu fazer! Você se saiu muito bem nas atividades 1 e 3.		21
27	VB	Increase-student-self-ability	Pat presents a message that aims to increase the student's self-ability	Você é muito inteligente! Está tendo um bom progresso na tarefa!		22
28	VB	New-skill	Pat shows the new abilities the student acquired	Uau! Veja que novas habilidades você adquiriu: Você aprendeu a colocar fundo e a inserir figuras em homepage.		21
29	VB	New-skill		Legal! Você aprendeu novas coisas! Por exemplo: inserir hyperlink em uma homepage e inserir figura.		22
30	VB	New-skill	Pat shows the new abilities the student acquired	O sucesso nessa atividade mosra que você adquiriu novas habilidades. Agora você sabe formatar o texto de uma homepage. Por exemplo, colocar o texto em cores, centralizar títulos e colocar o texto em negrito.		0
31	VB	Offer-help	Pat offers help to the student	Posso te ajudar?		76
32	VB	Offer-help	Pat offers help to the student	Deixa eu te passar o que eu sei sobre esse assunto?		71
33	VB	Offer-help		Quer saber mais sobre este assunto?		73
34	VB	Offer-help		Quer umas dicas?		75
35	VB	Recognize-student-effort	Pat recognizes student´s effort	Continue assim! O esforço é a chave do sucesso!		52
36	VB	Recognize-student-effort		Parabéns pelos esforços que tem feito. Continue assim!		49
37	VB	Show-curiosity	Pat shows some curiosities about the taught content	Você sabia que: a lição colocar fundo na homepage ensina até colocar figuras como fundo?		7
38	VB	Sorry-for-not-helping	Student denies agent help	Xiii. Acho que atrapalhei.Desculpa.		1
39	VB	Student-disables-agent	when student disables agent	Eu o estou triste por não ser útil a você. Você pode me dizer por que não quer mais a minha ajuda?		0
40	VB	Student-enables-agent	when student enables agent	Iupiiii! Eu estou tridi contente por poder ser útil a você!		1

Physical Behaviour						
Id	**Action**	**Type**	**Description**	**Speech**	**Optional[40]**	**Time**
41	PB	Congratulation	Pat plays darts and hits		estímulo8	13
42	PB	Congratulation	Pat kicks the ball and makes a goal		estímulo2	12
43	PB	Congratulation	Pat applauses		estímulo1	11
44	PB	Congratulation	Pat wears Olympiads clothes and it reaches the arrival line. There are many people waiting for it and applauding.		estímulo3	14
45	PB	Congratulation	Pat plays a circus´ toy and hits		estímulo9	15
46	PB	Empathic	Pat blinks to the student twice		idle2	54
47	PB	Encouragement	Pat blinks and smiles		estímulo4	45
48	PB	Encouragement	Pat is boxing and it strikes a sac which is wrote my difficulties	Eu sei que você é capaz de nocautear as suas dificuldades.	tutoria1	43
49	PB	Encouragement	Pat is tired and drops on the couch	Não desanime!	estímulo7	44
50	PB	Give-help	Pat wears like a sapient monk	Tenho muita sabedoria para te passar.	tutoria6	72
51	PB	Give-help	Pat takes a book from the bookcase		tutoria2	76
52	PB	Give-help	Pat opens a parchment and reads it		tutoria5	77
53	PB	Give-help	Pat looks like Sherlock Holmes	Tenho a pista que você precisa.	tutoria3	74
54	PB	Greeting	Pat waves to the student		saudação1	74
55	PB	Greeting	Pat wears a dress and waves to the student		saudação2	73
56	PB	Idle	Pat lies on the couch and yawns	Que tédio ficar parada.	estímulo6	15
57	PB	Idle	Pat yawns		idle1	14
58	PB	New-skill	Pat turns into a super-heroine and flies on the screen	Você adquiriu novos super-poderes.	tutoria7	15
59	PB	New-skill	Pat juggles with tennis balls		tutoria8	20
60	PB	Show-curiosity	Pat takes a book from the bookcase		tutoria2	3
61	PB	Show-curiosity	Pat opens a parchment and reads it.		tutoria5	1
62	PB	Sorry	Agent is sad		estímulo5	7
63	PB	Speak	While Pat is speaking		fala	9
64	PB	Student-aks-help	Pat makes a sign showing that it is ready to listen to the student		tutoria4	2

[40] For the physical behaviours of the agent, the optional field contains the animation's name used by Microsoft Agent.

7.5 Some Illustrative Scenarios

In order to better understand how the Mediating Agent selects an affective tactic and the behaviors that compose it, let's see some illustrative scenarios.

As we said previously, the student can have performance or mastery motivational orientation. Pat uses this information and the knowledge about the student's emotion in order to decide which affective tactic to apply.

Let's imagine that a student who has **performance** motivational orientation feels **disappointed** and **distressed** because he **did not accomplish the task correctly.** He feels that he is not able to accomplish the task when he fails. And he usually does not do greater effort when he has difficulties, because he thinks that it means lack of ability. In this situation the agent presents a message to increase the student's beliefs about his self-ability and says to the student that he is able to carry out the task with a little more effort. The idea is to show the student who has performance goal that when he didn't achieve success in a task, it does not mean lack of ability, but that he can achieve better results with more effort. Bellow, we can see the Mediating Agent's beliefs, in X-BDI notation, that infers the student's emotions and the affective tactics.

It is necessary to know if it is a prospect of event in order to know if the event elicits satisfactions and disappointment emotions:

```
bel(mediador,is_prospect_event(not_correct_answer)) if
    bel(mediador,event(not_correct_answer)).
```

After, we need to know the pleasantness of the event in order to know if it elicits negative or positive emotions:

```
bel(mediador,event_pleasantness(not_correct_answer,displeased)) if
    bel(mediador,student_goal(performance)),
    bel(mediador,event(not_correct_answer)).
```

When the student is displeased with an event, it experiences disappointment (when it is a prospect of an event) and distress.

```
bel(mediador,student_emotion(disappointment))if
    bel(mediador,event_pleasantness(Event,displeased)),
    bel(mediador,-is_mediador_action),
    bel(mediador,is_prospect_event(Event)).

bel(mediador,student_emotion(distress))if
    bel(mediador,event_pleasantness(Event,displeased)),
    bel(mediador,-is_mediador_action).
```

The intensity of the emotion is medium, since it was not detected any of the variables that increase its intensity.

```
bel(mediador,emotion_intensity(disappointment,medium)) if
    bel(mediador, -unexpectdness(high)),
    bel(mediador, -realization(high)),
    bel(mediador, -effort(high)),
    bel(mediador, -undesirability(high)),
    bel(mediador,student_emotion(disappointment)).
```

Once the agent knows the student's emotions, it tries to satisfy its desire of applying affective tactics. It then chooses the affective tactics:

```
bel(mediador, choose_tactics(increase_student_self_ability)) if
    bel(mediador,student_emotion(disappointment)),
    bel(mediador,event(not_correct_answer)),
    bel(mediador,student_goal(performance)).

bel(mediador, choose_tactics(increase_student_effort)) if
    bel(mediador,student_emotion(disappointment)),
    bel(mediador,event(not_correct_answer)),
    bel(mediador,student_goal(performance)).

bel(mediador, choose_tactics(offer_help)) if
    bel(mediador,student_emotion(disappointment)),
    bel(mediador,event(not_correct_answer)),
    bel(mediador,student_goal(performance)).
```

To this situation, the Pat's Mind selects the tactics (1) "increase student's self-ability", (2) "increase student's effort", and (3) "offer-help". The Mind module sends the tactics to the Body module which verifies the behaviours type that compose them. In the Table 6.5 we can see these tactics and the corresponding behaviours type. To the scenario described above, the behaviours type and the affective tactics are:

1) Increase-student-self-ability VB: Increase-student-self-ability; PB: Encouragement;	3) Offer-help VB: Offers-help PB: Give-help
2) Increase-student-effort VB: Increase-student-effort; PB: Speak	

Then, the Body module chooses the random behaviours of the specific type. For example, the first tactic is "increase-student-self-ability". For this tactic, the agent should show a verbal behaviour (VB) and a physical behaviour (PB). In the example above, for the increase student-self-ability tactic, the agent should choose a verbal behaviour of type "student-self-ability" and a physical behaviour of type "Encouragement". For each type of behaviour, there is more than one possible attitude.

Figure 7.5 shows two different examples of behaviours that can be chosen for the tactic "*Increase-student-self-ability*".

Figure 7.5: Examples of behaviours for the tactic "*Increase-student-self-ability*"[41]

[41] The verbal behaviours (agent's speeches) were translated from Portuguese to english.

Let's see another example, when an **extrinsic student** feels **shame** because he **asked for help** and it means lack of ability for him.

The agent's cognitive kernel (Mind module) infers the student's emotions from the following beliefs:

The agent knows that ask for helping is an action of the student.

```
bel (mediador,is_self_action) if
    bel (mediador,event(student_asks_for_helping)).
```

The agent also knows that the student is blamed with his action of ask for helping when he feels uncomfortable.

```
bel (mediador,action_praiseworthiness(Event,blame)) if
    bel (mediador,student_goal(performance)),
    bel (mediador,event(student_asks_for_helping)),
    bel (mediador,student_feels_uncomfortable).
```

When the student is blamed with an own action, he feels shame.

```
bel (mediador,student_emotion(shame))if
    bel (mediador,action_praiseworthiness(Event,blame)),
    bel (mediador,is_self_action).
```

As the blameworthiness of the student's action is not high, the intensity of the emotion is medium.

```
bel (mediador,emotion_intensity(shame,medium)) if
    bel (mediador, -blameworthiness(high)),
    bel (mediador,student_emotion(shame)).
```

The agent's intention of applying a pedagogical tactic chooses them.

```
bel (mediador, choose_tactics(explain_help_importance)) if
    bel (mediador,student_emotion(shame)),
    bel (mediador,event(student_asks_for_helping)),
    bel (mediador,student_goal(performance)).

bel (mediador, choose_tactics(give_help)) if
    bel (mediador,student_emotion(shame)),
    bel (mediador,event(student_asks_for_helping)),
    bel (mediador,student_goal(performance)).
```

The agent chooses the affective tactic of explaining the help importance in order to clarify the student's misconception that asking for help means lack of ability. After, it offers help to the student again. These affective tactics are composed of the following type behaviours:

1) Explain-help-importance VB: Explain-help-importance PV: Empathic
2) Give-help VB: Give-help PV: Give-help

Figure 7.6 shows an example of (verbal and physical) behaviours chosen randomly by the agent to the tactic "*Offer-help*" and Figure 7.7 shows an example of behaviours for the tactic "*Explain-help-importance*".

Figure 7.6: Example of Behaviours for the tactic "*Offer-help*"

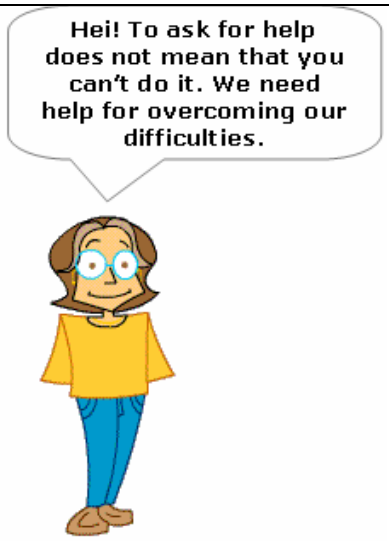


Figure 7.7: Example of Behaviours for the tactic "*Explain-help-importance*"

We cited above some examples of behaviours that the agent can show the student as an affective tactic. By the moment, we have 60 verbal and physical behaviours that are cited in Table 7.1. So, for the same scenarios presented in this section, the agent can chooses other different behaviours in order to be believable.

The number of verbal behaviours can be easily increased, since we use a voice synthesizer and, thus, the only work to be done is to add the speeches in natural language in the Database of Speeches and Behaviours. The physical behaviours, otherwise, must be designed by a professional designer and recorded in a format specific for the Microsoft Agent. The database just contains a reference to the physical behaviours.

7.6 The Communication Architecture of the Mediating Agent

The Mediating Agent is inserted in a Multi-agent system where each agent executes a determined task and they communicate among themselves in order to achieve a global objective which is teaching the student taking his individual profile into consideration. Thus, it is necessary to consider the communication architecture of the Mediating Agent. The specification and implementation of this communication architecture was accomplished as an undergraduate final course work (QUINTANS; PILATTI, 2002).

The FIPA's Agent Communication Language (ACL) was adopted as communication language for the agents. We chose ACL because it is already defined and formalised, which enables the code re-utilisation and allows to change messages with or without formatted content. Also, as the agents in the system send messages in ACL, which is a very well defined language, other agents that use the same language can be inserted in the system, allowing the system's improvement. The eXtensible Markup Language (XML) was chosen as the format for the messages' content because it allows to format the content, to apply style sheets to personalise the content and to define ontology through Document Type Definition (DTD).

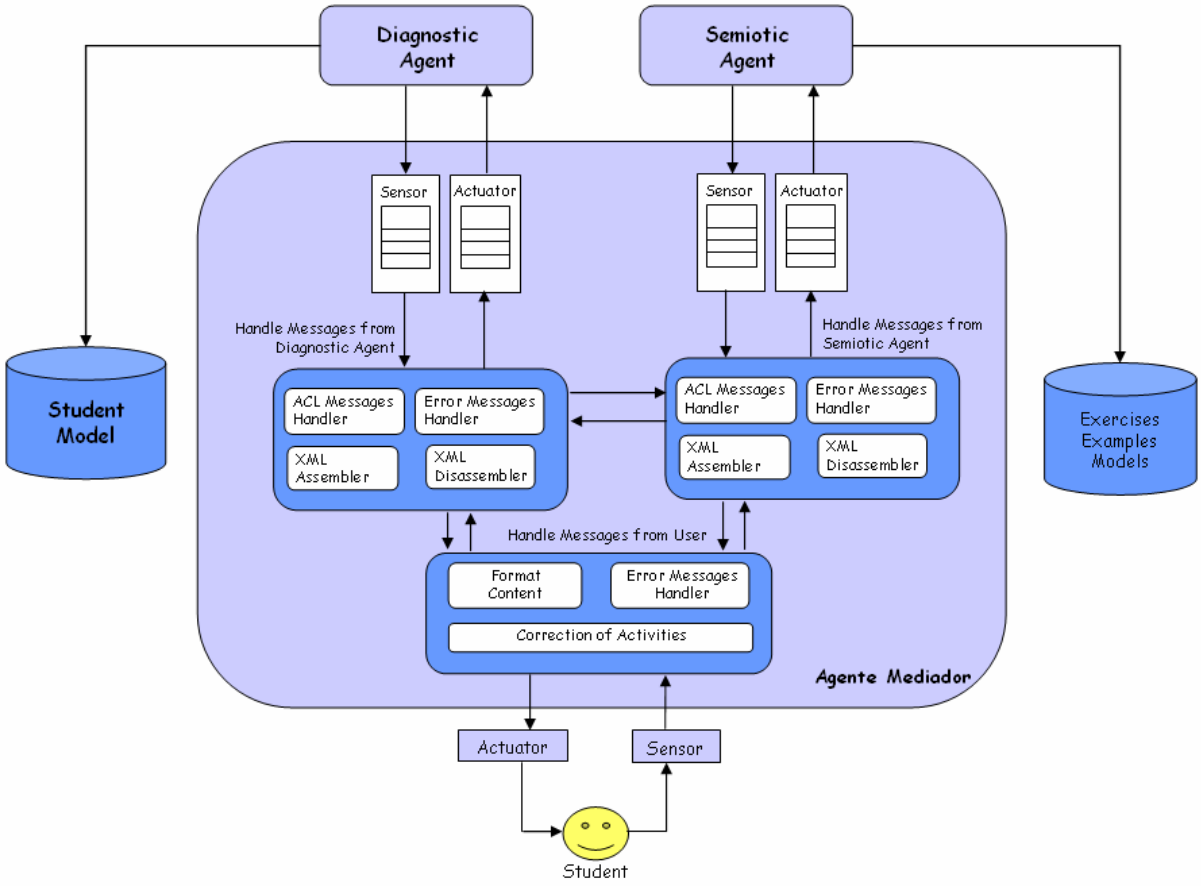


Figure 7.8: Mediating Agent's Architecture of Communication
(QUINTANS; PILATTI, 2002)

The architecture for the communication of the Mediating Agent is composed of three main components: Module for Handling Messages from Diagnostic Agent,

Module for Handling Messages from Semiotic Agent and Module for Handling Messages from the User. Each module has the following components: ACL Messages Handler, XML Assembler, XML Disassembler, Error Messages Handler, Show Content, Correct Activities and Sensor and Actuator.

The "*Handle Messages from Diagnostic and Semiotic Agent*" components are asynchronous and therefore they need a queue to order the received messages. This function is accomplished by the Sensor Component. The "*ACL Messages Handler"* component parses the received message and the message's content is sent to the *"XML Disassembler*" that separates the information and puts it in a data structure to be used by other modules of the program.

In the same way, the information to be sent is written in XML by the "*XML Assembler"* and an ACL message is created to be sent. Finally, the message is queued to be sent by the *Actuator* component.

The *Sensor* module (that interacts with the student) is responsible for catching the user's actions and sending them to the "*ACL Messages Handler"* that encapsulates the information received in ACL messages with the content in XML. These actions are also sent to the Perception Module that is presented in Figure 7.3.

Figure 7.9: Sequence Diagram of Pedagogical Content Requisition and Exhibition by the Mediating Agent represented in UML (QUINTANS; PILATTI, 2002)

When the received message is a content to be presented to the student, the *"Format Content"* component constructs the content pages (with the subject received in the message) in HTML to be presented to the student by the *Actuator* Component. The "*Correct Exercises"* component is responsible for verifying the student's performance on the exercises. This information is sent to the Diagnostic Agent and to the *Mind* module. The sequence diagram in Figure 7.9 represents the actions made by the Mediating Agent to requisite pedagogical content to the Semiotic Agent and to exhibit it to the student.

In the next section, the ACL messages exchanged between the Mediating Agent and other agents are presented.

Interaction Protocols

Interaction protocols support messages' exchanges and understanding among agents to accomplish a determined activity. For example, in order for the Mediating Agent to exhibit a pedagogical content asked by the Diagnostic Agent, it must send and receive a determined and ordered set of messages to obtain the content, present it to the student and inform other agents that the content has been presented.

The Mediating Agent has the following protocols:

- **Student Register**: to register the student in the system;
- **Student's Login and logout**: for the connection and disconnection of the student in the system;
- **Pedagogical Content**: to request pedagogical content and exhibit it to the student;
- **Subjective Exercise Response:** to send the user's response to a subjective exercise.
- **Objective Exercise Response:** to send the statistical information about the student's performance in an objective exercise.
- **Search:** to exhibit links about a subject studied by the student;
- **Subjective Exercise Appreciation**: to send the Diagnostic Agent appreciation and correction of a subjective exercise resolved by the student;
- **Accessed Pedagogical Content:** to inform the Diagnostic Agent if the student accessed completely a pedagogical content presented.
- **Student's Affective States:** to send to the Diagnostic Agent's the user's affective states.

In the ACL messages, basically two types of directives are exchanged: "*inform"* to send a determined message to the receiver, and "*request"* to ask information to the receiver. In Table 7.3 to Table 7.12, we present the messages exchanged in each protocol according to (QUINTANS; PILATTI, 2002). The actor entities are the Mediating Agent (**M**), Diagnostic Agent (**U**), the User (**U**), and Semiotic Agent (**S**).

For each ACL message, the *content* field contains the message's content in XML. The *conversation-id* field indicates which action must be taken by the destination agent when it receives the message. In Table 7.2 the relation between the messages' type and conversation-id is presented.

Table 7.2: Relation between Messages' Type and Conversation-id (QUINTANS; PILATTI, 2002)

Message Type	**Value of the Conversation-id field**
Student's register in the system	Student_Register
Validation of student's login and password	User_Validation
Query about the student's register data	Request_Student_Data
Alter student's register data	Alter_Student_Register
Student's login on the system	Student_Login
Student's logout on the system	Student_Logout
Response for the subjective exercises	Subjective_Exercise_Response
Request appreciation for subjective exercise	Request_Appreciation
Statistical information about student's performance in an objective exercise	Exercise_Statistic
Information about the pedagogical content accessed by the student	Accessed_Pedagogical_Content
Information about student's affective states	Student_Emotions

Table 7.3: Student's Register Protocol (QUINTANS; PILATTI, 2002)

Flow	**Message (ACL)**	**Description of the Message's Content**
U→M	(inform :sender U :receiver M :content <Student_Register> :conversation-id Student_Register)	Student's name, login and password.
M→D	(request :sender M :receiver D :content <Student_Register> :conversation-id Student_Register)	Student's name, login and password.
D→M	(inform :sender D :receiver M :content <User_Validation> :conversation-id User_Validation)	Inform if register was successful or not.
M→U	(inform :sender M :receiver U :content <User_Validation> :conversation-id User_Validation)	Inform the user that he can use the system if the register was successful.

Table 7.4: Student's Login Protocol (QUINTANS; PILATTI, 2002)

Flow	**Message (ACL)**	**Description of the Message's Content**
U→M	(inform :sender U :receiver M :content <Student_Login> :conversation-id Student_Login)	User's login and password.
M→D	(request :sender M :receiver D :content <Student_Login> :conversation-id Student_Login)	Request user's login and password.
D→M	(inform :sender D :receiver M :content <User_Validation> :conversation-id User_Validation)	Inform if login was sucessful.
M→U	(inform :sender M :receiver U :content <User_Validation> :conversation-id User_Validation)	Inform the user if he can login the system.

Table 7.5: Student's Logout Protocol (QUINTANS; PILATTI, 2002)

Flow	**Message (ACL)**	**Description of the Message's Content**
U→M	(inform :sender U :receiver M :content <Student_Logout> :conversation-id Student_Logout)	Login of the user that desires to login in the system.
M→D	(inform :sender M :receiver D :content <Student_Logout> :conversation-id Student_Logout)	Inform that the student logout.

Table 7.6: Pedagogical Content Protocol (QUINTANS; PILATTI, 2002)

Flow	**Messages (ACL)**	**Description of the Message's Content**
D→M	(request :sender D :receiver M :content <Request_Pedagogical_Content> :conversation-id Request_Pedagogical_Content)	Request for presenting a determined content for the student.
M→S	(request :sender M :receiver S :content < Request_Pedagogical_Content> :conversation-id Request_Pedagogical_Content)	Request pedagogical content to be presented to the student.
S→M	(inform :sender S :receiver M :content < proof > OR < exercise > OR < pedagogical_content > :conversation-id Request_Pedagogical_Content)	Send the pedagogical content.
S→M	(inform :sender S :receiver M :content <Content_is_sent> :conversation-id Request_Pedagogical_Content)	Information about the pedagogical content that will be presented to the student.
M→D	(inform :sender M :receiver D :content <content_sent> :conversation-id Request_Pedagogical_Content)	Information about the pedagogical content that was presented to the student in irder for the Diagnostic Agent to update the student's model.
M→U	(inform :sender M :receiver U :content < proof > OR < exercise > OR < pedagogical_content > :conversation-id Request_Pedagogical_Content)	Pedagogical content.

Table 7.7: Subjective Exercise Response Protocol (QUINTANS; PILATTI, 2002)

Flow	Message (ACL)	Description of the Message's Content
U→M	(inform :sender U :receiver M :content <Subjective_Exercise_Response> :conversation-id Subjective_Exercise_Response)	Student's response for a subjective exercise.
M→D	(inform :sender M :receiver D :content <Subjective_Exercise_Response> :conversation-id Subjective_Exercise_Response)	Student's response for a subjective exercise.

Table 7.8: Objective Exercise Response Protocol (QUINTANS; PILATTI, 2002)

Flow	Message (ACL)	Description of the Message's Content
M→D	(inform :sender M :receiver D :content <Exercise_Statistic> :conversation-id Exercise_Statistic)	Success rating in an objective exercise

Table 7.9: Search Protocol (QUINTANS; PILATTI, 2002)

Flow	Message Type (ACL)	Description of Message's Content
U→M	(inform :sender U :receiver M :content <Search> :conversation-id Search)	Search results.
M→D	(inform :sender M :receiver D :content <Search> :conversation-id Search)	Inform the Diagnostic Agent about the search made by the student in order for it to update the student's model.
M→S	(request :sender M :receiver S :content <Search> :conversation-id Search)	Request if the search was done.
S→M	(inform :sender S :receiver M :content <Search_Content> :conversation-id Search_Content)	Inform about the content of the search.
M→U	(inform :sender M :receiver U :content < Search_Content > :conversation-id Search_Content)	Inform the student about the result of the search.

Table 7.10: Subjective Exercise Appreciation Protocol (QUINTANS; PILATTI, 2002)

Flow	Messages (ACL)	Description of Message's Content
U→M	(inform :sender U :receiver M :content <Request_Appreciation> :conversation-id Request_Appreciation)	The student desires to access the appreciation of subjective exercises made by him.
M→D	(inform :sender M :receiver D :content < Request_Appreciation > :conversation-id Request_Appreciation)	Mediating Agent requests appreciation of subjective exercise made by the student for Diagnostic Agent.
D→M	(inform :sender D :receiver M :content <Subjective_Exercise_Response_Appreciation> :conversation-id Subjective_Exercise_Response_Appreciation)	Diagnostic Agent sends appreciation of subjective exercise made by the student.
M→U	(inform :sender M :receiver U :content < Subjective_Exercise_Response_Appreciation > :conversation-id Subjective_Exercise_Response_Appreciation)	Mediating Agent format the appreciation in order to present it to the student.

Table 7.11: Accessed Pedagogical Content Protocol (QUINTANS; PILATTI, 2002)

Flow	Messages (ACL)	Description of Content's Message
U→M	(inform :sender U :receiver M :content <Accessed_Pedagogical_Content> :conversation-id Accessed_Pedagogical_Content)	Contains the identifier of the pedagogical content accessed by the user.
M→D	(inform :sender M :receiver D :content < Accessed_Pedagogical_Content > :conversation-id Accessed_Pedagogical_Content)	Contains the identifier of the pedagogical content accessed by the user.

Table 7.12: Student's Affective States Protocols

Flow	Messages (ACL)	Description of Content's Message
D→M	(request :sender U :receiver M :content < Student_Emotions > :conversation-id Student_Emotions)	Diagnostic Agent requests to the Mediating Agent the Student's Affective States Profile.
M→D	(inform :sender M :receiver D :content < Student_Emotions > :conversation-id Student_Emotions)	The Mediating Agent sends to the Diagnostic Agent the Student's Affective State Profile.

8 PROTOTYPE VALIDATION

As we previously said, the Mediating Agent is inserted in MACES, a collaborative educational system modelled through a multi-agent architecture. As MACES is not totally implemented yet, it was not possible to make a complete validation of the proposed work, since we need all the system in order to create a virtual class. But, as we desired to validate the affective tactics and the appearance of the character, we made a partial validation of the work.

For the conception of the character we made interviews with 10 pedagogues and psychologists in order to define its appearance and appropriate behaviours (see (BOCCA, 2003)). In order to validate this character and also its tactics that are part of its behaviour, we made a validation with other 8 professionals of computer in education. For this partial validation, we presented different tactics and corresponding behaviours chosen randomly for some educational situations. An educational situation is an emotional reaction (an emotion) of the student that has a determined motivational orientation (extrinsic or intrinsic) for a determined event (examples of events can be found in Table 6.3 and in Table 6.4). These tactics were presented for 8 professionals of computer in education. The idea is to base on the pedagogical experience of these professionals to verify if the affective tactics of the Mediating Agent are pedagogically adequate (if they accomplish their role: encourage, motivate the student and promote in him positive emotions), and if the appearance of the character is adequate.

The validation was made in the following way. Initially, we made a brief presentation of the Mediating Agent, its role and how it works with the student. After, we explained more precisely how the validation will be made and what we expected from the evaluators. As, we had a small number of evaluators, we opted to accomplish a more qualitative evaluation: for each educational situation the evaluators described freely if they thought that the affective tactics and the corresponding behaviours are appropriate and why. After the presentation and evaluation of each educational situation, they filled another questionnaire relative to the appearance of the character. The questionnaires used as tool of evaluation are presented in Appendix D. As MACES is not yet implemented, for the validation, we implemented a software program that communicates with the Body module of the Mediating Agent and asks it to present some affective tactics.

These educational situations and the affective tactics applied are presented in Table 8.1.

Table 8.1: Educational Situations Presented in the Validation

Event	Intrinsic Motivation (Mastery Goals)	Extrinsic Motivation (Performance Goals)
Salutation	(Situation 1) *1) Salutation* VB: Salutation PB: Salutation	
1) Not correct task answer	(Situation 2) ***Distress/Disappointment:*** *1) Recognise-student-effort* VB: Recognise-student-effort PB: Empathic *2) Offer-help* VB: Offer-help PB: Speak	(Situation 4) ***Distress/Disappointment:*** *1) Increase-student-self-ability* VB: Increase-student-self-ability PB: Encouragement *2) Increase-student-effort* VB: Increase-student-effort PB: Speak *3) Offer-help* VB: Offer-help PB: Give-help
2) Correct task answer	(Situation 5) ***Joy/Satisfaction:*** *1) Congratulate-student* PB: Congratulation (moderate) VB: Congratulation (moderate) *2) Show-students-new-skills* VB: New-skill PB: New-skill	(Situation 7) ***Joy/Satisfaction:*** *1) Congratulate-student* PB: Congratulation VB: Congratulation
3) Not accomplished task	(Situation 8) ***Distress/Disappointment:*** *1) Encourage-student* VB: Encouragement PB: Encouragement *2) Offer-help* VB: Offer-help PB: Give-help (Situation 9) ***NE:*** *1) Show-students-new-skills* VB: New-skill PB: New-skill *2) Offer-help* VB: Offer-help PB: Give-help	(Situation 10) ***Distress/Disappointment:*** *1) Increase-student-self-ability* VB: Increase-student-self-ability PB: Encouragement *2) Increase-student-effort* VB: Increase-student-effort PB: Speak
4) Gave up the chapter	(Situation 11) ***NE:*** *1) Show-curiosity-about-subject* VB: Show-curiosity PB: Show-curiosity	
8) Student denies agent's help	(Situation 14) ***Anger:*** *if (agent_is_disturbing)* 1) Sorry-for-disturbing VB: Sorry-for-disturbing PV: Sorry	
14) Student is idle	(Situation 15) *1)Student-idle* VB: Idle. PV: Idle. *2) Show-curiosity-about-subject* VB: Show-curiosity PB: Show-curiosity	

For each affective tactic, the agent randomly chooses one corresponding physical and verbal behaviours among the behaviours showed in Table 7.1.

The evaluators' responses of the questionnaires of the validation are presented in Appendix E. Their main suggestions and considerations were:

- The evaluators pointed out that the validation was impaired because it was made out of its context. They said that it was difficult for them to evaluate the affective tactics of the agent without observing it in the educational environment (MACES). We explained that MACES is not totally yet implemented and that we aim at making other validations when the implementation of the environment is finished.
- Another difficulty was to evaluate the elocutions of the Mediating Agent, since it was designed for any age-group. The evaluators showed that some speeches are more appropriate to adolescent users, while more formal attitudes are more adequate for adults. Anyway, they preferred the more casual elocutions.
- Another important observation pointed out is that the quality of the speeches was impaired by the use of a voice synthesiser. The evaluators found that the elocutions of the agent seemed artificial and that the synthetic voice does not allow to make intonations and to express emotions by voice, which is important for the Mediating Agent. They suggested using recorded speeches of a human speaker. Other evaluators thought that the speeches were very close to the way that a Nipponese, that learns Portuguese, speaks.
- They also commented that the physical behaviours are showed separately of the verbal ones. For example, in order to encourage the student, the Mediating Agent can show a physical behaviour in which it plays football and makes a goal and after it shows another behaviour (when it is stand) to congratulate verbally the student. This is due to a restriction of implementation of the Microsoft Agent which requires that we use a specific physical behaviour of speech when the agent speaks. To overcome this difficulty is necessary to implement the character in another programming language. As the Microsoft Agent is dependent of platform, we intend to implement it in Flash as a future work.
- The evaluators also observed that it is interesting to have more interactivity between the Mediating Agent and the student. They suggested that after explain something the agent should ask to the student, for example: "Don't you think so?".
- In relation to the agent's gender (female or male), the evaluators thought that it is not applicable or that the system could let the student the option of choosing the gender of the agent as well as other characteristics, as its clothes, personality, and etc. This suggestion was not waited, since the psychologists and pedagogues interviewed when we was defining the appearance and personality of Pat suggested that a woman was more appropriate, since the majority of students had a women as teacher when child. But they also suggested that the student could choose a determined character among some options (For more details about these interviews see Section 7.2 and (BOCCA, 2003)).
- Finally, some speeches of the Mediating Agent showed to be inappropriate. For example, when the agent says: "I have a lot of knowledge to transmit to you (in Portuguese: Eu tenho muita sabedoria para passar a você)" in order to offer help to the student. The evaluators suggested using elocutions that seems more an

invitation. For example, instead of saying “I have a lot of knowledge to transmit to you”, the agent could say “I have some knowledge to share with you” (in Portuguese: Tenho algum conhecimento para compartilhar com você”).

These suggestions will be considered in the future works related to the Mediating Agent (see Section 9.2 for a description of the future works).

Besides the limitations cited above, the evaluators thought that the appearance of the character was appropriate, it has good attitudes of interaction with the user, the expression of emotions is adequate (characteristics that was pointed out as necessary by the pedagogues and psychologists which were interviewed for the conception of Pat (BOCCA, 2003)), and that it accomplishes its role of motivating the student and promoting positive emotions in him. In special, we would like to highlight the commentary of the person 4 that was interviewed: “First the work is excellent, very creative and very adequate for the necessity of searching more complex elements to support the educational research”.

Besides, when MACES is totally implemented we intend to accomplish a complete validation of the Mediating Agent in a real class. In this evaluation, we aim at observing a group of students using the educational system with the Mediating Agent’s character and the affective tactics and another group using the system without. Although pedagogues and psychologists have pointed out the important role of the motivation and the affectivity in learning, we believe that this more complete validation can show us that the Media Equation (REEVES; NASS, 1996) also applies for this situation. It means that computers can also have this type of social interaction with students - computers, represented by lifelike characters, can provide emotional support for the student and promote in him positive emotions that are more adequate for learning.

9 CONCLUSIONS, RESTRICTIONS AND FUTURE WORK

This thesis proposes an affective and animated pedagogical agent responsible for providing emotional support to the student as well as to induce positive emotions in him which fosters learning. As a case study, the proposed agent is implemented as the Mediating Agent of the multi-agent architecture of the educational environment MACES, which was described in Chapter 5.

These affective tactics are composed mainly by emotive attitudes and messages and domain-based tactics. To choose the most adequate affective tactic, the agent considers student's affectivity. The use of empathic and emotive behaviours of the agent for attempting to promote a positive mood in the student, by considering his current emotions, and for providing an emotional support to him is another contribution of this thesis.

As we previously said, the agent infers the student's emotions in order to choose the most appropriate tactic. The agent is more effective if it considers the student's emotions when chooses an affective tactic than when it shows some general empathic behaviour. This is an advance of our work in relation to other works presented in the section of animated pedagogical agents in this thesis (see in Section 2.6 a comparison between the Mediating Agent and other agents studied in this thesis).

Besides, we recognise the student's emotions joy/distress, satisfaction/frustration, gratitude/anger, and shame according to the OCC model. These emotions were not considered by the earlier works of the group (BERCHT, 2001) (PROLA, 2003).

Although we use the same approach adopted by Bercht (2001) for the implementation of the affective diagnosis, the BDI approach, our work differs from her work in the methodology used to recognise the student's emotions. The emotional state displeased in the Bercht's work is inferred by rules, inserted in the BDI agent as beliefs. Basically, Bercht based intuitively on the OCC model to construct the rules that infer the student's emotions from the user's actions. The inference of the student's appraisal was made by an expert that inserted the rules in the system. In our idealisation the inference of the student's appraisal is made by the agent itself. So, in our work, we benefit from the reasoning capacity of the BDI to infer the student's emotions according to the OCC model. An advantage of our proposal is that it is not necessary for an expert person to determine all the rules for the student's affective state inference to be implemented in the agent in advance. The system deduces the student's affective state by reasoning about his appraisal.

Besides, in relation to the affective recognition, we can point out that another contribution of this work is to propose a methodology for implementing computationally, relying on a BDI approach, the OCC model. The steps defined in the

OCC theory for the recognition of emotions are accomplished by an agent with reasoning capacity. The agent is able to identify events and agent's actions, the student's goals and the desirability of these events. The use of the BDI for this implementation of the OCC model is an alternative approach to other approaches found in the research literature, as probabilistic approaches proposed by Conati (2002) or rules as proposed by Faivre and colleagues (2002) and Elliot and colleagues (1999).

However, we found some restrictions and limitations in this work that we present in the next section. In order to attempt to minimize this limitation, we propose some future works which we describe in Section 9.2.

9.1 Some Restrictions and Limitations Found

The complete development of the multi-agent architecture of MACES is not the scope of this work. In this way, as MACES is not implemented, it was not possible to turn the Mediating Agent operational and we can just do it in the moment that other agents of the society are implemented and integrated. Therefore, as the system has not yet been implemented, it has not been possible to accomplish a complete and exhaustive validation of this work.

Also, as the graphical implementation of the animated character was not the scope of this thesis, we used the Microsoft Agent to design the character's attitudes and Microsoft API as voice synthesizer, which provided good quality of animations and speech. But this tool is dependent of the Windows operational systems, which turns our implementation platform-dependent.

Besides, another difficulty that we found is that the recognition of emotion is very dependent of the environment. As MACES is an educational environment that is independent of domain (it was designed to teach any domain of subject) it was very difficult to determine the student's goals and events in the educational system. Also as the system was designed for any age-group (since the student knows to use a computer), it was very difficult to determine the student's personality traits, which could be useful to help us to determine the student's goals that are used to infer the student's emotions.

We do not consider the past emotions of the students. In our work, for each emotion elicited, the agent chooses an appropriate action (tactic) that aims at maintaining the positive emotions and cancelling the negatives ones. But, we believe that in some cases a manifestation of the emotion can stay in lower intensity. It is very difficult to know when the student continues feeling or not an emotion when we infer the student's emotions from his observable behaviour. But we believe that this limitation can be overcome with the detection of emotions also through physiological sensors. This is commented in the next section.

Besides, another difficulty that we found has been to determine the intensity of student's emotions. Our model considers, in a simplistic way, that when one of the variables that affect emotion's intensity exists, the agent experiments the emotion with a higher intensity. Thus, in our model there are just two degree of emotion's intensity: high and medium.

In order to bypass some limitations and restrictions cited in this section, we propose some future works which are described in Section 9.2.

9.2 Future work

The main future work is to finalize the implementation of MACES and integrate the Mediating Agent into it. Some work must be developed on negotiation and collaboration to handle the conflicts that can arrive when the Mediating Agent and the Diagnostic Agent disagree about the affective and cognitive tactics that each one chose. Just with the consummation of these two steps, we could accomplish a more complete validation of this thesis.

We also intend to implement a domain-independent version of the Mediating Agent. We think that the flash technology is a good tool to design the attitudes of web animated agents. The speeches of the agent can be previously recorded in a domain-independent format (such as mp3) and could be stored in the database as audio-clips that are played when the agent should speak something. These recorded audio-clips will also resolve the problem of the lack of intonation in voice synthesisers, which was pointed out in the evaluation of this work (see Section 8).

In order to solve the limitations of the environment-dependent emotions, we intend to insert the Mediating Agent into an educational game. The educational games have a well-defined context, where it is easier to determine the student's goals, the events and also the student's actions. As educational games are designed for a specific age-group, it also turns simpler the task of identifying student's personality, which could give us good insights about student's goals.

Another work that we see is the implementation of other OCC model's emotions in BDI. The structure that we propose for the recognition of the student's emotions is prepared to recognise other emotions. All the work that it must be did is to insert the agent's beliefs necessary to infer other emotions.

As far as the intensity of the emotions is concerned, determining the emotion's intensity by the student's observable behaviour (as we made in this thesis) is a hard and inaccurate task. We believe that the insertion of physiological sensors which detect bodily expressions of emotions can help us to determine the intensity of student's emotions. The body sensors can help us to also identify when the student is feeling a past emotion. In this way, the architecture of the Mediating Agent already foresees the insertion of these other sensors. We should also accomplish a deeper study about these physiological sensors in order to choose the one(s) that give us more accurate information about student's emotions and their intensity.

Besides, a future work can be to extend the belief-desire-model, more specifically the X-BDI (the BDI tool used in the implementation of this thesis), in order to also include personality traits, emotions, and moods. According to de Rosis (2002), this approach offers several advantages. The first one is that it opens the opportunity of driving consistent behaviours of agents from a model of their cognitive state: the system of beliefs, desires, and intentions may trigger emotions, regulate the decision of whether to show or to hide them, and finally, drive externalized actions. In this case, we are incorporating an architecture of emotions (emotion synthesis) in the Mediating Agent in order for it to generate affective behaviour more consistent and believable.

The current version of X-BDI does not accept second-order beliefs (the agent believes that the student believes *X*). We implement the agent's beliefs about the student as predicates. But if the X-BDI is improved in order to accept second-order beliefs, this extended version of the BDI with emotions and personality could also be used for recognition of student's emotions.

Finally, in this thesis we worked with the emotions of the student in the interaction between artificial tutor and student. But, as MACES is a collaborative educational system, much work can be done in the recognition of emotion in the interaction student-student. This involves inferring the student's emotions from natural language in chat tools. Some initial studied has been realised by the group in relation to this subject as shows the articles (JAQUES et al., 2002) (JUNG et al., 2002).

Some of these works aim at be accomplished in a pos-doctorate project that is in evaluation.

10 UM AGENTE PEDAGÓGICO ANIMADO PARA INTERAGIR AFETIVAMENTE COM O ALUNO

10.1 Introdução

Psicólogos e pedagogos têm destacado a maneira como as emoções afetam a aprendizagem (GOLEMAN, 1995) (PIAGET, 1989) (VYGOTSKY, 1962). Segundo Piaget (1989), é incontestável o papel perturbador ou acelerador da afetividade na aprendizagem. Boa parte dos alunos que são fracos em matemática falha devido a um bloqueio afetivo. Os trabalhos de Izard (1984) mostram que emoções negativas induzidas no aluno mostram prejudicar o seu desempenho em tarefas cognitivas e emoções positivas possuem um efeito contrário.

Por esta razão, vários sistemas educacionais têm buscado considerar as emoções do aluno através da inferência de emoções, bem como responder emocionalmente a ele, através da geração de emoção, mostrando a riqueza presente na interação afetiva entre aluno e tutor.

Com o propósito de contribuir aos trabalhos existentes em computação afetiva aplicada à educação, nós propomos um agente pedagógico animado responsável por motivar o aluno, fornecer suporte afetivo e promover emoções positivas no aluno que são mais adequadas ao seu aprendizado. Para responder apropriadamente, esse agente infere e modela as emoções do aluno. Este trabalho avança no estado da arte em relação a outros trabalhos do grupo em modelagem afetiva de aluno (Bercht, 2001) (Prola, 2003) ao considerar as seguintes emoções do aluno: satisfação e frustração, alegria e tristeza, gratidão e raiva e vergonha. Outra contribuição do trabalho é se beneficiar da capacidade de raciocínio da abordagem BDI para inferir as emoções do aluno através de suas ações na interface do sistema usando um modelo psicológico cognitivista: o modelo OCC. O agente raciocina sobre as ações do aluno e eventos no sistema educacional e para que emoções esses eventos levam de acordo com os objetivos do aluno. Nós nos beneficiamos de trabalhos prévios do grupo em BDI que resultaram na ferramenta X-BDI (MÓRA, 1999), usada na implementação dessa tese.

O agente animado proposto é parte da arquitetura multiagente do ambiente educacional MACES (ANDRADE et al., 2001). A implementação de sistemas educacionais usando arquiteturas multiagente tem sido um dos tópicos de estudo do grupo, como mostram os trabalhos de (BICA, VICARI, 2000) (D´AMICO ET AL., 1998) (GIRAFFA, 1999) (SILVEIRA; VICCARI, 2002). O agente proposto se chama Agente Mediador. Ele é representado por um personagem animado chamado PAT (Pedagogical and Affective Tutor).

10.2 O Trabalho Proposto

Este trabalho propõe um agente pedagógico animado que aplica táticas pedagógicas afetivas que tem como objetivo promover um estado de espírito positivo no aluno o qual estimula o aprendizado, bem como fornecer um suporte emocional ao aluno, motivando e o encorajando. Como um caso de estudo, o agente proposto é implementado como o Agente Mediador da arquitetura multiagente do sistema educacional MACES (ANDRADE et al., 2001).

Para o agente escolher as táticas afetivas adequadas de acordo com a afetividade do aluno, o agente deve também reconhecer as emoções do aluno. O Agente Mediador reconhece as seguintes emoções do aluno: satisfação e frustração, alegria e tristeza, gratidão e raiva e vergonha. As emoções do aluno são inferidas através de seu comportamento observável, i. e. as ações do aluno na interface do ambiente educacional. A inferência das emoções foi baseada na teoria cognitiva das emoções, mais precisamente no modelo OCC, o qual é baseado na teoria cognitiva das emoções e é possível de ser implementado computacionalmente.

Devido à natureza dinâmica da informação afetiva sobre o aluno, nós adotamos uma abordagem BDI para implementar o modelo afetivo do aluno.

Nas próximas seções são descritas as etapas necessárias para a inferência das emoções do aluno e concepção do agente pedagógico animado.

10.2.1 Qual Mecanismo Utilizado para Reconhecer as Emoções do Aluno?

A inferência das emoções do aluno é um passo necessário para adaptar este sistema à afetividade do aluno. Por exemplo, se o aluno está frustrado com a sua performance, ele irá provavelmente desistir de continuar realizando as atividades propostas. O agente precisa saber as emoções que o aluno está sentindo em um dado momento para poder encorajá-lo na sua atividade.

Para poder inferir as emoções do aluno, o agente proposto possui um sensor (software) responsável por identificar as emoções do aluno e armazena estas informações em um modelo afetivo do aluno.

As emoções do aluno podem ser inferidas por vários mecanismos que estão aptos a detectar emoções por voz, expressões faciais, tensão muscular (eletromiograma), condutividade da pele, respiração e pelo seu comportamento observável.

O agente proposto infere as emoções do aluno pelo seu comportamento observável, isto é, pelas ações do aluno na interface do sistema. São exemplos de comportamentos observáveis: tempo de execução de uma atividade, sucesso ou falha na execução de um exercício e pedido de ajuda. Nós escolhemos este método porque ele é a forma mais acessível atualmente para o aluno interagir com o sistema. As pessoas podem se sentir desconfortáveis com outros mecanismos, como video-câmeras, e isso pode interferir no reconhecimento (PICARD, 2000). Além disso, equipamentos para reconhecimento de emoções do usuário são bastante caros e de difícil utilização. Esta abordagem foi também usada por outros grupos de pesquisa, como mostram os trabalhos de Vicent (1998) e Martinho (2000).

10.2.2 Como Reconhecer as Emoções do Aluno?

Como o agente proposto reconhece as emoções do aluno pelo seu comportamento observável, precisamos de uma teoria psicológica que o fundamente. A teoria cognitivista das emoções é adequada, pois ela considera que as emoções são disparadas por uma avaliação cognitiva (chamada *appraisal*) que um indivíduo faz baseado nos estímulos do mundo e no seu comportamento (CLORE; ORTONY, 1999) (SCHERER, 1999). Em especial, nós vamos utilizar o modelo OCC (ORTONY; CLORE; COLLINS, 1988) que é baseado na teoria cognitivista das emoções e é possível de ser implementado computacionalmente, já que ele fornece informações de como construir uma interpretação de uma situação do ponto de vista do usuário e para qual emoção esta interpretação nos leva.

O modelo OCC nos permite inferir até 22 emoções (tais como alegre por outra pessoa, ressentido, alegre com a infelicidade de outra pessoa, piedade, esperança, medo, satisfação, medo confirmado, frustração, alívio, alegria, tristeza, orgulho, vergonha, admiração, reprovação, gratificação, remorso, grato, raiva, amar, odiar). Nesta tese, nós reconhecemos as emoções satisfação e frustração, alegria e tristeza, gratidão e raiva e vergonha.

Segundo o modelo OCC, as emoções **alegria e tristeza** surgem quando uma pessoa foca na desejabilidade de um evento de acordo com os seus objetivos. Por exemplo, para um aluno que tem como objetivo agradar ao professor e aos seus pais, obter uma boa nota é um evento desejável e irá, provavelmente, disparar a emoção alegria. O modelo OCC define que alegria ocorre quando uma pessoa está agradada com um evento desejável e tristeza quando o evento é indesejável. As emoções **satisfação** e **frustração** surgem quando uma pessoa tem a confirmação da realização (satisfação) ou confirmação de não realização (frustração) de um evento que esperava que pudesse se realizar. As emoções **gratidão** e **raiva** são disparadas quando o agente avalia as ações de um outro agente em relação à interferência na realização de seus objetivos. Uma pessoa possui **gratidão** em relação à outra quando avalia que a ação da outra pessoa foi boa e teve conseqüência positiva para si. **Raiva** surge quando a ação de alguém é avaliada como censurável e tendo ainda uma conseqüência negativa para si. Se a ação avaliada é a própria ação, emoções como vergonha ou orgulho podem ser disparadas. **Orgulho** surge quando uma pessoa aprova sua ação e **vergonha** em caso contrário.

10.2.3 Determinando os Eventos do Ambiente Educacional

Até agora vimos que as emoções do aluno serão reconhecidas pelo seu comportamento observável e usando o modelo psicológico OCC. Mas como podemos chegar a uma emoção do aluno através de seu comportamento observável?

O modelo OCC diz, por exemplo, que as emoções satisfação e frustração são disparadas quando eventos do mundo são avaliados de acordo com a sua desejabilidade em relação aos objetivos do aluno. Em um ambiente educacional, os eventos do mundo são as situações que podem ocorrer como, por exemplo, aluno realizar um exercício com sucesso, falhar, pedir ajuda ou negar ajuda, entre outros. Nesta tese nós escolhemos um número limitado de eventos, mas que nos serão suficientes para validar a proposta desta tese. Na Table 10.1 nós podemos ver os eventos que ocorrem no ambiente MACES e que são analisados neste trabalho. Alguns eventos são ações do aluno e, neste caso, disparam a emoção vergonha. Estes eventos estão apresentados na Table 10.2.

Table 10.1: Eventos que Disparam as Emoções Satisfação/Frustração e Alegria/Tristeza

SEÇÃO	Aluno inicia seção (login)				
	Conteúdo Pedagógico	Iniciar conteúdo pedagógico (pode ser formado por muitos capítulos)			
		Novo capítulo	Conteúdo		
			Exemplos		Correto
			Exercícios	Respostas	Não correto
					Aluno não o realizou
			Aluno não o iniciou		
		Finalizar capítulo	Aluno não o realizou		
			Aluno não o finalizou		
	Finalizar Conteúdo Pedagógico	Aluno não o iniciou Aluno não o realizou Aluno não o finalizou			
	Finalizar seção (logout)				

O conteúdo pedagógico é formado por vários itens pedagógicos, por exemplo, um capítulo ou uma seção. Cada capítulo (ou outro item) é composto de um conteúdo pedagógico, exemplos e exercícios. Eles são escolhidos pelo agente de Diagnóstico. Em cada capítulo, o aluno solicita ao agente que vá ao próximo capítulo ou retorne ao anterior.

Table 10.2 mostras os eventos no ambiente educacional que são causados pelo agente Mediador. Quando estes eventos são avaliados pelo aluno, eles podem disparar emoções de raiva ou gratidão em relação ao agente que os causou, neste caso, o agente Mediador.

Table 10.2: Eventos que Disparam as Emoções Raiva e Gratidão

AÇÕES DO AGENTE	**Ajuda**	Agente oferece ajuda	Aluno nega ajuda do agente	
			Aluno aceita	Ajuda Específica
				Ajuda Genérica
		Aluno pede ajuda	Ajuda Específica	
			Ajuda Genérica	
	Mensagem	Agente apresenta uma mensagem de encorajamento ou de motivação ao aluno		
	Comportamento	Agente apresenta uma seqüência de animações. Este comportamento é usualmente apresentado juntamente com uma mensagem.		

O aluno pode pedir ajuda ou o agente pode decidir oferecer ajuda ao aluno. Esta ajuda pode ser do tipo específica ou genérica. Uma ajuda genérica fornece exemplos, fórmulas e explanações para um conteúdo pedagógico. A ajuda específica mostra como

realizar um exercício. O aluno pode negar a ajuda do agente, mas o agente sempre fornece ajuda ao aluno.

Como o agente é um agente animado com voz artificial, ele pode apresentar comportamentos animados e mensagens de encorajamento ao aluno.

O sistema está disponível na Internet, desta maneira o aluno deve se logar toda vez que desejar acessar o sistema.

10.2.4 Objetivos do Aluno

Numa primeira etapa do trabalho estes eventos foram determinados. Uma segunda etapa é determinar os objetivos do aluno a fim de sabermos se os eventos são desejáveis de acordo com estes objetivos e quando o aluno está agradado/desagradado com a ocorrência ou não destes eventos.

De acordo com Ames (1990), os alunos podem ter objetivos orientados à **aprendizagem** ou ao **desempenho** que são razões pelas quais eles se engajam.

Alunos que têm **objetivo de aprendizagem** são orientados a desenvolver novas habilidades, tentar entender seu trabalho, aperfeiçoar o seu nível e competência e aprender novas coisas. Estes indivíduos tentam fazer mais esforços para aprender algo novo ou quando se defrontam com tarefas desafiantes. Quando eles enfrentam dificuldades, eles aumentam os seus esforços porque acreditam que o esforço é necessário para o sucesso. Eles são chamados também de motivados intrinsecamente.

Os alunos que possuem **objetivos de desempenho** acreditam que o desempenho é importante e eles querem mostrar que tem capacidade. Eles sentem que obtiveram sucesso quando agradam o professor ou pais ou quando se saem melhores que seus colegas, ao invés de quando aprenderam algo novo. Quando enfrentam dificuldades, eles não aumentam os seus esforços porque isso significa falta de capacidade para eles. Eles também são conhecidos como motivados extrinsecamente.

A orientação motivacional do aluno é determinada pelo teste MSLQ (PINTRICH, 1991) que é aplicado no início da utilização do sistema pelo aluno.

10.3 As Emoções do Aluno

A Table 10.3 mostra as emoções que são disparadas, para cada evento, para os alunos que têm objetivo orientado à aprendizagem e a Table 10.4 apresenta as emoções que são disparadas quando o aluno possui objetivo orientado ao desempenho. Na coluna "eventos" nós apresentamos os eventos que podem acontecer. Uma vez que nós sabemos os objetivos e os eventos que podem acontecer em nosso sistema educacional, nós podemos determinar a desejabilidade do evento. Este processo é necessário para inferir o *appraisal* do aluno, e. do i. a avaliação cognitiva que dispara as emoções. Cada evento é classificado como desejável (marcado com um D na tabela), indesejável (marcado com um U), ou com nenhuma reação à situação (marcada com um N) na coluna "desejabilidade do evento". Às vezes, a fim de determinar se um evento é desejável ou não, o agente necessita fazer perguntas ao aluno ou acessar outro tipo de informação (por exemplo, o esforço do aluno). Estas perguntas são apresentadas na coluna "perguntas do agente". Na coluna "respostas do aluno", as respostas possíveis dadas pelo aluno são apresentadas. A coluna "variáveis de intensidade" descreve as variáveis que afetam a intensidade de cada emoção, e, finalmente, a coluna "emoções" apresenta as emoções disparadas. As emoções podem ser tristeza ou alegria, frustração (marcado com Frust) ou satisfação (marcada com Satisf), gratidão ou raiva, e vergonha.

Quando um evento é desejável, ele dispara a emoção alegria; e quando é indesejável dispara a emoção tristeza. Por exemplo, para um aluno orientado ao desempenho que tem o objetivo de agradar seus pais, fornecer uma resposta correta para um exercício é um evento desejável porque promove seu objetivo, e pela mesma razão, não fornecer uma resposta correta é um evento indesejável.

Para as emoções satisfação e frustração, é necessário saber quando o evento é esperado se realizar ou não. A maioria de eventos educacionais pode disparar emoções de satisfação e frustração porque são esperadas. Quando o aluno está agradado, em intensidade suficiente, porque um evento desejável e previsto aconteceu, ele sente a emoção satisfação.

Quando está desagradado porque o evento não aconteceu, ele tem a emoção frustração. Às vezes, o aluno pode ver um evento indesejável como um evento desejável e previsto que não aconteceu. Este é o exemplo do evento "o aluno não forneceu uma resposta correta para um exercício". Se o evento "fornecer uma resposta correta para o exercício" for um evento muito desejável e previsto, o aluno pode interpretar o evento "o aluno não forneceu uma resposta correta para um exercício" como um evento desejável que não aconteceu e assim é disparada a emoção frustração. As emoções do aluno que são disparadas para cada evento são mostradas na coluna "emoções".

A satisfação e a frustração, a alegria e a tristeza, e as emoções da raiva e gratidão têm valência opostas. O aluno não pode experimentar frustração e satisfação ao mesmo tempo. Desta maneira, quando o aluno tem a emoção frustração, a emoção de satisfação morre. Como o agente Mediador tem como objetivo promover um estado de espírito positivo no aluno, ele age a fim de cancelar as emoções negativas do aluno. Assim, nós consideramos que as intervenções do agente Mediador sempre anulam as emoções negativas do aluno.

10.3.1 Emoções Disparadas quando o Aluno Possui Objetivo Orientado à Aprendizagem

Os eventos 1, 2 e 3, mostrados na Table 10.3, concernem a realização das tarefas pelos alunos que têm objetivo orientado à aprendizagem. Se o aluno realizar a tarefa incorretamente ou não a terminar (eventos 1 e 3), é necessário saber se é importante para ele aprender sobre o tema pedagógico relacionado à tarefa, desde que os alunos orientados à aprendizagem são motivados a aprender aqueles assuntos que eles acham interessantes. Se tiver o objetivo de aprender esse assunto, o evento é indesejável. Quando o evento é indesejável, as emoções disparadas são tristeza e frustração. A intensidade destas emoções depende do *grau de realização* do evento, do *grau de expectativa* de que o evento aconteça, e também da *desejabilidade* evento. A variável de realização pode ser determinada pela nota obtida pelo aluno no exercício. O grau de realização é mais elevado, se a resposta for 70% incorreta, do que quando a resposta for 50% incorreta e, assim, o aluno fica mais frustrado na primeira situação. Nós consideramos que o grau de realização é mais forte para as respostas em que o grau de incorreção é superior a 50%. O grau de não expectativa pode ser medido pelo desempenho real do aluno. O evento "não fornecer uma resposta correta para um exercício" é menos inesperado quando o aluno está tendo um desempenho excelente. Nós consideramos que quando uma ou mais destas variáveis têm um grau mais elevado, uma emoção com uma intensidade mais elevada é disparada (marcado com um ++).

Se o aluno realizou a tarefa corretamente, que é um evento desejável, é importante saber se ele fez um esforço elevado (evento 2). Os alunos com objetivo de

aprendizagem tornam-se mais satisfeitos com os resultados bons obtidos nas tarefas que fizeram mais esforço. O grau de realização e de não-expectativa interfere também. É necessário verificar a nota obtida (se elevada, é mais alta a intensidade das emoções satisfação/alegria) e a não expectativa (se o aluno obtém sempre notas boas).

Um assunto pedagógico é composto de capítulos (seções do estudo). Se o aluno terminar o capítulo (evento 5), quando fêz todas as tarefas e seguiu todo o índice apresentado, o evento é desejável e dispara emoções de satisfação/alegria. Se ele desistiu ou não obteve uma nota boa (o evento 4), o evento é indesejável. Neste caso é também necessário verificar o grau de realização (nota) e a não expectativa do evento. O grau de desejabilidade pode também ser medido pela interferência deste evento na nota final do curso.

Quando o aluno pede ajuda (evento 7), é importante saber se a ajuda foi adequada para o aluno, assim nós temos um evento desejável, caso contrário o evento é indesejável. O ato de pedir ajuda (o evento 6) é um evento sem reação afetiva para o aluno orientado à aprendizagem.

Se o aluno aceitar a ajuda do agente (evento 9), a proposta é um evento desejável e o aluno tem a emoção gratidão. Quando o aluno negar a proposta de ajuda do agente (evento 8), não há reação afetiva. Mas, se o agente oferecer ajuda muitas vezes e o aluno não a necessitar, o agente pode estar perturbando o aluno. Assim, este evento transforma-se um evento indesejável e o aluno sente a emoção raiva.

Se o aluno desabilitar o personagem PAT (evento 10), isso significa que a presença do personagem é indesejável e que o aluno tem raiva do agente. Quando o aluno habilita o personagem (evento 11), as ações do agente são desejáveis porque o aluno pensa que o agente é útil e que pode lhe ajudar. Neste último caso, o aluno sente a emoção gratidão. Note que nestas últimas situações (eventos 6 a 11), o aluno foca no personagem como um agente dos eventos e neste caso ele têm emoções relacionadas ao julgamento de ações de uma pessoa (raiva e gratidão).

Table 10.3: Emoções Disparadas quando o Aluno possui Objetivo Orientado à Aprendizagem

Aluno possui Objetivo orientado à Aprendizagem **Objetivo do Aluno: aprender o conteúdo**						
Evento		**Questões do Agente**	**Resp. Alun**	**Desejab. Evento**	**Variáveis de Intensidade**	**Emoções do Aluno**
1	**Aluno forneceu uma resposta incorreta para o exercício**	perguntar ao aluno se é importante para ele aprender o conteúdo relacionado a tarefa.	sim	U	realização não expectativa	Tristeza/Frust
			não	N		NE
2	**Aluno forneceu uma resposta correta para o exercício**	esforço	alto	D	realização não expectativa	Alegria/Satisf++
			baixo	D		Alegria/Satisf
3	**Aluno não realizou a atividade**	perguntar ao aluno se é importante para ele aprender o conteúdo relacionado a tarefa.	sim	U	realização não expectativa	Tristeza/Frust
			não	N		NE
4	**Aluno desistiu de seguir o capítulo**	perguntar ao aluno se é importante para ele aprender o conteúdo relacionado a tarefa.	sim	U	realização não expectativa	Tristeza/Frust
			não	N		NE
5	**Aluno finalizou o capítulo**			D	realização não expectativa	Alegria/Satisf
6	**Aluno pediu ajuda**			N		NE
7	**Após ajuda do agente**	perguntar ao aluno se "a ajuda foi adequada"	sim	D		Gratidão
			não	U		Raiva
8	**Aluno negou ajuda do agente**	perguntar ao aluno se o agente está o incomodando	sim	U		Raiva
			não	N		NE
9	**Aluno aceitou ajuda do agente**			D		Gratidão
10	**Aluno desabilitou o agente**			U		Raiva
11	**Aluno habilitou o agente**			D		Gratidão

10.3.2 Emoções Disparadas quando o Aluno Possui Objetivo Orientado ao Desempenho

A Table 10.4 trata das emoções para os alunos que têm objetivo orientado ao desempenho. Para um aluno orientado ao desempenho, o evento "não realizou a tarefa corretamente ou não a terminou" é indesejável (eventos 1 e 3) e dispara as emoções tristeza e frustração. Estes eventos são mais indesejáveis se o aluno realizou um esforço maior e disparam assim emoções com intensidade mais elevada. Se ele realizou a tarefa corretamente, é importante saber se fez esforços (evento 2). Os alunos com orientação ao desempenho tornam-se mais satisfeitos pelos bons resultados obtidos nas tarefas em que fizeram menos esforço porque implica em habilidade elevada (MEECE; MCCOLSKEY, 2001). Mas, se ele fez esforços, ele espera mais fortemente ter sucesso e, então, o evento dispara uma emoção de intensidade mais elevada.

Se o aluno terminar o capítulo com sucesso (evento 5), o evento é desejável e a emoção disparada é alegria/satisfação.

Se o aluno terminar o capítulo sem sucesso ou desistir (evento 4), o evento é indesejável e dispara emoções de tristeza/frustração. A intensidade da emoção depende da variável de realização. Quanto mais elevada a nota, mais elevado o nível de realização e, conseqüentemente, (mais elevada) a intensidade da emoção positiva. Diferentemente, se a emoção for negativa, a intensidade é mais elevada quando o aluno obtém uma nota mais baixa. A variável esforço afeta também a intensidade da emoção. O esforço elevado implica que a intensidade da emoção é mais elevada. A variável não expectativa interfere também na intensidade da emoção. O grau de não expectativa pode ser medido pelo desempenho do aluno. O evento "aluno forneceu uma resposta incorreta para um exercício" é menos inesperado quando o aluno está tendo um desempenho excelente. Nós consideramos que quando uma ou mais destas variáveis têm um grau mais elevado, uma emoção com uma intensidade mais elevada é disparada.

Quando o aluno pede ajuda (evento 6), é importante perguntar ao aluno se ele se sente desconfortável ao fazê-lo. Pedir ajuda pode significar para o aluno que ele não é capaz de poder realizar a tarefa sozinho. Se o aluno responder que se sente confortável, não há nenhuma reação afetiva. Se ele se sentir desconfortável, significa que ele desaprova sua atitude de mostrar ao Agente Mediador que ele não pode realizar as atividades sozinho, e então ele sente vergonha. Se a ajuda não for apropriada (evento 7), o aluno está desagradado, já que o objetivo de receber uma ajuda apropriada pelo agente não se realizou. Neste caso o aluno sente raiva.

Quando o aluno não aceita a ajuda do agente (evento 8), é também importante saber se o aluno está desconfortável com a ajuda e se o agente o está perturbando. Se ele se sente confortável, não é disparada nenhuma emoção, mas se ele se sentir incomodado, o evento é indesejável e o aluno torna-se irritado com o agente, já que o agente oferecer ajuda pode significar ao aluno que o agente está sugerindo que ele não pode realizar a tarefa sozinho. Se o agente estiver perturbando o aluno, o aluno torna-se também irritado com o agente.

Se o aluno aceitar a ajuda do agente (o evento 9), o aluno sente gratidão porque a ajuda do agente foi útil para ele. Se o aluno desabilitar o personagem PAT (evento 10), significa que ele está irritado com o personagem, e porque ele teme o que o agente pensa sobre o seu desempenho. Quando o aluno habilita o personagem (evento 11), ele sente gratidão em relação às ações do agente, e pensa que pode confiar no agente, que ele é engraçado e que pode lhe ajudar.

Table 10.4: Emoções Disparadas quando o Aluno possui Objetivo Orientado ao Desempenho

Aluno possui Objetivo orientado ao Desempenho **Objetivo do Aluno: ter sucesso e obter recompensa**						
Evento		**Questões do Agente**	**Resp. Alun**	**Desejab. Evento**	**Variáveis de Intensidade**	**Emoções do Aluno**
1	**Aluno forneceu uma resposta incorreta para o exercício**			U	realização não expectativa esforço indesejabilidade	Tristeza/Frust
				N		NE
2	**Aluno forneceu uma resposta correta para o exercício**			D	realização não expectativa esforço indesejabilidade	Alegria/Satisf++
				D		Alegria/Satisf
3	**Aluno não realizou a atividade**			U	realização não expectativa esforço indesejabilidade	Tristeza/Frust
				N		NE
4	**Aluno desistiu de seguir o capítulo**		sim	U		Tristeza/Frust
			não	N	realização não expectativa esforço indesejabilidade	NE
5	**Aluno finalizou o capítulo**			D	realização não expectativa esforço indesejabilidade	Alegria/Satisf
6	**Aluno pediu ajuda**	o aluno se sente desconfortável por pedir ajuda	sim	U	desprezabilidade	NE
			não	N		
7	**Após ajuda do agente**	a ajuda foi apropriada	sim	D		Gratidão
			não	U	indesejabilidade desprezabilidade	Raiva
8	**Aluno negou ajuda do agente**	o aluno se sente desconfortável pelo agente oferecer ajuda e se o agente o está incomodando	sim	U	indesejabilidade desprezabilidade	Raiva
			não	N		NE
9	**Aluno aceitou ajuda do agente**			D	desejabilidade merecimento	Gratidão
10	**Aluno desabilitou o agente**			U	indesejabilidade desprezabilidade	Raiva
11	**Aluno habilitou o agente**			D	desejabilidade merecimento	Gratidão

10.3.3 Táticas Afetivas de Aprendizagem

A tabela a seguir mostra as táticas afetivas selecionadas de acordo com o evento, emoção do aluno e sua orientação motivacional. Para cada tática afetiva há mais de um comportamento a ser exibido. Por exemplo, quando o aluno acessar o sistema, o agente deve saudá-lo. Para tanto, ele deve usar um comportamento verbal de saudação e um comportamento físico de saudação. Para o agente ser real, existem mais de um comportamento para cada tipo. Os comportamentos são exibidos na Table 10.6. As siglas CV e CF representam:

CV = comportamento verbal (o que o agente fala)

CF = Comportamento físico (o que o agente faz)

Table 10.5: Táticas Afetivas de Apredizagem

Evento	**Motivação Intrínseca (Orientado à aprendizagem)**	**Motivação Extrínseca (Orientado à performance)**
Saudação	**1) Saudação** CV: Saudação **(1)** CF: Saudação	
1) Resposta do exercício não correta	**Tristeza/Frustração: (2)** **1) Reconhecer-esforço-aluno** CV: Reconhecer-esforço-aluno CF: Empático **2) Oferecer-ajuda** CV: Oferecer-ajuda. CF: Falar.	**Tristeza/Frustração: (4)** **1) Aumentar-auto-eficacia-aluno** CV: Aumentar-auto-eficácia-aluno CF: Encorajamento **2) Aumentar-esforço-aluno** CV: Aumentar-esforco-aluno CF: Falar **3) Oferecer-ajuda** CV: Oferecer-ajuda CF: Falar
	Neutro: (3) Aplica tática fornecida pelo agente de diagnóstico.	
2) Resposta do exercício correta	**Satisfação/Alegria: (5)** **1) Congratular** CF: Congratular CV: Congratular **2) Nova-habilidade** CV: Nova-habilidade CF: Nova-habilidade	**Satisfação/Alegria: (7)** **1) Congratular** CF: Congratular CV: Congratular
3) Não realizou tarefa	**Frustração/Tristeza: (8)** **1) Encorajamento** CV: Encorajamento CF: Encorajamento **2) Oferecer-ajuda** CV: Oferecer-ajuda CF: Dar-ajuda	**Frustração/Tristeza: (10)** **1) Aumentar-auto-eficacia-aluno** CV: Aumentar-auto-eficácia-aluno CF: Encorajamento **2) Aumentar-esforço-aluno** CV: Aumentar-esforco-aluno CF: Falar
	Neutro: (9) **1) Nova-habilidade** CV: Nova-habilidade CF: Nova-habilidade **2) Oferecer-ajuda** CV: Oferecer-ajuda CF: Dar-ajuda	
4) Desistiu do capítulo estudado	**Neutro: (11)** **1) Mostrar-curiosidade** CV: Mostrar-curiosidade. CF: Mostrar-curiosidade. **Frustração/Tristeza: (12)**	**Neutro: (13a)** **Se (esforço-aluno != alto)** **1) Aumentar-esforço-aluno** CV: Aumentar-esforco-aluno CF: Encorajamento

	1) Encorajamento CV: Encorajamento CF: Encorajamento **2) Oferecer-ajuda** CV: Oferecer-ajuda CF: Dar-ajuda	**Senão (13b)** **1) Encorajamento** CV: Encorajamento CF: Encorajamento
5) Finalizou o capítulo	**Satisfação/Alegria:** **1) Congratular** CF: Congratular CV: Congratular	**Satisfação/Alegria:** **1) Congratular** CF: Congratular CV: Congratular
6) Aluno pede ajuda	**Neutro:** **1) Dar-ajuda** CV: Dar-ajuda CF: Dar-ajuda	**Vergonha** **1) Explicar-importancia-ajuda** CV: Explicar-importancia-ajuda CF: Empático **2) Dar-ajuda** CV: Dar-ajuda CF: Dar-ajuda
		Neutro: **1) Dar-ajuda** CV: Dar-ajuda CF: Dar-ajuda
7) Após ajuda agente	**Raiva:** **1) Triste-por-não-ajudar** CV: Triste-por-não-ajudar CF: Triste **2) Informar ao Agente de Diagnóstico que a ajuda não foi apropriada**	**Raiva:** **1) Triste-por-não-ajudar** CV: Triste-por-não-ajudar CF: Triste **2) Informar ao Agente de Diagnóstico que a ajuda não foi apropriada**
	Gratidão: **1) Alegre-por-ajudar-aluno** CV: Alegre-por-ajudar-aluno CF: Alegre	**Neutro:** **1) Alegre-por-ajudar-aluno** CV: Alegre-por-ajudar-aluno **CF: Alegre**
8) Aluno nega ajuda do agente	**Raiva (14):** **if (agente-está-incomodando)** **1) Triste-por-incomodar** CV: Triste-por-incomodar PV: Triste	**Raiva (14):** **if (agente-está-incomodando)** **1) Triste-por-incomodar** CV: Triste-por-incomodar PV: Triste **senão se (aluno-sente-confortavel)** **1) Explicar-importancia-ajuda** CV: Explicar-importancia-ajuda CF: Empático **2) Dar-ajuda** CV: Dar-ajuda CF: Dar-ajuda
10) Aluno desabilita agente	**Raiva:** **1) Aluno-desabilita-agente:** CV: Aluno-desabilita-agente CF: Triste	**Raiva:** **1) Aluno-desabilita-agente:** CV: Aluno-desabilita-agente CF: Triste
11) Aluno habilita agente	**Raiva:** **1) Aluno-habilita-agente:** CV: Aluno-habilita-agente CF: Alegre	**Raiva:** **1) Aluno-habilita-agente:** CV: Aluno-habilita-agente CF: Alegre
12) Enquanto aluno está realizando uma tarefa	**1) Agente-observa-aluno** CV: Agente-observa-aluno CF: Agente-observa-aluno **2) Mostrar-curiosidade** CV: Mostrar-curiosidade CF: Mostrar-curiosidade	**1) Agente-observa-aluno** CV: Agente-observa-aluno CF: Agente-observa-aluno **2) Encorajamento** CV: Encorajamento CF: Encorajamento
13) Aluno faz grande esforço em	**1) Reconhecer-esforço-aluno** CV: Reconhecer-esforço-aluno CF: Empático	**1) Reconhecer-esforço-aluno** CV: Reconhecer-esforço-aluno CF: Empático

uma tarefa		**2) Encorajamento** CV: Encorajamento CF: Encorajamento
14) Aluno está sem fazer atividade	**(15)** **1) Aluno-ocioso** CV: Ocioso PV: Ocioso **2) Mostrar-curiosidade** CV: Mostrar-curiosidade CF: Mostrar-curiosidade	**1) Aluno-ocioso** CV: Ocioso PV: Ocioso **2) Aumentar-esforço-aluno** CV: Aumentar-esforco-aluno CF: Encorajamento

Para o evento 1 é mostrado o Comportamento de saudação que é exibido quando o aluno se conecta no sistema.

Quando o aluno que possui orientação intrínseca se sente frustrado porque ele não realizou a tarefa corretamente (evento 1), o agente apresenta uma expressão facial empática mostrando que ele entende as dificuldades que o aluno está tendo. Como o aluno intrínseco geralmente faz grandes esforços, o agente oferece uma ajuda ao aluno. O tipo da ajuda (especifica ou genérica) é fornecido pelo Agente de Diagnóstico. O aluno que possui motivação extrínseca, sente que ele não é capaz de realizar a atividade proposta quando ele falha. Geralmente não faz muitos esforços quando tem dificuldades porque realizar mais esforços significa falta de competência para ele. O agente apresenta uma mensagem para aumentar as crenças do aluno sobre a sua competência e diz para o aluno que ele é capaz de realizar a tarefa com um pouco mais de esforço. A idéia é mostrar para o aluno com motivação extrínseca que se ele não teve sucesso na atividade, isso não significa falta de competência, mas que ele pode obter resultados melhores com mais esforço.

Quando o aluno que tem motivação intrínseca está satisfeito porque ele cumpriu uma tarefa que lhe interessava com sucesso (evento 2), o tutor mostra qual a nova habilidade que foi adquirida, uma vez que o aluno está motivado para aprender novas coisas. O aluno que tem motivação extrínseca sempre está satisfeito pelo sucesso nas tarefas, uma vez que ele pensa que isto comprova a sua competência. Nestes casos, o agente o parabeniza fortemente por seu desempenho a fim de manter a sua motivação, desde que tais alunos precisam da aprovação de seu tutor.

Uma vez que alunos que têm orientação intrínseca usualmente fazem grandes esforços, o fato de eles não cumprir em uma tarefa (evento 3) não significa falta de esforço, mas uma dificuldade para efetuá-la. Por isso o tutor apresenta uma mensagem de incentivo para que o aluno continue se empenhando, bem como uma ajuda a fim de ajudar o aluno a superar suas dificuldades. Quando um aluno intrinsecamente motivado está emocionalmente indiferente (ele não está nem satisfeito nem desmotivado pois acredita que o tema não é importante nem interessante), o tutor lhe apresenta a nova habilidade que poderá adquirir com o tal tema para motivá-lo, bem como uma ajuda específica para lhe ajudar a continuar na solução do problema. O aluno orientado ao desempenho se decepciona quando não termina uma tarefa, pois avalia isso como uma falta de competência. Nesse caso o agente apresenta uma mensagem com a finalidade de aumentar a sua auto-eficácia (a imagem que ele tem de si próprio, de suas competências), uma vez que as crenças do aluno que dizem respeito a sua competência diminuíram com o fracasso. O tutor também tenta incentivar o aluno a fazer mais esforço, pois estes alunos se esforçam menos, já que associam esforço à falta de competência da parte deles. Caso o aluno não esteja decepcionado, é que ele não achou o assunto interessante; neste caso o agente destaca as curiosidades do assunto. Brewster

e Farger (2000) sugerem que apresentar as curiosidades de um assunto que sejam relevantes à vida do aluno é uma tática eficiente para motivá-lo.

Quando um aluno intrínseco desiste de finalizar um capítulo (evento 4), se ele está emocionalmente indiferente isso significa que ele não está interessado no tema relacionado ao assunto e, nesse caso, o agente apresenta algumas curiosidades sobre o assunto para motivá-lo. Se ele está frustrado, o agente o encoraja a continuar tentando e oferece uma ajuda. Se o aluno extrínseco realizou grande esforço, o agente o encoraja a continuar se esforçando, caso contrário o agente o estimula a se esforçar mais.

Quando os alunos (extrínsecos e intrínsecos) estão contentes porque finalizaram um capítulo com sucesso (evento 5), o agente os congratula.

Quando um aluno pede ajuda (evento 6), o agente oferece ajuda. Se o aluno extrínseco está com vergonha de pedir ajuda porque para ele isso significa falta de competência, o agente explica a importância da ajuda além de oferecer ajuda.

Após a ajuda (evento 7), se o aluno está com raiva porque a ajuda não foi eficiente, o agente mostra uma mensagem explicando que sente por não ajudar. Se a ajuda foi eficiente o agente diz que está feliz por ajudar.

Se o aluno nega ajuda do agente (evento 8) e ele está com raiva porque o agente o está incomodando, o agente se desculpa por atrapalhar o aluno. Caso o aluno extrínseco está com vergonha e nega ajuda porque se sente desconfortável ao aceitá-la, o agente explica a importância da ajuda e oferece ajuda ao aluno novamente.

Caso o aluno aceita ajuda do agente (evento 9), o agente fornece a ajuda.

Se o aluno desabilita o agente (evento 10), isso significa que ele está zangado com o agente. Neste caso, o agente apresenta uma mensagem explicando que está triste por não poder ajudar o aluno. No ambiente o aluno pode escolher não ter o acompanhamento do agente animado. O agente pergunta porque o aluno não deseja mais a sua ajuda a fim de saber como poder o ajudar melhor futuramente.

Se o aluno habilita o agente (evento 11), o agente diz para o aluno que está alegre por poder servir ao aluno novamente.

Enquanto o aluno está realizando uma tarefa (evento 12), o agente o observa. Ele pode ainda mostrar curiosidades ao aluno intrínseco para despertar o seu interesse no assunto, e encorajar o aluno extrínseco a fazer maiores esforços.

Se o aluno fez grandes esforços em uma atividade (evento 13), o agente reconhece os seus esforços e encoraja o aluno extrínseco a manter os seus esforços.

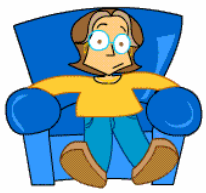
Se o aluno está algum tempo ocioso (evento 14) e é intrínseco, isso pode significar que ele não está achando o conteúdo suficientemente interessante, então nesse caso o tutor mostra uma curiosidade sobre o assunto. Se ele é extrínseco, ele deve estar parado porque a tarefa necessita de mais esforço, assim o tutor o incentiva a fazer mais esforços.

Para cada tática, existem mais de um comportamento possível de ser exibido. Por exemplo, para a tática de congratulação (elogio) o agente pode aplaudir o aluno ou mostrar uma cena em que as pessoas o estão aplaudindo A idéia é tornar o agente mais credível, ou seja, mais real e não tão robótico. Para isso, ele deve ter um número variado de falas e animações para uma mesma situação para que o seu comportamento não seja previsível. A Table 10.6 mostra a base de dados de comportamentos físicos e verbais do agente.

Table 10.6: Comportamentos de Pat

ID	ACAO	TIPO	DESCRICAO	FALA
1	cf	Congratulação 	Pat joga dardos e acerta O comportamento de congratulação é usado quando o agente deseja elogiar o aluno pelo sucesso nas atividades. Eles são meio exagerados porque alunos com motivação extrínseca gostam de receber reconhecimento e elogios.	
2	cf	Congratulação 	Pat chuta bola de fotebol e faz goal	
3	cf	Congratulação 	Pat aplaude aluno	
4	cf	Congratulação 	Pat participa do campeonato de corrida dos jogos olímpicos e vence. Tem varias pessoas a esperando e a apludindo.	
5	cf	Congratulação 	Pat joga brinquedo de circo e acerta	
6	cf	Empático 	Pat dá 2 piscadinhas rápidas para o aluno Os comportamentos empáticos são exibidos quando o agente deseja elogiar um aluno com motivação intrinseca (que não precisa de tanto reconhecimento quanto o aluno extrinseco e outras situações em que o agente deseja mostrar um comportamento mais neutro para acompanhar a mensagem.	
7	cf	Encouragement 	Pat dá uma piscadinha e sorri Os comportamentos de encorajamento são mostrados quando o agente desja encorajar o aluno a cotinuar a atividade, ou porque ele não teve muito sucesso nas atividades ou porque ele desistiu.	

8	cf	Encorajamento 	Pat está lutando boxe e ela acerta um saco de pancadas onde está escrito "minnhas dificuldades"	Eu sei que você é capaz de nocautear as suas dificuldades.
9	cf	Encorajamento 	Pat deita de cansaço em um sofa	Não desanime!
10	cf	Dar-ajuda 	Pat está vestida como um sábio monge Comportamentos exibidos quando o agente deseja oferecer uma ajuda ao aluno ou oaluno pede ajuda ao agente	Tenho muita sabedoria para te passar.
11	cf	Dar-ajuda 	Pat pega um livro na estante.	
12	cf	Dar-ajuda 	Pat abre um pergaminho e o lê	
13	cf	Dar-ajuda 	Pat está vestida como Sherlock Holmes (com uma lupa)	Tenho a pista que você precisa.

14	cf	Saudação 	Pat acena para o aluno Comportamento de saudação quando o aluno se loga no sistema	
15	cf	Saudação 	Pat está vestida como uma dama do século 18 e acena para o aluno	
16	cf	Ocioso 	Pat senta no sofa e boceja Quando o aluno está lum tempo sem realizar nenhuma atividade no sistema	Que tédio ficar parada.
17	cf	Ocioso 	Pat boceja	
18	cf	Nova-habilidades 	Pat se torna uma super heroína e voa na tela Quando o agente deseja mostrar para o aluno que novas habilidades ele adquiriu (que coisas ele aprendeu e é capaz de realizar)	Você adquiriu novos super-poderes.
19	cf	Novas-habilidades 	Pat faz malabarismos com bolas	

20	cf	Mostra-curiosidade 	Pat pega um livro na estante Quando Pat quer aprensentar uma curiosidade ao alunosobre a material ensinada para ele se interessar mais.	
21	cf	Mostra-curiosidade 	Pat lê pergaminho.	
22	cf	Triste 	Pat está triste Quando o aluno desabilita o agente	
23	cf	Fala	Enquanto Pat está falando	
24	cf	Aluno-pede-ajuda 	Pat faz um sinal mostrando que está pronta para ouvir aluno Quando o aluno pede ajuda.	

25	cv	Congratulação	Pat congratula aluno.	Uauuuuu! Você arrasou! Parabéns pelos esforços que você fez!
26	cv	Congratulação	Pat congratula aluno.	Parabéns! Você conseguiu um ótimo resultado! Continue assim!
27	cv	Congratulação	Pat congratula aluno.	Parabéns! Você conseguiu! A sua performance foi estupenda!
28	cv	Congratulação	Pat congratula aluno.	Parabéns pelos seus esforços! Você se saiu muito bem!
29	cv	Congratulação	Pat congratula aluno.	Parabéns! Você atingiu um bom resultado!
30	cv	Encorajamento	Pat encoraja aluno a manter performance	Juntos vamos superar! O importante é continuar tentando!
31	cv	Encorajamento		Vamos em frente! Você conseguirá!
32	cv	Explica-importancia-ajuda	Pat explica para o aluno extrínseco que pedir e obter ajuda não significa falta de competência (como pensam os alunos extrínsecos)	Heiii. Pedir ajuda não significa que você não seja capaz de realizar. Ninguém nasce sabendo e, por isso, precisamos de ajuda para aprender e ultrapassar as dificuldades!

33	cv	Explica-importancia-ajuda		Ganhar ajuda não significa que você não saiba fazer. Todo mundo precisa de ajuda!
34	cv	Dar-ajuda	Pat diz que vai ajudar o aluno (quando ele pede ajuda)	Vou te dar umas informações úteis que vão te ajudar!
35	cv	Dar-ajuda		Deixa-me ver no que eu posso te ajudar...
36	cv	Dar-ajuda		Boa hora para ter dúvida. Este conteúdo não é fácil mesmo!
37	cv	Dar-ajuda		Vou te mostrar outra alternativa.
38	cv	Saudação	Pat saúda o aluno	Olá!
39	cv	Saudação		Bom dia!
40	cv	Saudação		Boa tarde!
41	cv	Saudação		Boa noite!
42	cv	Saudação		Alôzinho!
43	cv	Feliz-por-ajudar	Pat diz que está felzi em ajudar o aluno	Estou feliz em poder te ajudar!
44	cv	Feliz-por-ajudar		Iupppi. Gosto de ser útil a você!
45	cv	Ocioso	Quando o aluno está muito tempo ocioso	Hei! Esta na hora de começar a trabalhar.
46	cv	Aumenta-esforço-aluno	Pat incentiva aluno extrínseco a fazer mais esforços (geralmente estes alunos não fazem muitos esforços porque isso significa falta de competência para eles)	É apenas necessário fazer um pouco mais de esforço! Vamos tentar mais uma vez?
47	cv	Aumenta-esforço-aluno		Não desista! Vamos em frente! Para ter bons resultados é necessário ser persistente e se esforçar!
48	cv	Aumenta-esforço-aluno		Continue com os seus esforços que o sucesso está a caminho.
49	cv	Aumenta-auto-eficacia-aluno	Pat incentiva aluno a acreditar mais na sua capacidade (geralmente alunos extrínsecos têm baixa auto-eficácia)	Eu sei que você é capaz de acertar!
50	cv	Aumenta-auto-eficacia-aluno		Você é um vencedor! Lembre de tudo que você já conseguiu fazer! Você se saiu muito bem nas atividades 1 e 3.
51	cv	Aumenta-auto-eficacia-aluno		Você é muito inteligente! Está tendo um bom progresso na tarefa!
52	cv	Nova-habilidade	Pat diz para o aluno que novas habilidades ele adquiriu	Uau! Veja que novas habilidades você adquiriu: Você aprendeu a colocar fundo e a inserir figuras em homepage.
53	cv	Nova-habilidade		Legal! Você aprendeu novas coisas! Por exemplo: inserir hyperlink em uma homepage e inserir figura.
54	cv	Nova-habilidade		O sucesso nessa atividade mosra que você adquiriu novas habilidades. Agora você sabe formatar o texto de uma homepage. Por exemplo, colocar o texto em cores, centralizar títulos e colocar o texto em negrito.
55	cv	Oferecer-ajuda	Pat oferece ajuda ao aluno	Posso te ajudar?
56	cv	Oferecer-ajuda		Deixa eu te passar o que eu sei sobre esse assunto?
57	cv	Oferecer-ajuda		Quer saber mais sobre este assunto?

58	cv	Oferecer-ajuda		Quer umas dicas?
59	cv	Reconhece-esforço-aluno	Pat reconhece esforço que o aluno realizou	Continue assim! O esforço é a chave do sucesso!
60	cv	Reconhece-esforço-aluno		Parabéns pelos esforços que tem feito. Continue assim!
61	cv	Mostra-curiosidade	Pat mostra curiosidade sobre o conteúdo ensinado	Você sabia que: a lição colocar fundo na homepage ensina até colocar figuras como fundo?
62	cv	Triste-por-não-ajudar	Quando o aluno nega ajuda do agente	Xiii. Acho que atrapalhei.Desculpa.
63	cv	Aluno-desabilita-agente	Quando o aluno desabilita o agente	Eu o estou triste por não ser útil a você. Você pode me dizer por que não quer mais a minha ajuda?
64	cv	Aluno-habilita-agente		Iupiiii! Eu estou tridi contente por poder ser útil a você!

10.4 A Implementação do Agente Pedagógico Proposto

Mas precisamos ainda de um aparato computacional para a implementação do mecanismo de inferência das emoções, bem como do modelo afetivo do aluno.

Nesta tese foi utilizada a abordagem BDI (belief-desire-intention) (BRATMAN, 1990) (RAO; GEORGEFF, 1995) para a implementação do "kernel" cognitivo do agente (responsável pela inferência das emoções do aluno e escolha das táticas afetivas) e para a implementação do modelo afetivo. A abordagem BDI é baseada em descrever o processamento interno do agente através de estados mentais (crenças, desejos e intenções) e definir a arquitetura de controle que racionalmente seleciona o curso de ações do agente. Para a modelagem e implementação em BDI do Kernel cognitivo, utilizamos a ferramenta X-BDI desenvolvida em nosso grupo de pesquisa pela tese de Michael Móra (MÓRA, 1998).

A abordagem BDI foi escolhida por apresentar algumas vantagens: permite a implementação em uma linguagem de altíssimo nível e permite tratar a dinamicidade das emoções, pois comporta freqüente revisão e modificação das informações sobre o aluno (BERCHT, 2000).

Vamos ver como o Kernel cognitivo X-BDI (a Mente de nosso agente – o agente Mediador) seleciona as táticas afetivas para o seguinte cenário: o estudante tem objetivos de desempenho e está decepcionado porque forneceu uma resposta incorreta a um exercício. O Kernel cognitivo recebe a seguinte informação dos sensores do agente:

```
[current_time(2),sense(student_goal(performance),1)].
[current_time(3),sense(event(not_correct_answer),2),sense(effort(hig
h),2)].
```

Os sensores notificam ao kernel cognitivo BDI que o aluno tem objetivos de desempenho, que seu esforço foi elevado, e que um evento aconteceu - o estudante forneceu uma resposta incorreta ao exercício. Assim, o agente ativa os desejos "apply_tactics" e "emotion_sent" como intenções. O desejo "emotion_sent" tem como objetivo enviar as emoções do aluno ao Agente de Diagnóstico. Ele usa esta informação para ajudar o agente Mediador a escolher as táticas pedagógicas que são adequadas do ponto de vista cognitivo e afetivo. O desejo "apply_tactics" é responsável por escolher as táticas afetivas que serão aplicadas.

```
/* O agente deseja aplicar uma tática afetiva */
des(mediador,apply_tactics(Tactic),Tf,[0.6]) if
bel(mediador,choose_tactics(Tactic)).
```

```
act(mediador,send_tactic(Tactic)) causes
bel(mediador,apply_tactics(Tactic)) if
bel(mediador,choose_tactics(Tactic)).

/* O agente Mediador deseja enviar as emoções do aluno ao Agente de
Diagn´sotico */

des(mediador, emotion_sent(Emotion, Intensity), Tf, [0.8]) if
bel(mediador, student_emotion(Emotion)),
bel(mediador, emotion_intensity(Emotion,Intensity)).

act(mediador, send_emotion(Emotion,Intensity))    causes
bel(mediador, emotion_sent(Emotion, Intensity))    if
bel(mediador,student_emotion(Emotion)),
bel(mediador, emotion_intensity(Emotion,Intensity)).
```

A fim do agente satisfazer sua intenção de aplicar táticas afetivas, ele deve realizar a ação de enviar esta tática ao atuador do agente (predicado "*send_tactic"*) – o modulo do Agente Mediador responsável por aplicar a tática afetiva. Para satisfazer a intenção "*emotion_sent*", ele precisa enviar a emoção do aluno ao Agente de Diagnóstico (predicado "*send_emotion"*).

Para enviar as emoções do aluno ao Agente de Diagnóstico, o Agente Mediador deve saber as emoções do aluno. Ele infere as emoções do aluno a partir das seguintes crenças:

```
/* O Aluno está desagradado com o evento */
bel(mediador,event_pleasantness(not_correct_answer,displeased)) if
bel(mediador,student_goal(performance)),
bel(mediador,event(not_correct_answer)).

/* É um evento com uma certa expectativa que acontecesse */
bel(mediador,is_prospect_event(not_correct_answer)) if
bel(mediador,event(not_correct_answer)).

/* Quando o aluno está desagradado, frustração (quando o aluno tinha
expectativas que o evento acontecesse) e tristeza podem surgir */
bel(mediador,student_emotion(disappointment))if
bel(mediador,event_pleasantness(Event,displeased)),
bel(mediador,-is_mediador_action),
bel(mediador,is_prospect_event(Event)).

bel(mediador,student_emotion(distress))if
bel(mediador,event_pleasantness(Event,displeased)),
bel(mediador,-is_mediador_action).
```

O aluno está desagradado com o evento porque ele é indesejável, ou é desejável mas não aconteceu. Quando ele está desagradado, ele experiencia as emoções tristeza e frustração, se o evento é um evento que se esperava acontecer, mas não se realizou (predicado *"is_prospect_event"*). Esse é o caso do evento "not_correct_task_answer", já que o aluno que realiza uma tarefa tem uma expectativa de que o evento "fornecer uma resposta correta" fosse acontecer. Para disparar emoções de tristeza e frustração o evento não pode ter sido causado pelo Agente Mediador. Ações do Agente Mediador geram emoções tais como raiva ou gratidão.

É também importante verificar o valor das variáveis que afetam a intensidade das emoções:

```
bel(mediador,emotion_intensity(disappointment, high)) if
bel(mediador, effort(high)),
bel(mediador, student_emotion(disappointment)).
```

As variáveis que afetam a intensidade das emoções são esforço, realização, não expectativa e indesejabilidade para tristeza. Se uma destas variáveis tem um valor maior (marcado como high), o estudante experiencia a emoção em questão com intensidade alta, caso contrário ele experiencia a emoção com intensidade média. O valor destas

variáveis que afetam a intensidade da emoção são enviadas ao módulo Corpo e esses valores podem ser médio ou alto. Ele é responsável por identificar os valores destas variáveis com questionário e observação do comportamento do aluno.

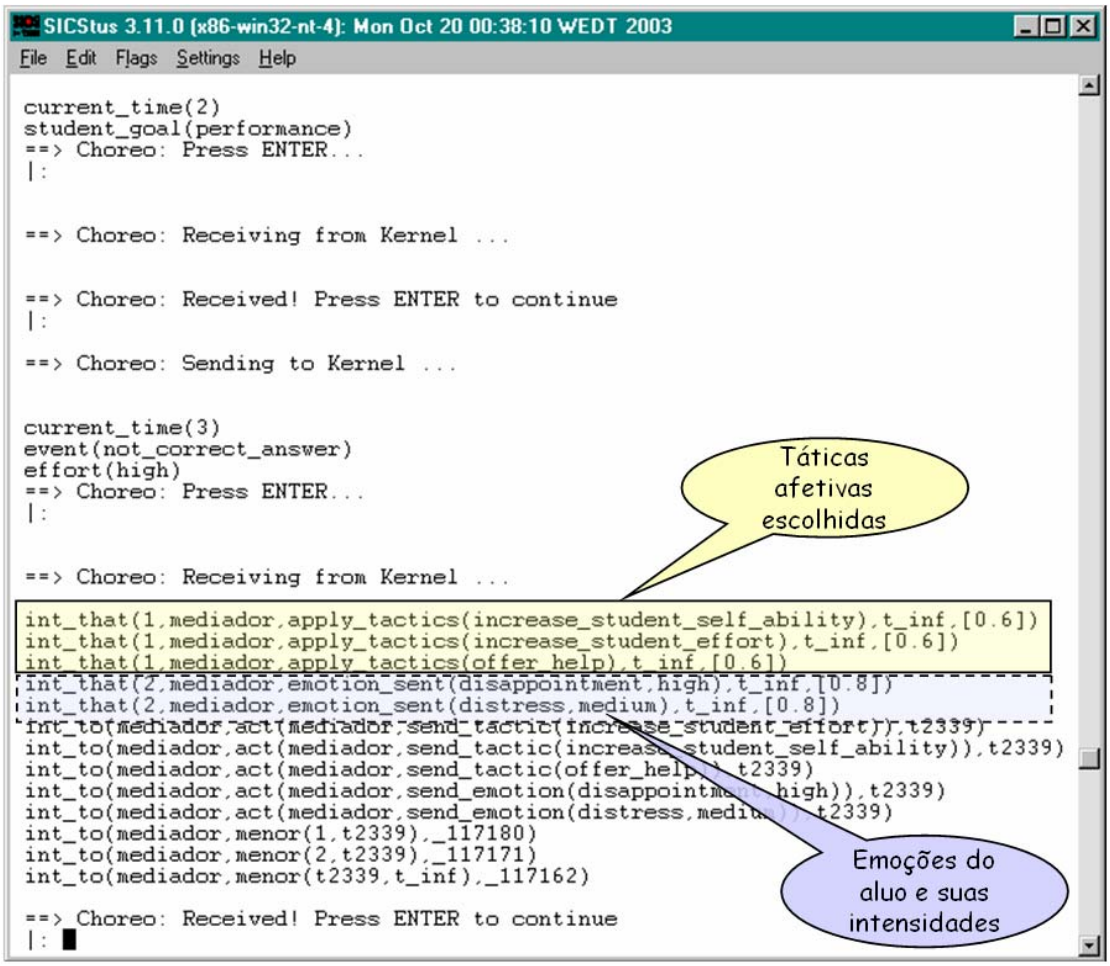


Figure 10.1: Escolha da Tática Afetiva pelo X-BDI

Finalmente, o agente escolhe as táticas através das crenças mostradas abaixo. As táticas afetivas são: (1) aumentar a auto-eficácia do aluno; (2) incentivar o aluno a fazer mais esforços, e (3) oferecer ajuda ao aluno. Uma vez que o agente tenha escolhido a tática afetiva, ele realiza a ação de enviar a tática ao módulo atuador. Como essa ação é a restrição para a intenção eleita ser satisfeita, a intenção do agente de aplicar uma tática afetiva é realizada.

```
bel  (agent, choose_tactics(increase_student_self_ability))  if
bel (agent,student_emotion(disappointment)),
bel (agent,event(not_correct_answer)),
bel (agent,student_goal(performance)).

bel  (agent, choose_tactics(increase_student_effort))        if
bel (agent,student_emotion(disappointment)),
bel (agent,event(not_correct_answer)),
bel (agent,student_goal(performance)).

bel  (agent, choose_tactics(offer_help))       if
bel (agent,student_emotion(disappointment)),
bel (agent,event(not_correct_answer)),
bel (agent,student_goal(performance)).
```

A inferência das emoções do aluno e a escolha das táticas afetivas pelo kernel X-BDI podem ser visualizados na interface Prolog que é mostrado na Figure 10.1. O conjunto de intenções escolhido pela mente do agente para o exemplo previamente descrito é representado pelos predicados *int_that* dentro do quadrado da Figure 10.1.

10.5 A Arquitetura do Agente Mediador

Figure 10.2 mostra a arquitetura do Agente Medidor. A arquitetura do agente é dividida em 2 partes: o módulo Corpo (Body) e o módulo Mente (Mind).

O Corpo do agente é responsável por capturar as ações do aluno na interface do sistema, realizar a comunicação com os outros agentes e mostrar os comportamentos animados e mensagens escolhidos pelo módulo Mente.

O módulo Mente é responsável por reconhecer os estados afetivos do aluno a partir de seu comportamento observável e escolher as táticas pedagógicas afetivas de acordo com o modelo afetivo do aluno.

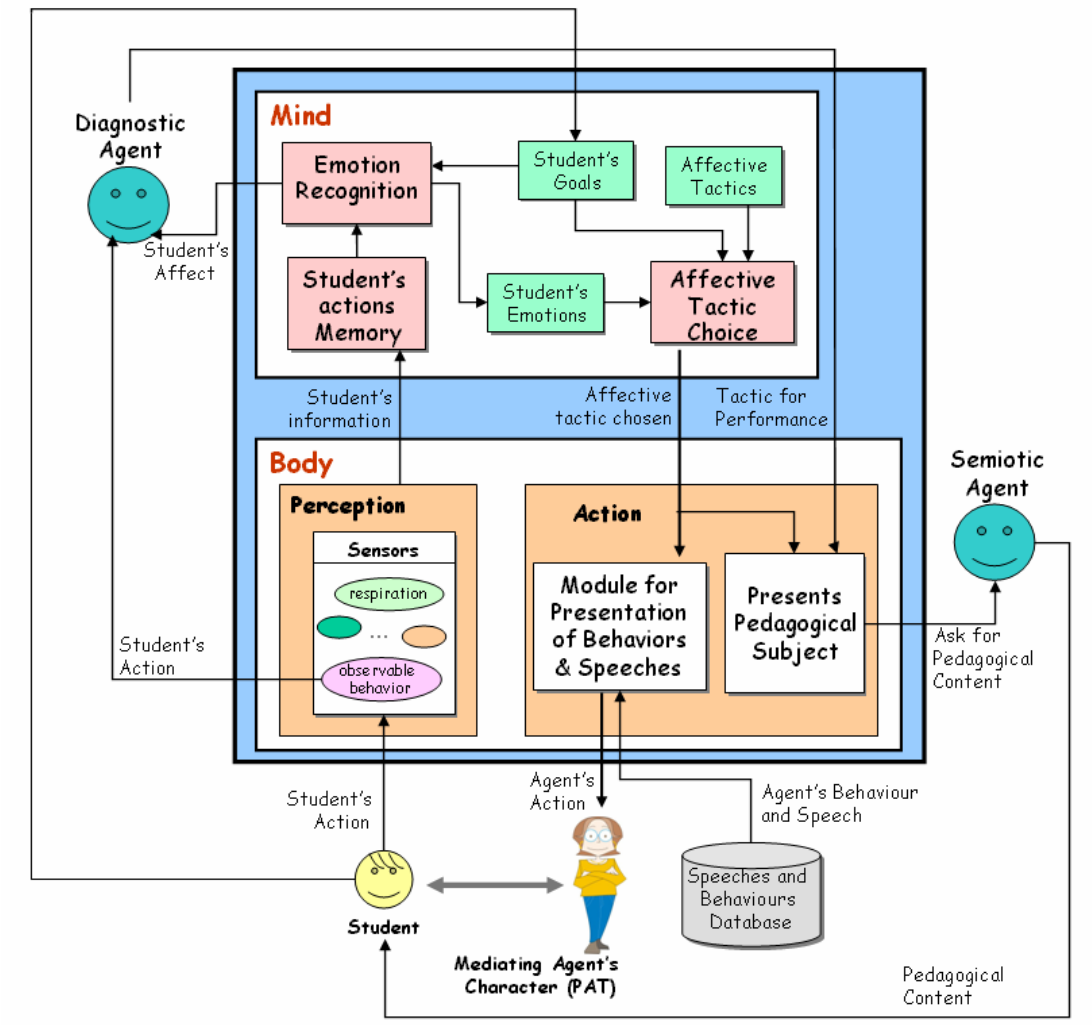


Figure 10.2: A Arquitetura do Agente Mediador

Durante todo o tempo, o Agente Mediador observa o aluno a fim de capturar dados que serão usados para inferir os estados afetivos do aluno. Estes dados são capturados

por sensores que compõem o módulo de Percepção (Perception). Alguns exemplos de sensores são: ferramentas para observar respiração e ritmo cardíaco. Em nosso protótipo, o agente infere as emoções do aluno a partir de seu comportamento observável; assim o sensor é apenas um software responsável por observar as ações do aluno na interface do sistema.

As ações do aluno capturadas pelo módulo de Percepção são enviadas ao Agente de Diagnóstico e ao módulo Mente do Agente Mediador. A Mente do agente é implementada como um kernel BDI que reconhece as emoções do aluno e atualiza o modelo afetivo, e também escolhe as táticas afetivas a serem aplicadas.

Primeiramente, quando a Mente recebe o comportamento observável do aluno, ele armazena a informação na Memória de Ações do Aluno (Student´s Actions Memory) e inicia o processo de reconhecimento das emoções. Algumas vezes, uma emoção é reconhecida através de algum padrão que é formado por um conjunto seqüencial de ações. Desta maneira, é necessário que ações passadas sejam armazenadas no sistema na Memória de Ações Passadas para futura recuperação.

O processo de reconhecimento de emoção verifica se ele pode inferir um estado afetivo a partir da informação recebida (com ou sem ações passadas). As informações recebidas são analisadas de acordo como objetivos do aluno seguindo o modelo OCC. Se alguma emoção é detectada, ela é mantida no modelo afetivo e se inicia o processo de escolha das táticas afetivas. O estado afetivo do aluno é também enviado ao agente Diagnóstico que usará esta informação para melhor definir as habilidades do aluno que estão na ZDP (ANDRADE; BRNA; VICCARI, 2002a). A tática é enviada ao módulo Ação (Action).

Se a tática afetiva do aluno é a apresentação de um comportamento emocional (por exemplo, congratular o aluno pelo sucesso no exercício), o Módulo de Seleção de Comportamentos e Falas (Module of Selection of Behaviour and Speeches) procura na base de dados o comportamento a ser apresentado de acordo com a tática escolhida.

O Agente Mediador também é responsável por receber as táticas de competência e desempenho do Agente de Diagnóstico. Se a tática é a apresentação de um conteúdo pedagógico, ele faz uma requisição ao Agente Semiótico e exibe o conteúdo ao aluno.

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APPENDIX A MSLQ[42]

Questionnaire for determining Students' Motivation Orientation

HERE ARE SOME QUESTIONS ABOUT YOURSELF AS A STUDENT IN THIS CLASS. PLEASE CIRCLE THE NUMBER THAT BEST DESCRIBES WHAT YOU THINK.

1. In a class like this, I prefer course material that really challenges me s I can learn new things.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

16. In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

22. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

24. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

7. Getting a good grade in this class is the most satisfying thing for me right now.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

11. The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.
1 2 3 4 5
NOT AT ALL TRUE SOMEWHAT TRUE VERY TRUE

13. If I can, I want to get better grades in this class than most the other students.
1 2 3 4 5
NOT AT ALL TRUE OF ME VERY TRUE OF ME

30. I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.
1 2 3 4 5
NOT AT ALL TRUE OF ME VERY TRUE OF ME

The items 1, 16, 22, and 24 are used to determine if the student has a Mastery Goal orientation (or Intrinsic Goal orientation). The items 7, 11, 13, and 30 allow us to determine if the student has a Performance Goal orientation (or Extrinsic Goal orientation). Others items concerns to subjects that are not interest of our work, and so, they are not presented to the students. In order to access the complete questionnaire, see (PINTRICH, 1991).

[42] Thanks to Combined Program in Education & Psychology (CPEP) of The University of Michigan for sending us a copy of MSLQ manual and for giving us license for using MSLQ.

APPENDIX B X-BDI BELIEFS

```
/* Agent's identification */
   identity(mediador).

   /* The agent desires to apply an affective tactic */
   des(mediador,apply_tactics(Tactic),Tf,[0.6]) if
       bel(mediador,choose_tactics(Tactic)).

   act(mediador,send_tactic(Tactic)) causes
       bel(mediador,apply_tactics(Tactic))
       if  bel(mediador,choose_tactics(Tactic)).

/* The Mediating Agent desires to the student's emotions to the Diagnostic
Agent */
   des(mediador, emotion_sent(Emotion, Intensity), Tf, [0.8])
       if bel(mediador, student_emotion(Emotion)),
          bel(mediador, emotion_intensity(Emotion,Intensity)).

   act(mediador, send_emotion(Emotion,Intensity))
       causes bel(mediador, emotion_sent(Emotion, Intensity))
       if bel(mediador,student_emotion(Emotion)),
          bel(mediador, emotion_intensity(Emotion,Intensity)).

/* ************** Mediating Agent's Beliefs ************************* */

   bel(mediador,is_self_action) if
       bel(mediador,event(student_asks_for_helping)).

   bel(mediador,is_mediador_action) if
       bel(mediador,event(after_agent_help)).
   bel(mediador,is_mediador_action) if
       bel(mediador,event(agent_offers_help)).
   bel(mediador,is_mediador_action) if
       bel(mediador,event(student_denies_help)).
   bel(mediador,is_mediador_action) if
       bel(mediador,event(student_accepts_help)).
   bel(mediador,is_mediador_action) if
       bel(mediador,event(student_disables_agent)).
   bel(mediador,is_mediador_action) if
       bel(mediador,event(student_enables_agent)).

   bel(mediador,is_prospect_event(not_correct_answer)) if
       bel(mediador,event(not_correct_answer)).
   bel(mediador,is_prospect_event(correct_answer)) if
       bel(mediador,event(not_correct_answer)).
   bel(mediador,is_prospect_event(task_not_accomplished)) if
       bel(mediador,event(task_not_accomplished)).
   bel(mediador,is_prospect_event(gave_up_chapter)) if
       bel(mediador,event(gave_up_chapter)).
   bel(mediador,is_prospect_event(finish_chapter)) if
       bel(mediador,event(finish_chapter)).
```

```
/* ********************************************************************* */
/* Beliefs about which emotions is elicited according the event's pleasantness
*/

   bel(mediador,student_emotion(gratitude)) if
       bel(mediador,event_pleasantness(Event,pleased)),
       bel(mediador,action_praiseworthiness(Event,praise)),
       bel(mediador,is_mediador_action).

   bel(mediador,student_emotion(anger)) if
       bel(mediador,event_pleasantness(Event,displeased)),
       bel(mediador,action_praiseworthiness(Event,blame)),
       bel(mediador,is_mediador_action).

   bel(mediador,student_emotion(disappointment))if
       bel(mediador,event_pleasantness(Event,displeased)),
       bel(mediador,-is_mediador_action),
       bel(mediador,is_prospect_event(Event)).

   bel(mediador,student_emotion(satisfaction))if
       bel(mediador,event_pleasantness(Event,pleased)),
       bel(mediador,-is_mediador_action),
       bel(mediador,is_prospect_event(Event)).

   bel(mediador,student_emotion(distress))if
       bel(mediador,event_pleasantness(Event,displeased)),
       bel(mediador,-is_mediador_action).

   bel(mediador,student_emotion(joy))if
       bel(mediador,event_pleasantness(Event,pleased)),
       bel(mediador,-is_mediador_action).

   bel(mediador,student_emotion(ne))if
       bel(mediador,event_pleasantness(Event,indifferent)),
       bel(mediador,-is_mediador_action).

   bel(mediador,student_emotion(shame))if
       bel(mediador,action_praiseworthiness(Event,blame)),
       bel(mediador,is_self_action).

/* ********* Beliefs about emotion's intensity *************************** */

/* Intensity for Satisfaction/Disappointment Anger and Gratitude Emotions */

   bel(mediador,emotion_intensity(satisfaction,high)) if
       bel(mediador, effort(high)),
       bel(mediador,student_emotion(satisfaction)).

   bel(mediador,emotion_intensity(satisfaction,high)) if
       bel(mediador, realization(high)),
       bel(mediador,student_emotion(satisfaction)).

   bel(mediador,emotion_intensity(satisfaction, high)) if
       bel(mediador, unexpectdness(high)),
       bel(mediador,student_emotion(satisfaction)).

   bel(mediador,emotion_intensity(satisfaction, high)) if
       bel(mediador, desirability(high)),
       bel(mediador,student_emotion(satisfaction)).

   bel(mediador,emotion_intensity(satisfaction, medium)) if
       bel(mediador, -unexpectdness(high)),
       bel(mediador, -realization(high)),
       bel(mediador, -effort(high)),
       bel(mediador, -desirability(high)),
       bel(mediador,student_emotion(satisfaction)).
```

```
    bel(mediador,emotion_intensity(joy,high)) if
        bel(mediador, desirability(high)),
        bel(mediador,student_emotion(joy)).

    bel(mediador,emotion_intensity(joy, medium)) if
        bel(mediador, -desirability(high)),
        bel(mediador,student_emotion(joy)).

    bel(mediador,emotion_intensity(disappointment, high)) if
        bel(mediador, effort(high)),
        bel(mediador,student_emotion(disappointment)).

    bel(mediador,emotion_intensity(disappointment,high)) if
        bel(mediador, realization(high)),
        bel(mediador,student_emotion(disappointment)).

    bel(mediador,emotion_intensity(disappointment,high)) if
        bel(mediador, unexpectdness(high)),
        bel(mediador,student_emotion(disappointment)).

    bel(mediador,emotion_intensity(disappointment,high)) if
        bel(mediador, undesirability(high)),
        bel(mediador,student_emotion(disappointment)).

    bel(mediador,emotion_intensity(disappointment,medium)) if
        bel(mediador, -unexpectdness(high)),
        bel(mediador, -realization(high)),
        bel(mediador, -effort(high)),
        bel(mediador, -undesirability(high)),
        bel(mediador,student_emotion(disappointment)).


    bel(mediador,emotion_intensity(distress,high)) if
        bel(mediador, undesirability(high)),
        bel(mediador,student_emotion(distress)).

    bel(mediador,emotion_intensity(distress, medium)) if
        bel(mediador, -undesirability(high)),
        bel(mediador,student_emotion(distress)).


/* **** Intensity for Gratitude and Anger Emotions ***** */

    bel(mediador,emotion_intensity(gratitude,high)) if
        bel(mediador, praiseworthiness(high)),
        bel(mediador,student_emotion(gratitude)).

    bel(mediador,emotion_intensity(gratitude,high)) if
        bel(mediador, desirability(high)),
        bel(mediador,student_emotion(gratitude)).

    bel(mediador,emotion_intensity(gratitude,medium)) if
        bel(mediador, -praiseworthiness(high)),
        bel(mediador, -desirability(high)),
        bel(mediador,student_emotion(gratitude)).

    bel(mediador,emotion_intensity(anger,high)) if
        bel(mediador, blameworthiness(high)),
        bel(mediador, undesirability(high)),
        bel(mediador,student_emotion(anger)).

    bel(mediador,emotion_intensity(anger,medium)) if
        bel(mediador, -blameworthiness(high)),
        bel(mediador, -undesirability(high)),
        bel(mediador,student_emotion(anger)).
```

```
/* ********************************************************************** */
/* Beliefs about the event's pleasantness for performance oriented students */

/* event 1 = not_correct_answer */
   bel(mediador,event_pleasantness(not_correct_answer,displeased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(not_correct_answer)).

/* event 2 = correct_answer */
   bel(mediador,event_pleasantness(correct_answer,pleased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(correct_answer)).

/* event 3 = task_not_accomplished */
   bel(mediador,event_pleasantness(task_not_accomplished,displeased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(task_not_accomplished)).

/* event 4 = gave_up_chapter */
   bel(mediador,event_pleasantness(gave_up_chapter,indifferent)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_has_minimal_grade).

   bel(mediador,event_pleasantness(gave_up_chapter,displeased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,-student_has_minimal_grade).

/* event 5 = finish_chapter */
   bel(mediador,event_pleasantness(finish_chapter,pleased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(finish_chapter)),
       bel(mediador,student_has_minimal_grade).

/* event 6 = student_asks_for_helping */
   bel(mediador,event_pleasantness(student_asks_for_helping,indifferent)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,-student_feels_uncomfortable).

   bel(mediador,action_praiseworthiness(Event,blame)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,student_feels_uncomfortable).

/* event 7 = after_agent_help */
   bel(mediador,event_pleasantness(after_agent_help,indifferent)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_think_help_was_appropriate).

   bel(mediador,action_praiseworthiness(after_agent_help,indifferent)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_think_help_was_appropriate).

   bel(mediador,event_pleasantness(after_agent_help,displeased)) if
       bel(mediador,student_goal(performance)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,-student_think_help_was_appropriate).

   bel(mediador,action_praiseworthiness(after_agent_help,blame)) if
       bel(mediador,student_goal(performance)),
```

```
        bel(mediador,event(after_agent_help)),
        bel(mediador,-student_think_help_was_appropriate).

/* event 8 = student_denies_help */
    bel(mediador,event_pleasantness(student_denies_help,indifferent)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,-student_feels_uncomfortable).

    bel(mediador,action_praiseworthiness(student_denies_help,indifferent)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,-student_feels_uncomfortable).

    bel(mediador,event_pleasantness(student_denies_help,displeased)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,student_feels_uncomfortable).

    bel(mediador,action_praiseworthiness(student_denies_help,blame)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,student_feels_uncomfortable).

/* event 9 = student_accepts_help */
    bel(mediador,event_pleasantness(student_accepts_help,pleased)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_accepts_help)).

    bel(mediador,action_praiseworthiness(student_accepts_help,praise)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_accepts_help)).

/* event 10 = student_enables_agent */
    bel(mediador,event_pleasantness(student_enables_agent,pleased)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_enables_agent)).

    bel(mediador,action_praiseworthiness(student_enables_agent,praise)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_enables_agent)).

/* event 11 = student_disables_agent */
    bel(mediador,event_pleasantness(student_enables_agent,displeased)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_disables_agent)).

    bel(mediador,action_praiseworthiness(student_enables_agent,blame)) if
        bel(mediador,student_goal(performance)),
        bel(mediador,event(student_disables_agent)).


/* Beliefs about the event's plesantness for mastery oriented students */
/* event 1 = not_correct_answer */
    bel(mediador,event_pleasantness(not_correct_answer,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_wants_know_subject).

    bel(mediador,event_pleasantness(not_correct_answer,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,-student_wants_know_subject).

/* event 2 = correct_answer */
    bel(mediador,event_pleasantness(correct_answer,pleased)) if
```

```
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_effort(high)).

    bel(mediador,event_pleasantness(correct_answer,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_effort(low)).

/* event 3 = task_not_accomplished */
    bel(mediador,event_pleasantness(task_not_accomplished,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_wants_know_subject).

    bel(mediador,event_pleasantness(task_not_accomplished,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,-student_wants_know_subject).

/* event 4 = gave_up_chapter */
    bel(mediador,event_pleasantness(gave_up_chapter,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(gave_up_chapter)),
        bel(mediador,-student_wants_know_subject).

    bel(mediador,event_pleasantness(gave_up_chapter,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(gave_up_chapter)),
        bel(mediador,student_wants_know_subject).

/* event 5 = finish_chapter */
    bel(mediador,event_pleasantness(finish_chapter,pleased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(finish_chapter)).

/* event 6 = student_asks_for_helping */
    bel(mediador,event_pleasantness(student_asks_for_helping,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_asks_for_helping)).

/* event 7 = after_agent_help */
    bel(mediador,event_pleasantness(after_agent_help,pleased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(after_agent_help)),
        bel(mediador,student_think_help_was_appropriate).

    bel(mediador,action_praiseworthiness(after_agent_help,praise)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(after_agent_help)),
        bel(mediador,student_think_help_was_appropriate).

    bel(mediador,event_pleasantness(after_agent_help,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(after_agent_help)),
        bel(mediador,-student_think_help_was_appropriate).

    bel(mediador,action_praiseworthiness(after_agent_help,blame)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(after_agent_help)),
        bel(mediador,-student_think_help_was_appropriate).

/* event 8 = student_denies_help */
    bel(mediador,event_pleasantness(student_denies_help,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_denies_help)),
```

```
        bel(mediador,disturbing_student).

    bel(mediador,action_praiseworthiness(student_denies_help,blame)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,disturbing_student).

    bel(mediador,event_pleasantness(student_denies_help,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,-disturbing_student).

    bel(mediador,action_praiseworthiness(student_denies_help,indifferent)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_denies_help)),
        bel(mediador,-disturbing_student).

/* event 9 = student_accepts_help */
    bel(mediador,event_pleasantness(student_accepts_help,pleased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_accepts_help)).

    bel(mediador,action_praiseworthiness(student_accepts_help,praise)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_accepts_help)).

/* event 10 = student_disables_agent */
    bel(mediador,event_pleasantness(student_disables_agent,displeased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_disables_agent)).

    bel(mediador,action_praiseworthiness(student_disables_agent,blame)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_disables_agent)).

/* event 11 = student_enables_agent */
    bel(mediador,event_pleasantness(student_enables_agent,pleased)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_enables_agent)).

    bel(mediador,action_praiseworthiness(student_enables_agent,praise)) if
        bel(mediador,student_goal(mastery)),
        bel(mediador,event(student_enables_agent)).

/* ********************************************************************** */
/* Beliefs about which tactic to choose */

/*** event 1 ***/
/* Mastery */
    bel(mediador, choose_tactics(recognise_student_effort)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(offer_help)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_goal(mastery)).

/* performance */
    bel(mediador, choose_tactics(increase_student_self_ability)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_goal(performance)).

    bel(mediador, choose_tactics(increase_student_effort)) if
```

```
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_goal(performance)).

    bel(mediador, choose_tactics(offer_help)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(not_correct_answer)),
        bel(mediador,student_goal(performance)).

/**** event 2 *******/
/* Mastery */
    bel(mediador, choose_tactics(new_skill)) if
        bel(mediador,student_emotion(satisfaction)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(congratulation)) if
        bel(mediador,student_emotion(ne)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(new_skill)) if
        bel(mediador,student_emotion(ne)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_goal(mastery)).

/* performance */
    bel(mediador, choose_tactics(congratulation)) if
        bel(mediador,student_emotion(satisfaction)),
        bel(mediador,event(correct_answer)),
        bel(mediador,student_goal(performance)).

/**** event 3 *******/
/* Mastery */
    bel(mediador, choose_tactics(encouragement)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(offer_help)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(new_skills)) if
        bel(mediador,student_emotion(ne)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(mastery)).

    bel(mediador, choose_tactics(offer_help)) if
        bel(mediador,student_emotion(ne)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(mastery)).

/* Performance */
    bel(mediador, choose_tactics(increase_student_self_ability)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(performance)).

    bel(mediador, choose_tactics(increase_student_effort)) if
        bel(mediador,student_emotion(disappointment)),
        bel(mediador,event(task_not_accomplished)),
        bel(mediador,student_goal(performance)).
```

```
/* ************ event 4 ************************ */

/* Mastery */
   bel(mediador, choose_tactics(show_curiosity)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(mastery)).

   bel(mediador, choose_tactics(encouragement)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(mastery)).

   bel(mediador, choose_tactics(offer_help)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(mastery)).

/* Performance */
   bel(mediador, choose_tactics(increase_student_effort)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(-student_effort(high)).

   bel(mediador, choose_tactics(encouragement)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(student_effort(high)).

   bel(mediador, choose_tactics(increase_student_self-ability)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(-student_effort(high)).

   bel(mediador, choose_tactics(increase_student_effort)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(-student_effort(high)).

   bel(mediador, choose_tactics(increase_student_self-ability)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(student_effort(high)).

   bel(mediador, choose_tactics(encouragement)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(gave_up_chapter)),
       bel(mediador,student_goal(performance)),
       bel(student_effort(high)).

/* **********************   Event 5 ***************************  */

/* Mastery */

   bel(mediador, choose_tactics(congratulation)) if
       bel(mediador,student_emotion(satisfaction)),
       bel(mediador,event(finish_chapter)),
       bel(mediador,student_goal(mastery)).
```

```
/* Performance */

   bel(mediador, choose_tactics(encouragement)) if
       bel(mediador,student_emotion(disappointment)),
       bel(mediador,event(finish_chapter)),
       bel(mediador,student_goal(performance)).

   bel(mediador, choose_tactics(congratulation)) if
       bel(mediador,student_emotion(satisfaction)),
       bel(mediador,event(finish_chapter)),
       bel(mediador,student_goal(performance)).

/* **********************   Event 6 **************************  */

/* Mastery */

   bel(mediador, choose_tactics(give_help)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,student_goal(mastery)).

/* Performance */

   bel(mediador, choose_tactics(explain_help_importance)) if
       bel(mediador,student_emotion(shame)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,student_goal(performance)).

   bel(mediador, choose_tactics(give_help)) if
       bel(mediador,student_emotion(shame)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,student_goal(performance)).

   bel(mediador, choose_tactics(give_help)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(student_asks_for_helping)),
       bel(mediador,student_goal(performance)).

/* **********************   Event 7 **************************  */

/* Mastery */

   bel(mediador, choose_tactics(agent_is_sorry_for_not_helping)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(mastery)).

   bel(mediador,
choose_tactics(informs_diagnostic_agent(help_not_appropiate))) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(mastery)).

   bel(mediador, choose_tactics(agent_is_happy_for_helping_student)) if
       bel(mediador,student_emotion(gratitude)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(mastery)).

/* Performance */

   bel(mediador, choose_tactics(agent_is_sorry_for_not_helping)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(performance)).
```

```
   bel(mediador,
choose_tactics(informs_diagnostic_agent(help_not_appropiate))) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(performance)).

   bel(mediador, choose_tactics(agent_is_happy_for_helping_student)) if
       bel(mediador,student_emotion(ne)),
       bel(mediador,event(after_agent_help)),
       bel(mediador,student_goal(performance)).

/* **********************   Event 8 ***************************  */

/* Mastery */

   bel(mediador, choose_tactics(sorry_for_disturbing)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(student_denies_help)),
       bel(mediador,student_goal(mastery)),
       bel(mediador,disturbing_student).

/* Performance */

   bel(mediador, choose_tactics(sorry_for_disturbing)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(student_denies_help)),
       bel(mediador,student_goal(performance)),
       bel(mediador,disturbing_student),
       bel(mediador,-student_feels_uncomfortable).

   bel(mediador, choose_tactics(explain_help_importance)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(student_denies_help)),
       bel(mediador,student_goal(performance)),
       bel(mediador,-disturbing_student),
       bel(mediador,student_feels_uncomfortable).

   bel(mediador, choose_tactics(offer-help)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(student_denies_help)),
       bel(mediador,student_goal(performance)),
       bel(mediador,-disturbing_student),
       bel(mediador,student_feels_uncomfortable).

/* **********************   Event 9 ***************************  */

   bel(mediador, choose_tactics(give_help)) if
       bel(mediador,student_emotion(gratitude)),
       bel(mediador,event(student_accepts_help)).

/* **********************   Event 10 ***************************  */

   bel(mediador, choose_tactics(student_disables_agent)) if
       bel(mediador,student_emotion(anger)),
       bel(mediador,event(student_disables_agent)).

/* **********************   Event 11 ***************************  */

   bel(mediador, choose_tactics(student_enables_agent)) if
       bel(mediador,student_emotion(gratitude)),
       bel(mediador,event(student_enables_agent)).
```

APPENDIX C PARTIAL RESULTS

We had some national and international publications that are result of this work. These articles and the conferences where they were presented are listed bellow. We classify our publications in two main groups. In the first one, we cite the articles that present the work of this thesis and some partial results. In the second group are the papers that are related to MACES, the educational environment where the Mediating Agent is inserted, that were made jointly with other colleagues who are also master and PhD students of Rosa Viccari.

We had some difficulties in publishing articles in periodicals since MACES is not yet implemented and, thus, it is difficult for us having a complete validation of the work. But we believe that with the future implementation of MACES we can overcome this limitation of our work.

Publications related to this thesis proposal:

- JAQUES, Patricia A.; VICCARI, Rosa; PESTY, Sylvie; BONNEVILLE, Jean-François. Affective Tactics for a Better Learning. European Conference on Artificial Intelligence (ECAI), Valence, Spain, 2004. (To be presented).
- JAQUES, Patricia A.; VICCARI, Rosa. *Towards User's Emotion Recognition: A Case in an Educational System*. 2nd IEEE International conference on Computational Intelligence, Robotics and Autonomous Systems (CIRAS 2003). 15-18 de dezembro de 2003. Cingapura.
- JAQUES, Patricia A.; BOCCA, Everton; VICCARI, Rosa. *Considering Student's Emotions in Computational Educational Systems*. Simpósio Brasileiro de Informática na Educação. 12 a 14 de novembro de 2003, Rio de Janiero.
- BOCCA, Everton; JAQUES, Patricia A.; VICCARI, Rosa. *Modelagem e Implementação da Interface para Apresentação de Comportamentos Animados e Emotivos de um Agente Pedagógico Animado*. RENOTE - Revista Novas Tecnologias na Educação (ISSN 1679-1916), Setembro/2003, Vol. 1, No 2.
- JAQUES, Patricia A.; BERCHT, Magda; BOCCA, Everton; VICCARI, Rosa. *Cognitive Reasoning to Respond Affectively to the Student*. In: The IASTED International Conference on Computers and Advanced Technology in Education. Proceeedings... June 30 - July 2, 2003. Rhodes, Greece.
- JAQUES, Patricia A.; PESTY, Sylvie; VICARI, Rosa. *An Animated Pedagogical Agent that Interacts Affectively with the Student.* 11th International Conference on Artificial Intelligence in Education. Proceedings... Sydney, Australia, 2003. (Poster)
- JAQUES, Patrícia A.; KIST, Tania; FRANZEN, Evandro; PIMENTA, Marcelo; VICARI, Rosa. *Interação com Agentes Pedagógicos Animados: Um Estudo*

Comparativo. IHC 2001 - IV Workshop on Human Factors in Computer Systems. 15 a 17 de outubro de 2001, Florianópolis, SC.

Publications related to MACES:

- JUNG, J. L.; ANDRADE, A. F.; JAQUES, P. A.; VICCARI, R. M. *Um agente semiótico como parte de um modelo social de aprendizagem a distância*. Informática na Educação Teoria Prática. Porto Alegre: , v.4, n.2, p.97 - 108, 2001.
- JUNG, João L.; JAQUES, Patrícia A.; ANDRADE, Adja F. de; BORDINI, Rafael H.; VICARI, Rosa M. *The Conception of Agents as Part of a Social Model of Distance Learning.* In: Brazilian Symposium on Artificial Intelligence, SBIA, 16., 2002, Recife, Brazil. Proceedings... Berlin: Springer-Verlag, 2002.
- JAQUES, Patrícia A.; OLIVEIRA, Flavio M.; VICCARI, Rosa. *An Experiment using Software Agents for Dialogue Analysis in Collaborative Distance Learning.* Conference in Computer Supported Collaborative Learning 2002 (CSCL 2002). Boulder, Colorado – EUA, Janeiro 7-11. Stahl, G. (Ed.) Proceedings of CSCL 2002. New Jersey: Lawrence Erlbaum Associeates, 2002. pp. 560-561. (poster)
- JAQUES, Patrícia A.; JUNG, João L.; ANDRADE, Adja F. de; BORDINI, Rafael H.; VICARI, Rosa M.. Using Pedagogical Agents to Support Collaborative Distance Learning in Computer Supported Collaborative Learning 2002 (CSCL 2002). Boulder, Colorado – EUA , Janeiro 7-11. Stahl, G. (Ed.) Proceedings of CSCL 2002. New Jersey: Lawrence Erlbaum Associeates, 2002. pp. 546-547.
- JUNG, João L.; JAQUES, Patrícia A.; ANDRADE, Adja F. de; BORDINI, Rafael H.; VICARI, Rosa M. *Um agente Inteligente Baseado na Engenharia Semiótica Inserido em um Ambiente de Aprendizado à Distância*. IHC 2001 - IV Workshop on Human Factors in Computer Systems. 15 a 17 de outubro de 2001, Florianópolis, SC.
- ANDRADE, Adja; JAQUES, Patricia; VICARI, Rosa; BORDINI, Rafael; JUNG, João. *A Computational Model of Distance Learning Based on Vygotsky's Sociocultural Approach*. MABLE WORKSHOP (Multi-Agent Based Learning Environments). X International Conference on Artificial Intelligence on Education. Antonio, Texas, May 19-23 2001.
- ANDRADE, Adja; JAQUES, Patricia; VICARI, Rosa; BORDINI, Rafael; JUNG, João. *Uma Proposta de Modelo Computacional de Aprendizagem à Distância Baseada na Concepção Socio-Interacionista de Vygotsky*. Anais... Workshop de Ambientes de Aprendizagem baseados em Agentes. XI Simpósio Brasileiro de Informática na Educação. Maceió, 8 a 10 de Novembro de 2000.

APPENDIX D VALIDATION QUESTIONNAIRES

Entrevistado No X

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista					
II. Dá uma noção do todo					
III. Roupas					
IV. Cor					
2. Gênero					
I. Mulher					
II. Homem					
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)					
II. Expressão das emoções: positivas e negativas					
III. Adequação das emoções					
IV. Postura no momento de interferir					
V. As mudanças de postura e face					
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela					
II. Dinamismo: Movimentos e gestos na Tela					
III. Forma de interagir com o aluno					
IV. Modo de interferência do Personagem (Táticas)					

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 2	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 4	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 5	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 7	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 8	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 9	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 10	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 11	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 14	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	
Situação 15	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	

Sugestões e comentários:

APPENDIX E RESPONSES FOR THE VALIDATION QUESTIONNAIRES

Entrevistado 1

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista					x
II. Dá uma noção do todo				x	
III. Roupas					x
IV. Cor					x
2. Gênero					
I. Mulher					x[1]
II. Homem					x[1]
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)			x		
II. Expressão das emoções: positivas e negativas			x		
III. Adequação das emoções			x		
IV. Postura no momento de interferer				x	
V. As mudanças de postura e face			x		
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela					x
II. Dinamismo: Movimentos e gestos na Tela					x
III. Forma de interagir com o aluno					x
IV. Modo de interferência do Personagem (Táticas)					x

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

1) Mulher ou Homem: Qualquer um fica bem.

2) A expressão facial é muito estática. Isso prejudica a própria comunicação das emoções e a inferência destas por parte dos usuários. Praticamente não percebi mudanças de face.

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim, entretanto penso que poderiam haver falas mais descontraídas.*
Situação 2	Táticas	Adequada? Por quê?	*Ok*
	Comportamentos	Adequada? Por quê?	*Achei apenas o 3 adequado.* *As 2 primeiras seriam mais adequadas para adultos, talvez. Para adolescentes, apenas a 3a fala "fala" a lingua deles.*
Situação 4	Táticas	Adequada? Por quê?	*Ok.* *Boas falas.*
	Comportamentos	Adequada? Por quê?	
Situação 5	Táticas	Adequada? Por quê?	*Ok*
	Comportamentos	Adequada? Por quê?	*A linguagem está bem próxima à usada pelos adolescentes. Isso é muito bom.*
Situação 7	Táticas	Adequada? Por quê?	*Ok.* *Os feedbacks do agente satisfazem a personalidade do aluno e ainda o motivam a engajar mais em sua aprendizagem.*
	Comportamentos	Adequada? Por quê?	*Ok.*
Situação 8	Táticas	Adequada? Por quê?	*Ok.* *O agente poderia lembrar ao aluno tudo que ele ja conseguiu, etc.*
	Comportamentos	Adequada? Por quê?	*Embora as táticas sejam boas, os comportamentos verbais poderiam ser mais carinhosos.*
Situação 9	Táticas	Adequada? Por quê?	*Nova redação dos comportamentos.*
	Comportamentos	Adequada? Por quê?	
Situação 10	Táticas	Adequada? Por quê?	*Ok.*
	Comportamentos	Adequada? Por quê?	*Ok. Muito bom!*

Situação 11	Táticas	Adequada? Por quê?	*Muito bom! Esse é, na verdade, o papel do educador. Tentar motivar o aluno, despertar o seu interesse.*
	Comportamentos	Adequada? Por quê?	*Ok.*
Situação 14	Táticas	Adequada? Por quê?	*Ok.*
	Comportamentos	Adequada? Por quê?	
Situação 15	Táticas	Adequada? Por quê?	*Ok. Parabéns!*
	Comportamentos	Adequada? Por quê?	

Sugestões:

Sugiro que o áudio seja feito com locutores (gravações com a voz de uma pessoa). A distância entre o usuário e o agente diminuiria significativamente.

Entrevistado 2

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista				x	
II. Dá uma noção do todo				x	
III. Roupas					x
IV. Cor					x
2. Gênero					
I. Mulher					x[1]
II. Homem					x[1]
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)					x
II. Expressão das emoções: positivas e negativas				x	
III. Adequação das emoções				x	
IV. Postura no momento de interferir				x	
V. As mudanças de postura e face				x	
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela				x	
II. Dinamismo: Movimentos e gestos na Tela				x	
III. Forma de interagir com o aluno				x	
IV. Modo de interferência do Personagem (Táticas)					x

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

Poderia ser disponibilizada a imagem a ser escolhida pelo usuário do ambiente, isto é, a escolha do tipo físico seria aberta: Homem ou mulher, roupa, cabelos, etc. O professor ou o usuário comporia o tipo físico adequado aos alunos.

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Não.* *A dequação para um público genérico talvez seja acentuar a frustração. O agente dizer que "tenho muita sabedoria …". Mesmo adulto, compreende melhor é "dica".*
Situação 4	Táticas	Adequada? Por quê?	*Sim*
	Comportamentos	Adequada? Por quê?	*Sim*
Situação 5	Táticas	Adequada? Por quê?	*Sim*
	Comportamentos	Adequada? Por quê?	*Sim* *De qualquer forma o levantamento das habilidades do aluno pelo agente não deve ser extensa (fala concisa)*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 9	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Não. Precisa de nova redação.*
Situação 10	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 14	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim. Muito bom!*

Situação 15	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim. Muito bom!*

Sugestões:

1) Situação 1 – A entonação da voz (apesar de ser sintetizada) é importante. Daí que o simples "Posso te ajudar?" alcança melhor o objetivo de somar-se ao "reconhecimento dos esforços".

Entrevistado 3

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista					x
II. Dá uma noção do todo					x
III. Roupas					x
IV. Cor					x
2. Gênero					
I. Mulher				x[1]	
II. Homem				x[1]	
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)				x	
II. Expressão das emoções: positivas e negativas				x	
III. Adequação das emoções					x
IV. Postura no momento de interferir					x
V. As mudanças de postura e face				x	
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela				x	
II. Dinamismo: Movimentos e gestos na Tela				x	
III. Forma de interagir com o aluno			x		
IV. Modo de interferência do Personagem (Táticas)				x	

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

1) Acho que a questão do gênero é muito pessoal, mas por outro lado pode ser neutralizada com uma empatia.

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.* *Dá uma reação imediata para responder, ou pelo menos, dar um sorriso na tela.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.* *Funciona como estímulo ao aluno.*
	Comportamentos	Adequada? Por quê?	*A fala "parabéns pelo esforço … " não convence, pois o aluno não acredita que realizou esforço correto. Algo como "o teu esforço já te levou por um pedaço de caminho…" seria melhor.* *A fala "tenho muita sabedoria para te passar" me chocou. Seria melhor um convite como "vamos refletir juntos".*
Situação 4	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim, embora as falas "tenho a pista …", "tenho muita sabedoria …" poderiam ser sempre como convite, ou mais genérico, como "Tenho uma pista …", "tenho sabedoria (conhecimento) para compartilhar…".*
Situação 5	Táticas	Adequada? Por quê?	*Sim.* *Reforça ao aluno tudo que ele ja aprendeu ou talvez ele nem tenha se dado conta.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim. Sugetão para o comportamento "brinquedo de circo": colocar o som da sineta quando atingir o topo.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 9	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Não. Deve mostrar o potencial que pode ser desenvolvido.*

Situação 10	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*O "não desanime" no sofá seria melhor se fosse a seqüência: ela sentada, levantando-se para agir.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Provoca curiosidade e a pesquisa.*
Situação 14	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim. Achei sensacional, mostra talvez a maior "empatia" com o aluno.*
Situação 15	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.*

Sugestões:

Entrevistado 4

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista			x		
II. Dá uma noção do todo			x		
III. Roupas			x		
IV. Cor				x	
2. Gênero					
I. Mulher				x[1]	
II. Homem				x[1]	
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)			x		
II. Expressão das emoções: positivas e negativas			x		
III. Adequação das emoções				x	
IV. Postura no momento de interferir				x	
V. As mudanças de postura e face			x		
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela			x		
II. Dinamismo: Movimentos e gestos na Tela			x		
III. Forma de interagir com o aluno				x	
IV. Modo de interferência do Personagem (Táticas)					

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

1) *O gênero: acho que é relevante apenas se pensarmos no aluno ou na tela.*
2) *Talvez o uso da animação pudesse ser mais criativo, usando as linguagens de animação (fala) integradas a movimentos e desenhos e não ao texto que está sendo usado. Por exemplo, quando diz o que aprendeu, pode ter uma telinha com os recursos que aprendeu aparecendo (homepage, hyperlink, inlcuir figura). A outra possibilidade de agilização da linguagem da animação é não dividir em uma primeira fala e uma segunda ação. A fala pode ser concomitante à ação, o que ganharia em sinergia entre ambos que parecem dissociados.*
3) *As falas recitadas sinteticamente não são compatíveis com transmissão de emoção, soam falsas e excessivamente irreais. A opção deveria ser pela gravação de voz humana, com entonação que deixem passar afetividade, discordância, inclusive.*

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Parcialmente.* *Talvez pudesse ser algo mais caloroso, do tipo "olá ... que bom encontrá-lo de novo ..." A formalidade/informalidade da saudação tem que ser compatível com a coerência das demais intervenções.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Parcialmente.* *1) A fala sobre esforço realizado soa artificial, formal demais para um professor que saudou com abaninho e alozinho.* *2) A imagem do frade não é adequada porque pode não ser identificada.* *3) A fala "tenho muito sabedoria para te passar" é pervástica.*
Situação 4	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Oferecer ajuda. Parcialmente.* *É um pouco longa a fala, embora o tom do estímulo seja adequado.* *A idéia de "pista" poderia ser trocada, nesse caso, para algo mais competitivo como um instrumento para realizar algo.*
Situação 5	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Observadas as considerações sobre a animação em si, em especial a dessincronia entre uma açao e outra.*

Situação 9	Táticas	Adequada? Por quê?	*Não.* *Deve ficar claro que o agente percebe que o aluno está neutro e deve incentivá-lo mostrando a importância da atividade.*
	Comportamentos	Adequada? Por quê?	*Não.* *Não adequada à tática.*
Situação 10	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Não.* *Deve ser mais identificada.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Mantida a consideração sobre o uso da animação de forma mais produtiva.*
Situação 14	Táticas	Adequada? Por quê?	*Sim.* *Achei ótimo que o agente culpabiliza a si próprio e não ao aluno.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 15	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Parcialemnte.* *Talvez pudesse ser mais criativo para chamar à ação.*

Sugestões:

1) Em primeiríssimo lugar, o trabalho é excelente, muito criativo e extremamente adequado à necessidade de busca de elementos complexos para apoiar a pesquisa educacional.
2) Tem limitações relacionadas à tecnologia em si e fica prejudicado quando visto for a do ambiente e do contexto do conteúdo.
3) Tem limitações quanto ao uso da linguagem de animação no diálogo com o ambiente, até por estarem dissociados nesta apresentação.
4) Poderia ter mais interatividade na fala com o aluno. Por exemplo, após o agente explicar algo para o aluno, falar "O que achas?".
5) Sugestão: estudar um pouco da linguagem de mídias.

Entrevistado 5

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista					x
II. Dá uma noção do todo				x	
III. Roupas					x
IV. Cor					x
2. Gênero					
I. Mulher					x
II. Homem					
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)				x	
II. Expressão das emoções: positivas e negativas			x		
III. Adequação das emoções				x	
IV. Postura no momento de interferir				x	
V. As mudanças de postura e face				x	
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela			x		
II. Dinamismo: Movimentos e gestos na Tela				x	
III. Forma de interagir com o aluno				x	
IV. Modo de interferência do Personagem (Táticas)			x		

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

3.II Expressões faciais da Pat poderiam ser mais fortes.

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Achei que a Pat não precisa dizer que tem "muita sabedoria para passar".*
Situação 4	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Acho as falas que lembram sucesso passado mais eficazes para aumentar a uto-eficácia do que elogios do tipo "Como você é iteligente!".*
Situação 5	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 9	Táticas	Adequada? Por quê?	*Acho que as táticas deveriam mostrar desafios ao aluno intrínseco em vez de mostrar as habilidades que ele pode adquirir.*
	Comportamentos	Adequada? Por quê?	*Mudar comportamentos de acordo com a nova tática.*
Situação 10	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Falas longas não são muito adequadas.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*

Situação 14	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 15	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim. Outras sugestões: bater pezinho e assobiar.*

Sugestões:

Entrevistado 6

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista				x	
II. Dá uma noção do todo				x	
III. Roupas				x	
IV. Cor	x				
2. Gênero					
I. Mulher				x	
II. Homem					
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)			x		
II. Expressão das emoções: positivas e negativas				x	
III. Adequação das emoções			x		
IV. Postura no momento de interferir				x	
V. As mudanças de postura e face					x
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela				x	
II. Dinamismo: Movimentos e gestos na Tela			x		
III. Forma de interagir com o aluno			x		
IV. Modo de interferência do Personagem (Táticas)				x	

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

1.IV) Cor não favorável a daltônicos.

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim. São saudações dentro do padrão.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.* *Pois tem uma estratégia utilizada convencional. Ficaria melhor numa colaboração com outro agente.*
	Comportamentos	Adequada? Por quê?	*Sim. Devido a simpatia na tentativa de motivar o aprendiz.*
Situação 4	Táticas	Adequada? Por quê?	*Sim. A tentativa é sempre no sentido de motivar o aprendiz a não cair no astracismo.*
	Comportamentos	Adequada? Por quê?	*Sim. Está dentro do padrão de comportamento para motivar um aprendiz.*
Situação 5	Táticas	Adequada? Por quê?	+- *As colocações são bastante acanhadas para adultos, e para os adolescentes seriam mais propícias.*
	Comportamentos	Adequada? Por quê?	+- *o comportamento (animação) seria mais voltado para uma faixa etária de adolescente.*
Situação 7	Táticas	Adequada? Por quê?	+- *As táticas estão bastante primário.*
	Comportamentos	Adequada? Por quê?	+- *O comportamento é muito infantil.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.* *A estratégia está bem colocada dentro de uma categoria de alunos.*
	Comportamentos	Adequada? Por quê?	*Sim.* *A animação está bem contextualizada.*
Situação 9	Táticas	Adequada? Por quê?	*Sim.* *Estrategicamente tem pontos positivos para motivar o aluno.*
	Comportamentos	Adequada? Por quê?	*Sim.* *As animações estão dentro do contexto.*

Situação 10	Táticas	Adequada? Por quê?	*Sim.* *Mas teria que apresentar um pouco mais de ênfase na motivação.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Pois a animação está dentro do contexto.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.* *Está dentro do contexto.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Mas está faltando + opções de comportamentos verbais.*
Situação 14	Táticas	Adequada? Por quê?	*Sim.* *Apresenta uma forma de estratégia para estreitar relacionamentos.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 15	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.* *A colocação é bastante sutil.*

Sugestões:

1) Para todas as falas:tonalidade e ritmo das falas estão voltados para estrangeiros orientais falando português [devido a voz sintética]. Desta maneira, a personagem poderia ter uma aparência oriental para estar mais de acordo com a fala.

Entrevistado 7

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista				x	
II. Dá uma noção do todo				x	
III. Roupas					x
IV. Cor					x
2. Gênero					
I. Mulher				x	
II. Homem				x	
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)				x	
II. Expressão das emoções: positivas e negativas				x	
III. Adequação das emoções				x	
IV. Postura no momento de interferir				x	
V. As mudanças de postura e face				x	
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela					x
II. Dinamismo: Movimentos e gestos na Tela					x
III. Forma de interagir com o aluno				x	
IV. Modo de interferência do Personagem (Táticas)				x	

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.* *Construtiva.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Criativos por apresentar encenações.*
Situação 4	Táticas	Adequada? Por quê?	*Sim.* *Motivadora.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 5	Táticas	Adequada? Por quê?	*Sim.* *Reforço e esclarecimento.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 8	Táticas	Adequada? Por quê?	*Razoável.* *CV*: Poderia apresentar pensamentos motivadores mais variados.* *CF*: Não precisaria sempre apresentar uma reação criativa para não ficar cansativo e previsível.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 9	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 10	Táticas	Adequada? Por quê?	*Razoável.* *Apresentou a mesma resposta de situações anteriores. Pode desmotivar o uso.*
	Comportamentos	Adequada? Por quê?	*Razoável.* *Idem.* *CV*: O discurso deve ser adequado em função da tática escolhida.*

Situação 11	Táticas	Adequada? Por quê?	*Sim.* *Apresenta uma dica e cria novos horizontes.*
	Comportamentos	Adequada? Por quê?	*Sim.* *CV: Quando uma frase for utilizada pela segunda vez seria mais interessante que o personagem afirmasse que aquilo já foi falado.*
Situação 14	Táticas	Adequada? Por quê?	*Sim.* *Pede desculpas.*
	Comportamentos	Adequada? Por quê?	*Sim (muito bom!).*
Situação 15	Táticas	Adequada? Por quê?	*Sim.* *Chama o aluno.*
	Comportamentos	Adequada? Por quê?	*Sim.* *CV*: Poderia se optar por apresentar o texto ou a voz ou ambos simulataneamente.*

Sugestões:

1) *Sintetizador de voz lembra um japonês.*
2) **CV = comportamento verbal (fala) e CF (comportamento físico) = as animações físicas do agente.*

Entrevistado 8

Parte I - Validação da Aparência do Personagem

Índice de satisfação em relação às características do personagem

Para cada característica, marque um 'X' indicando o quanto satisfatória ela é.

Características do Personagem	Muito Insatisfatório	Insatisfatório	Regular	Satisfatório	Muito Satisfatório
1. Apresentação do Personagem					
I. Realista				x	
II. Dá uma noção do todo				x	
III. Roupas				x	
IV. Cor			x		
2. Gênero					
I. Mulher				*	
II. Homem					
3. Expressão Facial e Comunicação					
I. Expressão e Comunicação (no sentido de reagir às ações do aluno)			x		
II. Expressão das emoções: positivas e negativas				x	
III. Adequação das emoções			x		
IV. Postura no momento de interferir			x		
V. As mudanças de postura e face				x	
4. Comportamento do Personagem na tela					
I. Tempo de Permanência na tela				x	
II. Dinamismo: Movimentos e gestos na Tela				x	
III. Forma de interagir com o aluno				x	
IV. Modo de interferência do Personagem (Táticas)			x		

Comentários (caso tenha considerado algum item insatisfatório explique aqui o porquê):

** Seria interessante pensar em uma imagem que não priorise a questão de gênero.*

Parte II – Questionário para Validação das Táticas Afetivas

Para cada situação, responda se você acredita que os comportamentos do agente são adequados em relação ao objetivo das táticas. Lembre-se que as táticas visam promover no aluno emoções que sejam mais positivas para a aprendizagem, bem como motivá-lo e encorajá-lo. Assim, as táticas devem ser avaliadas de acordo com este objetivo.

Situação 1	Táticas	Adequada? Por quê?	
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 2	Táticas	Adequada? Por quê?	*Sim.* *Tenho dúvidas quanto ao responder às necessidades intrínsecas do aluno.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 4	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Penso que seria importante procurar comportamentos que promovam a auto-estima.*
Situação 5	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 7	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 8	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 9	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim. Mas o discurso deve ser adequado.*
Situação 10	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*
Situação 11	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Falto algo. Me pareceu incompleta.*
Situação 14	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.* *Idem situação 11.*

Situação 15	Táticas	Adequada? Por quê?	*Sim.*
	Comportamentos	Adequada? Por quê?	*Sim.*

Sugestões:

1) Sintetizador de voz lembra um japonês.

*2) *CV = comportamento verbal (fala) e CF (comportamento físico) = as animações físicas do agente.*

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