Chapter 8
E-Learning through Gaming: Unfolding Children’s Negotiation Skills

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ABSTRACT
A generic theoretical framework on teaching children to negotiate is presented, founded on Piaget’s child development and Thompson and Hastie’s negotiation theories and validated through an experiment. The framework was implemented as CLIPS knowledge base, the back-end of an Intelligent Tutoring Agent (ITA). Negotiation skills were assessed through an online JAVA implementation of the board game Settlers of Catan (SoC). The CLIPS knowledge base was connected by JCLIPS to SoC. The ITA was thoroughly tested and found to be robust, with an excellent multithread handling. After installing a client, SoC can be played over Internet against other artificial or/and human players. The integrated ITA helps children to improve their negotiation skills and helps science to improve the theoretical framework, which makes it unique in its kind.

Tell me and I forget. Show me and I remember. Involve me and I understand. -- Old Chinese Proverb

INTRODUCTION
Almost half a century ago, Roberts & Sutton-Smith (1962) started their influential paper “Child Training and Game Involvement” with: “Games are systemic culture patterns which are distinctive, ancient, and widespread...” (Roberts & Sutton-Smith, 1962). In their paper, they explain that games are of all times and places. Moreover, they illustrate the importance of games for our development both as individuals and as society. The statements of Roberts & Sutton-Smith can be considered as a specific instantiation of the old Chinese proverb shown above.

With the rise of the computer, a new type of games was given birth. With the increasing availability and speed of Internet, gaming over Internet evolved rapidly. Similar to traditional (e.g., board)
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In this paper, an intelligent tutoring system (ITS) is introduced that facilitates e-learning through gaming. Such a system should be able to provide individualized instruction, while dynamically adapting to the level of knowledge, intelligence, and needs of individual students. Compared to traditional teaching scenarios, an ITS has various advantages; e.g., it is always available, is non-judgmental, and provides tailored feedback (Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008).

ITSs are developed for a range of purposes; e.g., military (Doesburg, Heuvelink, & van den Broek, 2005). This research deviates from most other research on two aspects: 1) it focuses on a rather fixed age span and 2) its topic: learning negotiation skills. Where other researchers have also focused on specific target groups, in most cases the students were adult or adolescent, we focus on children with the age of 8–12. Negotiation processes are of interest to a range of settings and, consequently, have been studied from a range of perspectives. However, the combination of these two aspects has not been made so far. This, while also children negotiate with both other children and with their parents.

With the aim to train children in negotiating using an e-learning environment, a game was sought that could be utilized for this purpose. The popular board game Settlers of Catan (SoC) was chosen; Table 1 provides a brief description of the game. The use of SoC has another advantage: an open source JAVA implementation of the game was available. Consequently, not the complete game including all its rules had to be implemented.

This chapter introduces an Intelligent Tutoring Agent (ITA) that helps children understand the negotiation processes through playing SoC. It is connected to the open source implementation of SoC. After providing some background information on Games in Education and ITSs, the paper describes the complete process of development of the ITA. It starts with a new theoretical framework on negotiation processes with children, which is founded on 1) Piaget’s theory of child development and 2) adult negotiation strategies, as will be described in the section ‘Theoretical framework’. Next, the validation of this theoretical framework is described. The development of the ITA itself is described in the section ‘Design and implementation’. Next, the testing of the ITA is described in the section ‘The ITA in practice’. The paper ends with a Discussion in which we reflect upon the work presented.

GAMES IN EDUCATION

In order to explain the usefulness of games for education, let us start with a definition of a game. Salen and Zimmerman (2004) define a game as: ‘A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.’ (p. 80). This definition contains a number of important elements that need further clarification. We explain these elements in line with the work of Salen and Zimmerman (2004). A system is a set of parts that interrelate to form a complex whole. All systems have four common elements: objects, attributes, internal relationships and an environment. Systems can manifest itself in different ways; e.g., a math-

<table>
<thead>
<tr>
<th>Table 1. Short description of the Settlers of Catan board game, taken from the Mayfair website: <a href="http://www.mayfairgames.com/">http://www.mayfairgames.com/</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Players are recent immigrants to the newly populated island of Catan. Expand your colony through the building of settlements, roads, and villages by harvesting commodities from the land around you. Trade sheep, lumber, bricks and grain for a settlement, bricks and wood for a road, or try to complete other combinations for more advanced buildings, services and specials. Trade with other players, or at local seaports to get resources you might lack. The first player to achieve 10 points from a combination of roads, settlements, and special cards wins.</td>
</tr>
</tbody>
</table>
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tematical system, a social system. A game has to be played by one or more players; they interact with the system to experience the play of the game. Games are artificial; they are separate from the real world. They occur in the real world, but they themselves are not real, artificiality is one of the defining features of a game. A game always contains an element of conflict or contest. This can manifest itself in different ways, there can be cooperation between players, or there can be competition between them, there can be conflict between players or conflict between a player and the system, but there is always an element of conflict. A crucial part of a game is made up by its rules. They provide the structure of the game, by (de)limiting the possibilities within the game. At the end of the game, a player has won or lost, or a numerical score can be given: its quantifiable outcome, which distinguishes games from more informal forms of play.

The sheer amount of different kind of games shows the importance of games in society. There are for instance games that are played outside with friends (e.g., hide and seek, hopscotch, marbles), official team games / sports (e.g., soccer, baseball, basketball), puzzles and riddles, digital games, etc. In the last decades, the interest in computer games has increased dramatically, and its potential for educational purposes has been duly noted. As indicated by Salen and Zimmerman (2004), there are four special traits that distinguish computer games from regular games. First, computer games have immediate but narrow interactivity. One of the most compelling qualities about digital games is that they provide immediate feedback, offering the player real-time game play. Though most people think that the interactivity of digital games is very broad, it is in fact, very limited. The user has only a (small) set of options from which to choose. Second, digital games manipulate information, as becomes apparent when studying them from an information system perspective. Everything in the game, audio, graphics, and even the program code itself, is information and can be manipulated. Third, a digital game can be seen as an automated complex system. Hence, things that are impossible in “regular” games, because they are too complex, become possible. Fourth and last, digital games are able to utilize networked communication and consequently can facilitate communication between distant players; e.g., players of the game World of Warcraft1 can play the game together, even when on different sides of the continent.

Games may be important to society and are often associated with children and childhood, but are children able to understand games? In particular, games as they are defined by Salen and Zimmerman (2004)? According to Gobet, Voogt, and Retschitzki (2004): “children understand the concept of rules [...] at about 6 years of age, even if they sometimes forget specific rules or change them during play. They also understand the concepts of winning and losing. But they only apply rules consistently [...] at 11 or 12 years of age.” (p.139). They also state that there exists “an association between level of games played by children and their presumed level of cognitive development based on their age.” (p. 140). Hence, games can be used in education from the age of 6 but their difficulty has to be tailored to the mental development of the children (from ages 6 to 15). Coleman (1967) poses that children do not learn by being taught, but by experiencing the consequences of their actions, as is facilitated through using games in education. Games have i) an attention-focusing quality, which enriches the depth of involvement and ii) students experience the consequences of their actions in games with no teacher to blame in the case of failure, as their role is diminished to that of judge and jury.

For educational purposes, games are also interesting because they are challenging, which is defined as that: “an activity should have a goal, whose outcome is uncertain.” (Malone, 1983)(p. 241). This is confirmed by Salen and Zimmerman (2004): “Uncertainty is a key component of every game. If a game is completely predetermined, the
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players actions will not have an impact on the outcome of the game and meaningful play will be impossible.” (p. 189). This all makes games very useful for educational purposes.

Despite all their advantages, computer games on their own can hardly be used for educational purposes, since didactic functionality is missing (Leutner, 1993). There is a trade-off between learning to play the game and acquiring the intended skills or domain knowledge. Students that play games without instructional support learn to play the game, but acquire only limited domain-specific concepts, facts, rules, and principles, where students that play games with instructional support learn to play the game only to a limited degree, but do acquire a high degree of domain knowledge (Conati & Zhao, 2004; Leutner, 1993). This holds for different age groups and educational standards (Leutner, 1993).

To improve the efficiency and effectiveness of instruction using games, instructional support should be embedded. The latter can be achieved through, i) provide essentially unlimited examples and problems, ii) facilitate visualization and manipulation; link visualization with symbolic representations, iii) provide adaptive sequencing and feedback, and iv) provide sustained contextualization in a meaningful and engaging application (Klawe, 1998). When adding this functionality to games, a game is transformed into a, so called, ITS, as will be described in the next section.

INTELLIGENT TUTORING SYSTEMS (ITS)

“An Intelligent Tutoring System allows for errors to occur and provides the student with feedback and associated remedial action” (Siemer & Angelides, 1995, p. 1377). An ITS can deliver personal (tailored) instruction to a student, taking his or her progress into account (Beck & Woolf, 2000).

An ITS should be able to give personal instruction in an automatic and cost effective manner, mostly within a highly interactive learning environment. An ITS assesses the actions of the learner and develops a model of the learners knowledge, skills, and expertise. Based on this model, it can offer explanations, hints, examples, and demonstrations (Craighead, 2008; Gulz & Haake, 2006; McQuiggan, Mott, & Lester, 2008; Romero & Ventura, 2007; van Rosmalen, et al., 2008; Wang, Johnson, Mayer, Rizzo, Shaw, & Collins, 2008; Keleş, Ocak, & Gürçü, 2009).

An ITS consists of four knowledge modules: the domain knowledge module, the user or student model, the pedagogical module, and the communication module (Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008).

The domain knowledge module includes an explicit representation of domain-specific knowledge. It contains a computer representation of the knowledge that has been elicited from domain experts by knowledge engineers. The knowledge in this model is compared to the student’s actions to determine what the student’s state of knowledge is.

The student model contains information on student. It includes a model of the current knowledge of the student; i.e., which concepts does he understand, which can be understood with a minimum of guidance, and which are out of reach (for the moment). To model the student either single or hybrid formalisms can be used. Single formalisms are based on one theory; e.g., symbolic rules (as used in this project), case-based reasoning, neural networks. Hybrid formalisms combine multiple formalisms.

The pedagogical module contains teaching expertise; i.e., how to present the information in such a way that it aids the student in learning.

The communication module is responsible for all communication with the learner.

Generally, there are three types of users of an ITS: domain experts, who provide knowledge concerning the domain of the ITS, knowledge engineers, who manage the development of the ITS, and learners, who are the end-users of the ITS. Each of these users pose their own requirements
on the system. For a more detailed description of these requirements, see the article by Hatzi-
lygeroudis & Prentzas (2004). In this research, the domain expert and knowledge engineer are
embodied by the researcher and the learners or end-users are children, who will be guided while
playing the game.

THEORETICAL FRAMEWORK

The amount of research done on either children and board games or children and negotiation is
very limited (Gobet, Voogt, & Retschitzki, 2004). Therefore, we choose to develop a new theoreti-
cal framework founded on two theories: 1) the child development theory of Piaget (Lourenço
& Machado, 1996) and 2) Thompson & Hastie’s (1990) theory on negotiation between adults. The
combination of the latter theories enabled us to determine the initial level of understanding of
the negotiation process in children. We will now first briefly introduce both theories and derive
some general cognitive notions. Subsequently, the general cognitive notions are related to the
stages Piaget distinguishes. Knowledge gathered through the latter three steps is merged to a new
theoretical framework.

Piaget’s Stage Theory

Although various theories on child development have challenged Piaget’s stage theory, his work
is still and by far the most influential. Moreover, much of the criticism on Piaget’s work is founded
on misconceptions and misinterpretations of his work, as is shown by Lourenço and Machado
(1996). They defend Piaget’s work through rejecting 10 common criticisms on it. This article also
provides an excellent overview of both Piaget’s most important works and those of others who
either agree or disagree with Piaget. More than anything else, this shows that although Piaget’s
theory is well known its interpretation is a source for discussion and child development is general
is a challenging topic.

Piaget defined four stages, which make up his Stage Theory; e.g., see Lourenço and Machado
(1996) for an overview. These four stages are also called periods and are provided with an indication
of the period in life they apply to.

In the sensorimotor period (birth to 2 years), children look at the world around them in terms of
physical, overt actions on that world. They move from simple reflexes to organized behavior in
six sub stages: modification of reflexes, primary circular reactions, secondary circular reactions,
coordination of secondary schemes, tertiary circular reactions, and invention of new means
through mental combinations.

The preoperational period (2-7 years) is mainly defined by: Egocentrism: children a) do not have a
complete differentiation between themselves and the world and b) have the tendency to look at the
world in terms of the self. This makes it difficult to take another person’s view; Rigidity of thought:
a) centration, the tendency to focus on one salient feature of an object or event and ignore the other
features and b) the tendency to focus on states rather than on transformations linking the states
emerges; and Semi logical reasoning: thought is often linked together in a loose way instead of in
a logical relationship. Limited social cognition entail that social development undergoes a similar
process as cognitive development.

In the concrete operational period (7-11 years), the regulations, functions, and identities turn into
operations as they become more complete, differentiated, quantitative, and stable. With the ability
to use operations, the child’s representations are no longer isolated, rigid, or simply juxtaposed.
In the formal operational period (11-15 years), adolescents carry the concrete operations one step
further: they generate hypotheses that follow the results of concrete operations. With that, thought
has become truly logical, abstract, and hypothetical, which is often called the scientific method.
Children generate hypotheses and test them against
Six Judgments with Negotiation

An excellent up-to-date book on negotiating is that of Saner (2008). This book has both a scientific merit and is of high value in practice. Moreover, it explores the process of negotiating from a generic perspective, which is illustrated by a range of cases. Although the book has an extensive bibliography, it is far from exhaustive. More than anything else, this illustrates the vast amount of research that has been done in the field of negotiating.

An exhaustive overview of theories on negotiation is beyond the scope of this chapter. For the interested reader, we refer to Saner (2008) and Thompson and Hastie (1990), which are complementary and as such make a good pair for an overview on the topic.

We have chosen for the theory of Thompson and Hastie (1990) on negotiating. This choice is founded on two reasons: 1) it is explicit, which enables its use for a rule-based system, such as ours and 2) it maps reasonably well on Piaget's stage theory (Lourenço & Machado, 1996).

According to Thompson and Hastie (1990), six judgments are of importance when negotiating: 1) Judgments of the Other Party; e.g., the other party's strength or firmness, competitiveness, and fairness; 2) Judgments of the Self: the negotiator's own tastes, values, and preferences; 3) Interpersonal Judgments of Utilities: the negotiator's perception of his own utilities and those utilities of the other party and the amount of resources that will be negotiated about; 4) Judgments of Offers and Counter-offers: predictions about future moves; e.g., if one sees that the other really wants a resource, one might expect the next offer to be higher; 5) Judgments of Outcomes: the final outcome of the negotiation, the worth of the solution to the negotiator and the other party as well as the joint payoff for both. This determines the satisfaction of both parties and can influence future negotiations; 6) Judgments of Negotiation Process: the fairness and satisfaction of the whole negotiation process, including the rules, fair play, norms, etc. As is specified through the six judgments, the negotiator makes judgments about the other party, the self, the interpersonal utilities, offers and counter-offers, outcomes and the negotiation process itself.

The six judgments imply the utilization of various cognitive resources throughout the process of negotiating (Thompson & Hastie, 1990). To be able to make judgments about the other party, the negotiator has to be able to imagine what the other party wants and values. For self-reflection, a clear self-image and goal are needed (Saner, 2008). With judging offers and counter-offers, the negotiator requires an image of both himself and the other party and has to be able to hypothesize about the future. Judgments about the outcomes of the negotiation can only be made when the negotiator has a feeling for the utility (value) for himself, but also for the other party. In order to make judgments about the negotiation process itself, the negotiator has to know about the rules, about fairness, and about norms surrounding the negotiation (Saner, 2008). Though this last part is more of a goal in this research. Another important ability needed when negotiating is to keep one's goal in mind, and not get sidetracked by less important dimensions of the negotiation. The judgments give rise to the following cognitive aspects needed for negotiation: Feeling for numbers, fairness, utility for self, and utility of other party as well as the ability to keep one's goal(s) in mind and to predict/hypothesize.

A Theory on Negotiation Processes with Children

The general cognitive aspects were determined taking in consideration they should be: 1) based on the judgments put forward by Thompson and
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Table 2. Overview of the Cognitive aspects and the judgments on negotiation (Thompson & Hastie, 1990) they are based upon

<table>
<thead>
<tr>
<th>Cognitive Aspect</th>
<th>Judgment(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling for numbers</td>
<td>4</td>
</tr>
<tr>
<td>Feeling for fairness</td>
<td></td>
</tr>
<tr>
<td>Feeling for utility to self</td>
<td>2, 3, 4, 5</td>
</tr>
<tr>
<td>Feeling for utility to other party</td>
<td>1, 3, 4, 5</td>
</tr>
<tr>
<td>Ability to keep one's goal in mind</td>
<td>4, 5</td>
</tr>
<tr>
<td>Ability to hypothesize</td>
<td></td>
</tr>
</tbody>
</table>

Hastie (1990), 2) applicable on the domain of Settlers of Catan and be generalizable to a broader domain, and 3) able to match with the stage theory of child development to tailor these aspects to children. The general cognitive aspects and the judgments they are based upon are summarized in Table 2.

The fourth and last step in setting up the theoretical framework was to denote for each stage defined by Piaget (Lourenço & Machado, 1996), whether or not each of the general cognitive aspects is already present in children in that stage of development. Let us illustrate the latter by sketching the decision process for the Feeling for utility to other party aspect. In the pre-operational stage, this aspect is not yet developed since children have a limited social cognition and are egocentric. Children in this stage have problems taking another’s viewpoint; e.g., when a child is looking at a picture in a book and draws his mother’s attention to this picture, it does not realize that the mother is not able to see the picture when she is sitting opposite the child. From this, one can deduce that they will not be able to determine the utility of a negotiation to another party. In the concrete operational stage, the egocentrism fades away and children’s limited social cognition is improved, enabling them to make judgments about utility to another by the end of the concrete operational stage. Once a certain level of development has been reached there will be no regression; therefore, once a cognitive aspect has been developed, it will not be lost. This explains why the Feeling for utility to other is also developed in the formal operational stage.

Table 3 summarizes the results of mapping the cognitive aspects to Piaget’s stage theory. This table denotes that in the concrete operational stage, most of the cognitive aspects are developed. From these results, the target group age could be determined. According to Piaget (Lourenço & Machado, 1996), the developments are only complete at the end of each stage. He also showed, using the containment experiment (Lourenço & Machado, 1996), that children are not able to learn a certain task when they have not yet reached the required level of development. Keeping this in mind, the target group age was determined to be around 10 years of age. The mapping of the aspects to Piaget’s theory was confirmed by a semi-experiment, in which three 10-year-old children played a game of Settlers of

Table 3. Overview of the combination of the Piaget’s Stage Theory (Lourenço & Machado, 1996) and the cognitive aspects derived from the judgments on negotiation (Thompson & Hastie, 1990)

<table>
<thead>
<tr>
<th>Aspect / Stage</th>
<th>Pre-operational</th>
<th>Concrete operational</th>
<th>Formal operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling for numbers</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for fairness</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for utility to self</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for utility to other party</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ability to keep one’s goal in mind</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ability to hypothesize</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Catan. This is also the lower age limit set by the makers of Settlers of Catan.

The findings presented in Table 3 are also confirmed by Gobet, Voogt, & Retschitzki (2004) who states: “Parker argues that children understand the concept of rules... at about 6 years of age, even if they sometimes forget specific rules or change them during play. They also understand the concepts of winning and losing. But they only apply rules consistently... at 11 or 12 years of age.” (p.139) and “Sutton-Smith... reports an association between level of games played by children and their presumed level of cognitive development based on their age.” (p. 140).

**VALIDATION OF THE THEORETICAL FRAMEWORK**

The theoretical framework, described in the previous section, is based on two theories. The next step is to validate this framework in practice, as is done by a validation experiment. The experiment utilized a Likert scale questionnaire (Likert, 1932). In the first subsection, the pilot study that was executed to determine the size of the intervals for the Likert scale is described. The actual validation experiment is described in second (and last) subsection.

**Pilot**

A questionnaire was developed to be able to determine whether or not a certain cognitive aspect has evolved. For each cognitive aspect, a number of questions were posed that would determine whether or not the aspect has been developed. These questions were specific to the context of Settlers of Catan.

An overview of all questions in the questionnaire is provided in Table 4. The answers could be provided through a Likert scale that denoted three intervals. The size of these intervals was determined in this pilot study.

**Table 4. Questionnaire used in the validation of the theoretical framework.** For each of the cognitive aspects, there are a number of questions that can be asked to poll their development. The questions in italics were answered by the experimenter in the pilot study and the other questions were answered by the subjects.

<table>
<thead>
<tr>
<th>General considerations:</th>
<th>Feeling for numbers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many times does he stray from the rules?</td>
<td>How often does the subject offer a ratio to a player that he can also trade with a bank or port?</td>
</tr>
<tr>
<td>In the beginning (First 20 minutes)?</td>
<td>Does the subject understand probabilities? Does he choose places with high probability (5, 6, 8, and 9)?</td>
</tr>
<tr>
<td>Middle (middle 30 minutes)?</td>
<td>Feeling for fairness:</td>
</tr>
<tr>
<td>At the end (Last 20 minutes)?</td>
<td>How often does the subject try to close an unfair (asking more than giving) deal?</td>
</tr>
<tr>
<td>Which rules, simple or complex ones?</td>
<td>How often does the subject accept an unfair deal?</td>
</tr>
<tr>
<td>How many times does he have to ask for certain rules?</td>
<td>Feeling for utility to self:</td>
</tr>
<tr>
<td>In the beginning (First 20 minutes)?</td>
<td>How often does the subject trade resources that he needs himself?</td>
</tr>
<tr>
<td>Middle (middle 30 minutes)?</td>
<td>Feeling for utility to other:</td>
</tr>
<tr>
<td>At the end (Last 20 minutes)?</td>
<td>How often does the subject offer to someone who is about to win?</td>
</tr>
<tr>
<td>Which rules, simple or complex ones?</td>
<td>How often does the subject accept offer from someone who is about to win?</td>
</tr>
<tr>
<td>Ability to hypothesize:</td>
<td>Ability to hypothesize:</td>
</tr>
<tr>
<td>Does he pick strategic starting places?</td>
<td>Does he pick strategic starting places?</td>
</tr>
<tr>
<td>Does the subject form an consequent strategy (city building, longest road, monopoly, etc.)?</td>
<td></td>
</tr>
</tbody>
</table>

**Method**

Three university students (one male, two females) participated in the pilot experiment on voluntarily basis. They were between 21 and 25 years old. The experiment was performed in a natural setting; i.e., at on of the student’s homes. The questionnaire as depicted in Table 4, was divided into two parts. One part that was answered by the experimenter (marked with italics). The other part was answered by the subjects. With that, the factor of awareness was taken into account. For some questions, the
action would not occur if the subject is aware of it; e.g., trade with player instead of bank. These questions were allotted to the experimenter. Other questions are difficult for the experimenter to determine; e.g., conscious strategy changes. These questions were allotted to the subject.

Summarizing, the subjects were asked to keep track on how often they performed certain key actions; e.g., changed their overall strategy or negotiate with an almost winning player. In parallel, the experimenter kept track on how often players did violate the rules, how often they traded for resources with players instead of with the bank or port, etc.

Results

The results of the pilot experiment are given in Table 5 and Table 6. The experimenter observed that all students abode the rules: they did not trade for a resource with a player while they could also trade with the bank. In addition, each player chose strategic starting places and no unfair deals were made.

Summarizing, the questionnaires the subjects filled in indicated the following:

- The number of questions concerning the rules dropped while playing the game;
- Multiple strategy changes were made, some as a reaction to actions of opponents;
- Trades were more for required resources;
- No (conscious) decisions were made not to trade;
- No trades with winning players were initiated;
- Offers of winning players were accepted.

Discussion

The questionnaire was updated with the three item Likert scales for a number of questions. It was assumed that the score of the students would be the ideal case; i.e., when all cognitive aspects are fully developed. These scores determined the range of the Likert scales. An example of this can be seen in Table 7.

Table 5. Results of the pilot study, questions answered by the experimenter

<table>
<thead>
<tr>
<th>Question</th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stray from rules beginning/middle/end</td>
<td>0/0/0</td>
<td>0/0/0</td>
<td>0/0/0</td>
</tr>
<tr>
<td>Trade with player instead of bank</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Choose strategic starting places</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of unfair offers</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of unfair accepts</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6. Results of the pilot study, questions answered by the subjects

<table>
<thead>
<tr>
<th>Question</th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask for rules beginning/middle/end</td>
<td>8/5/1</td>
<td>4/0/0</td>
<td>1/0/2</td>
</tr>
<tr>
<td>Change overall strategy</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>How often determined by opponent</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Trade for resources needed now</td>
<td>12</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Not decide to trade</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Initiate trade with winning player</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Respond to offer from winning player</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7. Example of a question used in the experiment. Here, the Likert scales have been added. The expected interval when the cognitive aspects if fully developed it marked with an asterisk.

- How often does the subject offer a ratio to a player that he can also trade with a bank or port?
  - 0 - 5 *
  - 5 - 10
  - 10
- Does the subject understand probabilities? Does he choose places with high probability (5, 6, 8, and 9)? (YES)
Please note that subject one, who won the game, has higher values for all questions than the other subjects. The answers she gave on the questions possibly indicate the use of more fruitful strategies compared to the other two players. However, the higher values could also be attributed to her paying more attention to the questionnaire, due to her mathematical background. Moreover, it could be that the other players performed the key events as much as subject one, but in the heat of the game forgot to write it down.

Validation Experiment

The aim of the experiment was to validate the newly developed theoretical framework. The experiment should determine whether children (10-13 years) have effectively developed the cognitive abilities, as described in the framework. To test this, the questionnaire shown in Table 4 was used.

Method

In the experiment, the board game Settlers of Catan was played with three 10-year-old boys, who already knew each other. Two of the boys were in group six, and one in group seven of the Dutch education system. The research was explained to the boys and they were asked whether or not they were willing to participate. In parallel, their parents were given an informed consent, which they signed.

The game was played in a natural setting; i.e., at one of the children’s homes. This eliminated the period where the children have to acquaint themselves. The game was recorded on video of which a transcription was made afterward. Based on the transcription, the actions of the children were identified. A frame of the video is shown in Figure 1 to give an idea of the experimental situation. The questionnaire was used in the analysis of the game, where the experimenter tallied the occurrences of the events of interest.

Results

The complete results of the validation experiment are given in Table 8. This table shows all the questions in the questionnaire and the score of each of the subjects. For the questions with a Likert scale, the intervals are indicated with ”Low”, ”Middle”, and ”High”. Whether or not a cognitive ability was developed by a player was determined by checking whether the answer found in the experiment is the same answer that would be expected if the aspect has been developed (indicated in the ”Desired” column). The results of this analysis are summarized in Table 9. As can be seen, all players have developed all cognitive aspects except for the ability to hypothesize, which has only been developed by one subject. One of the children made the following remark to a fellow player: ”I will give you a tip, put it at what you want, that one will probably have it.”, where ‘it’ denotes the robber, the piece that allows a player to steal from another (see Table 1) and ‘what’ refers to a resource tile, showing an understanding of probabilities. Another observation was that one of the players showed an obvious strategy (largest army), by buying a large number of development cards in a row.
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Table 8. Complete results of the validation experiment, sorted by cognitive aspect, where ‘L’, ‘M’, ‘H’, denote the Low, Middle, High Likert intervals

<table>
<thead>
<tr>
<th>Question</th>
<th>Desired</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Aspects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stray from rules beginning/middle/end</td>
<td>L/L/L</td>
<td>L/L/L</td>
<td>L/M/L</td>
<td>L/M/L</td>
</tr>
<tr>
<td>Which rules</td>
<td>Complex</td>
<td>Simple</td>
<td>Both</td>
<td>Both</td>
</tr>
<tr>
<td>Ask for rules beginning/middle/end</td>
<td>L/L/L</td>
<td>M/L/L</td>
<td>M/M/M</td>
<td>L/L/L</td>
</tr>
<tr>
<td>Which rules</td>
<td>Complex</td>
<td>Complex</td>
<td>Complex</td>
<td>Simple</td>
</tr>
<tr>
<td>Feeling for numbers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade with player not bank</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Understand probability</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for fairness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offer unfair deal</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Accept unfair deal</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Feeling for utility to self</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade for resources needed</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Deny trade when resources needed</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for utility to other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offer to winning player</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Accept from winning player</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Ability to hypothesize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pick strategic starting places</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Form strategy</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 9. Overview of the developed cognitive aspects for each of the three subjects in the validation experiment

<table>
<thead>
<tr>
<th>Aspects / Player</th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling for numbers</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for fairness</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for utility to self</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feeling for utility to other</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ability to keep goal in mind</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ability to hypothesize</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Discussion

The children in the experiment show the same cognitive aspects that could be expected from children at the end of the concrete operational period; thus, sustaining the theoretical framework. An advantage of the experiment is that it was done in a natural setting and that the children were familiar with each other, making it easier for the children to forget they are participating in an experiment, which facilitates the natural behavior of the children. Three improvements could be made to enhance the results of the experiment: (i) The game could be played multiple times to determine if the results hold over multiple games. (ii) It could be played with only girls, and a mixture of boys and girls to determine if there is difference between genders. (iii) The age could be more varied over
the interval of 10-13 years old. The experiment could also be performed with children under 10 years of age, to determine whether or not the theoretical framework holds for children that are not at the end of the concrete operational period; e.g., with children between 5 and 7 or children between 7 and 10 years of age.

**DESIGN AND IMPLEMENTATION**

This section describes the development of the Intelligent Tutoring Agent itself. First, a short introduction to JSettlers to which the ITA was added. Next, the design of the agent is discussed and some of the design decisions are highlighted. Last, the actual implementation is documented.

**JSettlers**

JSettlers has been developed by Robert S. Thomas at Northwestern University. It has been designed and implemented using a client/server architecture, this has been done to be able to collect data about games being played at a central location. The JSettlers server can host a number of games and manages all the game state information for each of the games initiated on the server. One or more clients are connected to each game. If there are not enough real players the remaining number of players can be filled by robot clients. The client/server architecture could also facilitate the addition of the ITA to be developed. There are not many operational versions of Settlers of Catan. Another operational version called Pioneers has been found. This program was developed under Linux, and using the C programming language. It is not portable to any other operating system. This was the main reason for choosing JSettlers, which is developed under JAVA and is, therefore, platform independent.

**Design of the Intelligent Tutoring Agent (ITA)**

The ITA was designed as an integrated part of the original JSettlers client. This way, the agent is able to retrieve information about the game through the client. Alternatively, the agent could have been implemented as a stand-alone application; however, then all game information had to be retrieved and interpreted from the JSettlers Server manually.

In the section Intelligent Tutoring Systems, an architecture for ITSs was presented. There are four important components in an ITS: a Domain Knowledge Base, a Student Model, a Pedagogical Module, and a Communication Module. The design of the ITA was based on these four components, as can be seen in the conceptual architecture in Figure 2. The player interacts with JSettlers, the game upon which the ITA is built. JSettlers has a link with the Agent user interface (UI), through which the interface is presented to the user and the actions of the player are communicated to the agent. These actions are passed on to the Strategy DB and the Offer Judge components. The Strategy database (DB) component contains domain information about the possible strategies within Settlers of Catan. The Offer Judge contains domain information about negotiations; e.g., how to recognize an unfair offer or an offer for a trade that could also have been made with the bank. The Strategy DB, communicates its findings to the Strategy Monitor, which maintains information about which strategy the player is or is not employing. The Strategy Monitor relays this information to the Generate Hypotheses component. The Offer Judge relays information about the negotiations to the Generate Hypotheses component. This component then generates hypotheses about the development of the cognitive aspects in the monitored player. These hypotheses are tested in the Test Hypotheses component. When a hypothesis has been judged true, an advice is generated in
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the Generate Advice component. This advice is relayed through the Agent UI and JSettlers to the player. The Check Effect component keeps account of the number of times an aspect has been disproved. This influences the advice generated through the generate and test hypotheses cycle.

Each of these components (see also Figure 2) is explained in more detail below.

Agent UI provides the UI of the agent. It is also the direct link between the ITA and JSettlers and, thus, the only link between the agent and the player. All actions of the player and information

Figure 2. Schematic overview of the design of the ITA. The circles denote the different modules traditionally found in ITS: Communication Module, responsible for all the communication with the user; the Pedagogical Module, responsible for tailoring the information provided to the learner; the Domain Knowledge Module, which contains the information about the domain: Settlers of Catan, Student Model, which contains information about the learner. In boxes the specific sections of the ITA and how they interact with each other.
on the state of the game arrive at the Agent UI, which relays some of this information to the other modules for further processing.

**Strategy DB** receives game information from the Agent UI concerning the placement of game pieces and a buy history. It contains domain information about the possible strategies in Settlers of Catan. For each of these strategies, it also contains information on how it can be determined whether or not a player is employing this strategy. By combining the game information and the knowledge about strategies, it is able to determine which strategy or strategies are employed by the player. In determining these strategies from the game information, it also takes the number of parallel strategies into account; other conditions apply when multiple strategies are employed than when a single strategy is used.

**Offer Judge** receives information about negotiations in the game from the Agent UI. It is able to keep track of all offers that have been made and is able to judge these offers. A judgment could for instance indicate whether a certain offer is fair or not.

**Strategy Monitor** receives information on the strategies detected by the Strategy DB module and compares these to the strategies the player indicated in the interface. The information whether any strategy is being used and whether the indicated strategies match with the detected strategies is passed on to the Generate Hypotheses module.

**Generate Hypotheses** This component receives information from different components about the game and the player, and generates hypotheses about the cognitive aspects of the player. When there is an indication that a certain cognitive aspect may not be fully developed, it generates a hypothesis that states this.

**Test Hypotheses** receives the hypotheses that have been generated by the Generate Hypotheses component and tries to confirm them. This is done by checking whether all conditions to falsify a certain cognitive aspect have been met. If this is the case, the confirmation of this hypothesis is relayed to the Generate Advice module. If not all conditions have been met, nothing happens and the module waits for more game information to become available.

**Generate Advice** This component generates the advice that is presented to the player when the system has detected that one of the cognitive aspects has not been fully developed. This advice is specific to the aspect and depends on how often advice on the same cognitive aspect has been given before. The advice starts out generally and becomes more explicit.

**Check Effect** keeps track of how often a cognitive aspect has been disproved. If an aspect is not falsified again after advice has been given to the player then it can be concluded that the advice had an effect.

The last four modules: Generate Hypotheses, Test Hypotheses, Generate Advice, and Check Effect, together form an expert system architecture for a diagnosis expert system. When choosing an expert system architecture, there are many different model templates that can be used as a basis, or architecture. These model templates vary with the task that needs to be performed; the continuous detection of errors and the reason for them. Schreiber et al. (2000), suggest three models that can be of use in this case: the assessment, diagnosis, and monitoring templates. Of these three models, assessment only takes one point in time into account and monitoring only registers a discrepancy and does not look at the cause of it. Diagnosis does incorporate both these characteristics and is, therefore, applied. See also the Student model in Figure 2.

The rules in the diagnosis modules were designed from global to specific, with the cognitive aspects as starting point. The agent assumes that all the cognitive aspects have been developed and tries to disprove them: First, the system determines whether or not a cognitive aspect needs to be elicited. Next, the system checks whether or not that aspect has been developed by asking a set of questions.
Determining the Symbolic Rules

For each of the six cognitive aspects, questions were defined and, subsequently, converted into symbolic rules. As an example we take the Ability to hypothesize aspect. The first step consists of determining how this aspect manifests itself in the game. For the ability to hypothesize, in other words to think ahead, two actions in the game are of importance. The selection of strategic starting places when setting up the board and the employment of a general game strategy. These were turned into two questions that could be tested when playing, for our example, the questions are given in Table 10. These questions are then transformed into symbolic rules that could disprove the cognitive aspect in question. For our example the resulting symbolic rules are given in Table 11. For each of the conditions in the general rules, more specific, or auxiliary, rules were constructed to determine when these generic conditions were met. An example for the Not using strategy condition is given in Table 12, including rules for two of the six strategies.

Table 10. Example questions used for the cognitive aspect: Ability to hypothesize

| • Does he or she pick strategic starting places? (YES/NO) |
| • Does the subject form a consequent strategy (city building, longest road, monopoly, etc.)? |

Table 12. Example of auxiliary rules used to determine one of the conditions of the generic rules shown in Table 11

| IF ANY Strategy |
| THEN NOT Not using strategy |
| IF More than 2 same resource incomes |
| AND Port of that resource |
| THEN Strategy Monopoly |
| IF Built more than 3 roads in short interval |
| AND Longest road is less than 2 roads away |
| THEN Strategy Road building |

Table 14. Example of how the system determines a specific fact, in this case Offer to player instead of bank, which is used in the rule depicted in Table 15

| Given Negotiation(fromPlayer, toPlayer, giveSet, getSet), |
| IF fromPlayer == monitoredPlayer |
| AND resourceAmount(resources, giveSet) == 4 |
| AND size(getSet) == 1 |
| THEN Offer to player instead of bank |

Table 13. Example questions used to test for the cognitive aspect: Feeling for numbers. This table is identical to Table 7 and is replicated for convenience

| • How often does the subject offer a ratio to a player that he can also trade with a bank or port? |
| ○ 0 - 5 * |
| ○ 5 - 10 |
| ○ 10 |
| • Does the subject understand probabilities? Does he choose places with high probability (5, 6, 8, and 9)? (YES) |

Table 15. Example of how the questions in Table 13 are transformed into symbolic rules used in the expert system

| IF Offer to player instead of bank |
| OR No strategic starting place |
| THEN Hypothesis(NOT feeling for numbers) |
| IF Hypothesis(NOT feeling for numbers) |
| AND Offer to player instead of bank |
| AND No strategic starting place |
| THEN NOT Feeling for numbers |
from the theoretical framework are implemented into the Student model.

Implementation

The ITA has been divided into two packages. One package, developed in JAVA, handles the interaction with the game, the interpretation of game information, and the extraction of user actions from this game information. The other part, representing information about the player has been captured in symbolic rules. These symbolic rules have been implemented in CLIPS (Riley), a symbolic rule language developed by NASA. The JAVA components make up one package (the JAVA Agent package) and the CLIPS components make up the other package (the CLIPS package). A package diagram of the implementation of the system can be found in Figure 3 where the JAVA package can be seen in the middle of the figure. At the top of the figure, the link to the slightly adapted JSettlers client; at the bottom, a more elaborate representation of the Student model is presented, as it is implemented in CLIPS. The KBCommunicator component in the ITA is the only component communicating with the CLIPS package. This communication goes through JCLIPS (Menken). JCLIPS is able to assert and retract facts in the fact base that is shared by all components in the Student model. JCLIPS is also able to start the inference engine of CLIPS that evaluates all the rules in each of the Student model’s components. These rules can assert and retract facts in the fact base, that is observed through JCLIPS by the KBCommunicator, which relays this information back to the relevant JAVA component. Each of the classes in the package diagram are explained in more detail below.

• JAVA client: This package contains the original JSettlers interface with some minor changes that attach the ITA to this package. The adaptations were necessary for the agent to be able to receive important game information. The JAVA client package uses a number of events that indicate actions by players or important game states. Some of these events are now forwarded to the ITA. This package is represented by the box with JSettlers in Figure 3.
  • SOC Agent: This class is an implementation of the Agent UI from Figure 3. It contains the interface of the agent and communicates with the user through a connection with the SOCPlayerClient, which is the standard client that is included in JSettlers. The SOC Agent class uses the SOCStrategyMonitor, SOCOfferJudge, and KBCommunicator classes to handle specific tasks.
  • SOC Strategy Monitor: This class is responsible for handling information about the strategies the user is employing. It is able to determine whether a certain strategy is being used or not and compare this with the strategies that are manually selected by the player from the interface. In order to do this, it utilizes the Strategy Module in the CLIPS package, by communicating with the KBCommunicator. If there is a discrepancy between the deducted strategies and the indicated strategies, the SOC Agent is alerted and a message can be sent to the user. The SOCStrategyMonitor is an implementation of the Strategy DB in Figure 3.
  • SOC Offer Judge: The SOC Offer Judge is an implementation of the Offer Judge from Figure 3, and is responsible for monitoring all the negotiations that the player is engaged in.
  • KB Communicator: The KB Communicator is responsible for all the communication between the JAVA agent package and the CLIPS package. This class contains methods that are specific for the communication between the classes in the two packages. This class was added to keep application specific functions separate from JCLIPS.
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Figure 3. Class diagram of the implementation of the ITA. It is subdivided into three packages: JAVA Client, JAVA agent, CLIPS. Each of these packages contains a number of communicating classes. The lines indicate with which other classes a class communicates. Links between packages are indicated with dashed lines.

- **JCLIPS**: functions as a bridge (Gamma, Helm, Johnson, & Vlissides, 1995) between JAVA and CLIPS. It is able to manipulate the CLIPS fact base and control the inference engine. JCLIPS is written in JAVA with native methods written in C that control CLIPS.
- **Inference Engine**: This class corresponds to the inference engine in CLIPS. This inference engine interprets the symbolic rules in each of the components in combination with the facts in the fact base. The inference engine is incorporated in a CLIPS distribution.
- **Fact Base**: This class represents the fact base that is incorporated in CLIPS. This fact base contains all the facts that are used by the symbolic rules in the different components.
- **Strategy Module**: This class contains the symbolic rules that pertain to the monitoring of the strategies employed by a player.
It corresponds to the Strategy Monitor in Figure 3.

- **Generate Hypotheses:** This class holds the symbolic rules that generate the hypotheses concerning the development of the cognitive aspects.
- **Test Hypotheses:** The symbolic rules that test the hypotheses from the last component are stored in the Test Hypotheses class.
- **Generate Advice:** This class generates the advice that is presented to the player. This is also done with symbolic rules. Because of this, the generate advice class is contained within the CLIPS package and not in the JAVA agent package where it would be expected when looking at the conceptual architecture.
- **Check Effect:** This class contains the symbolic rules that determine whether a certain

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**Figure 4.** The different UI screens of the ITA: On the left hand, the main interface. The green colored screen at the bottom is the status screen of the ITA. It is used to communicate which strategies are being followed and to give tips to the user based on this information. On the right: Top: Offer statistics, indicates how many offers have made and how many accepted and rejected. Middle: Cognitive Aspects, shows which of the cognitive aspects are developed according to the ITA. Bottom: Message pop up, shows a text message to the user containing guidance.
cognitive aspect has been disproved more than once, i.e., whether or not the generated advice had an effect on the player.

In order to generate transparent programming code, the domain knowledge base was implemented in JAVA.

The interface is an added panel to the JSettlers interface, which is shown in Figure 4. This panel contains an area where the user can communicate the strategies he is using to the agent. It contains a button that opens a new window that contains statistical information on the negotiation history. It also contains an area where tips to the user can be displayed. Tips are only displayed inside the panel itself. Changes in the cognitive aspects detected by the agent, and the corresponding text messages, are provided to the user inside a dialog window. These windows pop-up at the end of a turn. The agent collects messages until the user ends his turn and they are displayed then.

THE ITA IN PRACTICE

Throughout its developed, the ITA has been iteratively tested. Each of the symbolic rules used in the CLIPS package were first tested by manually asserting the required facts in the fact base and running the inference engine. In such way we were able to determine whether or not the required behavior emerged. When this was the case, the CLIPS package was connected to the JAVA agent. Next, JSettlers was played in such a way what the circumstances for each symbolic rule were satisfied. Debugging continued until all symbolic rules functioned correctly under the required game circumstances. Through this iterative testing procedure, the following implementation issues were solved:

The first version of the Test Hypotheses and Generate Hypotheses modules were initially only able to disprove an aspect once. This would not enable the Generate Advice module to offer different messages each time a mistake was made again. To enable this feature, an aspect has be able to be disproved more than once. In the first version, an aspect was a condition for a rule that disproved it, but this means that if it is disproved, the rule will not be activated again. To be able to disprove the aspect more than once, the aspect was removed from the condition list. Consequently, it was needed to keep track of the occurrences of each action and to remember the occurrence of the action when the facts are retracted and only regenerate when the occurrence changes. For example, when the Feeling for fairness was disproved the first time, the occurrence of Offer unfair deal was 2 and the occurrence of Accept unfair deal was 1. When both occurrences have changed, only then may be concluded that the mistake has been made again (Offer unfair deal > 2 AND accept unfair deal > 1).

When the user selects a strategy in the user interface, the facts that are the basis of this strategy are asserted into the knowledge base. The Strategy Monitor looks at the buy history of the player and concludes which strategies the player has employed. The problem here is that when the user selected the strategy in the interface, the Strategy Monitor looked at the buy history and concluded that the selected strategy was not used and it was immediately disabled again. The cause of this, was that the Strategy Monitor did not give the user any time to demonstrate that he was going to employ the selected strategy. The solution to this problem was to have the Strategy Monitor check whether the strategy has been selected when updating the facts. When the strategy has not been selected (the Monitor is trying to prove that the strategy is being used), the monitor will look back in time to see whether or not the strategy has been employed. When the strategy has been selected (the Monitor is trying to prove that the strategy is not being used), the Monitor will withhold judgment until the interval, associated
with the selected strategies, has passed since the strategy was selected and then determine if it was used or not.

At the start of the game, no strategy has been selected yet (neither manually or deducted from the buy history). The agent immediately concludes that the player is not using strategies at all and asserts the hypothesis that the player is not able to hypothesize. This was not desirable, the player should have a certain interval to be able to select or start employing strategies. To be able to support this, the turn numbers that were already being monitored by the agent, were also asserted into the knowledge base and incorporated into the rules. The no-strategy rule was adapted to take the turn numbers into account.

When the knowledge bases had been largely implemented and the link to the JAVA agent had to be made an exception occurred. It was determined that the exception occurred because JCLIPS was not thread-safe while the JSettlers Client was using threads. The JCLIPS code was rewritten to make it thread-safe, which solved the problem.

To conclude, all major problems have been solved and the ITA is operational. On our website (http://eidetic.ai.ru.nl/e-learning), a number of videos of the use of the agent are available. Moreover, the software packages can be downloaded.

**DISCUSSION**

After the introduction of the project, the concept “Games in Education”, a rapidly evolving field of science is presented; e.g., Doesburg, Heuvelink, and van den Broek (2005), Kelly (2005), and Squire and Jenkins (2003). In the section on Intelligent Tutoring Systems, a brief explanation of these systems is given. Next, the domain of application is introduced: negotiation processes with children. Subsequently, Piaget’s stage theory (Lourenço & Machado, 1996), Thompson & Hastie’s (1990), and the combination of both are discussed. The latter resulted in a new theoretical framework, which is validated through an experiment. After the theoretical framework was found to be valid, it was used as foundation for the development of the ITA. The usage as well as the pros and cons of the ITA in practice are presented in *The ITA in practice*.

As was already denoted in 1962 (Roberts & Sutton-Smith, 1962), without any doubt games are among the most powerful means to enhance education (Squire & Jenkins, 2003). With the acceleration of processing power of PCs and the advances in computer graphics, the involvement (or presence) of users of games brought to high levels, as is ultimately done through Virtual Reality techniques (Doesburg, Heuvelink, & van den Broek, 2005; Murray, Fox, & Pettifer, 2007; Takatalo, Nymana, & Laaksonen, 2008). However, also ‘classic’ 2D screen games can be very appealing as is illustrated by a new type of addiction that evolved this century: game addiction. In addition, various other risks are denoted; e.g., see “Harnessing the power of games in education” of Squire & Jenkins (2003) for an overview. Despite the drawbacks, it is (still) envisioned that games will become more important for educational purposes (Doesburg, Heuvelink, & van den Broek, 2005; Kelly, 2005).

The theoretical framework that is developed within this project has a solid foundation and is validated. Nevertheless, one can debate its foundation with respect to both its origins. Within the field of education, various theories on the development of human beings exist. Happily, these theories have their foundation in the same field of research. In contrast, the topic negotiation is assessed from various fields of science (e.g., psychology (Bazerman, Curhan, Moore, & Valley, 2000), management (Nadler, Thompson, & Boven, 2003; Wolfe & Murthy, 2006), and artificial intelligence (AI) (Jonker, Robu, & Treur, 2007)). We will now briefly denote both theories and explain our choice for Piaget’s theory (Lourenço & Machado, 1996) and Thompson and Hastie’s judgments (Thompson & Hastie, 1990).
Piaget’s theory has been a topic of heavy debate (Lourenço & Machado, 1996; Palmer, 2001) and still there are groups either strongly in favor or against Piaget’s work. Lourenço and Machado (1996) provide a concise overview of ten common criticisms and counter them. However, despite the excellent defense of Lourenço and Machado (1996), one can argue to replace Piaget’s stage theory by another theory; see Palmer (2001) for a recent overview of the most important alternative theories.

As a consequence for the broad interest in negotiation processes (Bazerman, Curhan, Moore, & Valley, 2000; Boven & Thompson, 2003; Jonker, Robu, & Treur, 2007; Nadler, Thompson, & Boven, 2003; Wolfe & Murthy, 2006), an enormous variety of theories, perspectives, and methods exist with respect to negotiation research. This makes it very hard to provide an overview of the field. There has also been research conducted specifically on training or teaching negotiation skills; e.g., Druckman, Harris, and Ramberg (2002), Gillespie, Thompson, Loewenstein, and Gentner (1999), and Shell (1995). In addition, since roughly a decade, in parallel with theoretical models often founded on qualitative data, computer applications were developed that either analyzed negotiation processes, modeled them (Jonker, Robu, & Treur, 2007), or supported them (Wolfe & Murthy, 2006). Within this broad palette of research, the work of Thompson and Hastie (1990) is prominent and has been quoted frequently; e.g., Bazerman, Curhan, Moore, and Valley (2000), Boven and Thompson (2003), Nadler, Thompson, and Boven (2003), and Wolfe and Murthy (2006). Therefore, we also adopted the theory of Thompson and Hastie on negotiation processes.

For both Piaget’s (Lourenço & Machado, 1996) and Thompson and Hastie’s (1990) theory, multiple alternatives are available. However, the theories adopted are (at least among) the most generally accepted. Moreover, in particular criticism on Piaget’s theory is often founded on misconceptions and misinterpretations of his work (Lourenço & Machado, 1996). Therefore, these two theories were chosen to develop the new theoretical framework on negotiation processes with children.

The development of robust rule-based systems requires a tremendous effort. Moreover, rule-based systems often lack the ability to be generically applicable, again this is true for our system. However, in the development of the system, future adaptations were taken into account. Its modular setup, as depicted in Figure 3, allows smooth adaptations of the system. Although the ITS as implemented works according to plan, some issues can be addressed that would probably enhance the ITS and improve children’s learning. The ITS consists of four modules: the domain, student, tutoring, and communication module; we will denote three of such possible improvements on these modules:

1. In the current study, the communication module is simply the interface between the ITS and the child. However, since communication is of the utmost importance in the communication between a child and his teacher, we expect that the implementation of a good communication would support the effect of the ITA substantially (Vugt, Konijn, Hoorn, Keur, & Eliëns, 2007). For example, a Virtual Reality environment could enhance the communication substantially (Doesburg, Heuvelink, & van den Broek, 2005; Murray, Fox, & Pettifer, 2007; Takatalo, Nymana, & Laaksonen, 2008) and even probe their experience (Westerink, Ouwerkerk, Overbeek, Pasveer, & Ruyter, 2008).

2. The pedagogical model generates the advice that is given to the child through the communication module. Advice can be given through various strategies, depending on domain and student’s features. Hence, it would be of interest to extend this model with various strategies on generating advice.

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the future of intelligent tutoring systems”, which addresses the exploitation of emotion in ITS. They baptize this next generation ITS as: Affective Tutoring Systems. Without any doubt, empathic ITS would substantially advance the communication process and with that the learning of the student. The ITS should be able to sense the student’s emotional state and act appropriately to it. This sensing should be done unobtrusively; for example, through speech signal processing (Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008; van den Broek, 2004) or psycho physiological measurements (e.g., galvanic skin response and facial electromyography) (Westerink, Ouwerkerk, Overbeek, Pasveer, & Ruyter, 2008).

Where the first two improvements only require adaptations to one of the systems modules or models, bringing empathy into the ITS requires substantially more effort (Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008; van den Broek, 2004; Westerink, Ouwerkerk, Overbeek, Pasveer, & Ruyter, 2008). The incorporation of the signal processing techniques and their interpretation has to be embedded in the pedagogical model, the communication model, and the student model. Consequently, the complete architecture would have to be adapted.

Throughout the research presented in this chapter, the complexity of the project’s aims became evident. Subtle shifts in strategy of explaining by human tutors that fit the student’s understanding remain striking (Person & Graesser, 2003). Despite the progress in behavioral research and the technological advances, true advances in the evolution of agent technology, expert systems, ITS, and AI in general still have to come (Shoham, Powers, & Grenager, 2007; Spector, 2006). However, various forms of AI exist that have proved their use (Doesburg, Heuvelink, & van den Broek, 2005; Jonker, Robu, & Treur, 2007; Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008). In this line, the project has delivered a unique ITS founded on a newly developed and validated theoretical framework on negotiation processes with children. It has proved to be stable and shown its value in learning children to negotiate. Moreover, it can be used to further specify the theoretical framework. Hence, the value of the online ITS system introduced in this paper is bi-directional: it helps science to understand children’s negotiation processes and helps the children to improve their negotiation skills through gaming by use of an artificial tutor.

REFERENCES


**ENDNOTES**

1. World of Warcraft is a Massive Multiplayer Online Role Playing Game (MMORPG), where thousands of people can play with and against each other in a fictive virtual world. http://www.worldofwarcraft.com/

2. For details about JSettlers, see http://jsettlers.sourceforge.net/

3. For details about Pioneers, see http://pio.sourceforge.net/