Interactive Narrative for Adaptive Educational Games:
Architecture and an Application to Character Education

Rania Hodhod

Ph.D. Thesis
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The University of York

Artificial Intelligence Group
Department of Computer Science
United Kingdom

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To my dad, the absent the present

Abstract

This thesis presents AEINS, Adaptive Educational Interactive Narrative System, that supports teaching ethics for 8-12 year old children. AEINS is designed based on Keller's and Gagné's learning theories. The idea is centered around involving students in moral dilemmas (called teaching moments) within which the Socratic Method is used as the teaching pedagogy. The important unique aspect of AEINS is that it exhibits the presence of four features shown to individually increase effectiveness of edugames environments, yet not integrated together in past research: a student model, a dynamic generated narrative, scripted branched narrative and evolving non-player characters. The student model aims to provide adaptation. The dynamic generated narrative forms a continuous story that glues the scripted teaching moments together. The evolving agents increase the realism and believability of the environment and perform a recognized pedagogical role by helping in supplying the educational process.

AEINS has been evaluated intrinsically and empirically according to the following themes: architecture and implementation, social aspects, and educational achievements. The intrinsic evaluation checked the implicit goals embodied by the design aspects and made a value judgment about these goals. In the empirical evaluation, twenty participants were assigned to use AEINS over a number of games. The evaluation showed positive results as the participants appreciated the social characteristics of the system as they were able to recognize the genuine social aspects and the realism represented in the game. Finally, the evaluation showed indications for developing new lines of thinking for some participants to the extent that some of them were ready to carry the experience forward to the real world. However, the evaluation also suggested possible improvements, such as the use of 3D interface and free text natural language.

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Declaration

This thesis has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree other than Doctor of Philosophy of the University of York. This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by explicit references.

I hereby give consent for my thesis, if accepted, to be made available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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Book Chapters

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5. Rania Hodhod. (2009). Educational Narrative-Based Environment to Teach Ethics. *In proceedings of the* 14^{th} *International Conference on Artificial Intelligence in Education (AIED'09).*

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11. Rania Hodhod and Daniel Kudenko. (2007). Interactive Narrative for Adaptive Educational Games. *In Proceedings of YDS'07: The First York Doctoral Symposium on Computing.*

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CHAPTER 1

Introduction

"To educate a person in mind and not in morals is to educate a menace to society."

President Theodore Roosevelt.

1.1 Introduction

Education has always been considered as potentially one of the most productive breeding grounds for technology. On the other hand, technology can be considered as a catalyst for teaching and learning and can help in enhancing positive educational change (Gibson et al. 2007).

Educational domains are divided into well-defined domains such as maths and physics and ill-defined domains, such as ethics and argumentation. The well-defined domains exhibit the presence of conceptual models that define the relationships and dependencies of concepts in these domains. This characteristic allows building various educational platforms that serve in teaching these domains and provide personalized learning. However, ill-defined domains pose a number of unique challenges for computer science researchers, such as defining a viable computational model for aspects of underspecified or open-ended domains, the provision of feedback when the problem-solving model is not definitive, and structuring the learning experiences in the absence of a clear problem, strategy, and answer.

Ethics and character education is an important ill-defined domain, where promoting ethical, responsible, and caring young people is a perennial aim of character education. Schools are invited to include moral teaching in every possible curriculum and as standalone ones. The development of skills of participation and responsible action is a fundamental part of the citizenship curriculum and touches on important topics in character education for middle and high schools. At all key stages citizenship education comprises three strands:

Social and Moral Responsibility which focus on how pupils can take responsibility for themselves and each other.

Community Involvement which deals with issues like road safety, security, school catering, and fund raising events.

Political Literacy that aims to teach young people democracy by letting them try it out.

Development in each of these strands could not be achieved by only acquiring knowledge, but actually through developing skills. In a domain like ethics, knowing and acquiring knowledge is not a proof of mastering a concept (knowing is different from doing). As Watson (2003) illustrates: "getting high scores in an ethical course does not guarantee at all the actual behavior of that learner." What is also important in this domain is to build the desire for good and be strong enough to act morally in the face of adversity, as Watson puts it: "The trick lies not solely with knowing what is right and good but also in building a love for the good and the worthwhile." That is, by giving the learners the opportunity to see successful people doing what is right and good, we may increase the chance that learners will be more inclined to follow suit themselves than they might otherwise.

The first strand is of primary interest for us. It focuses on learners' moral development and how to increase their awareness towards social and moral responsibilities. Developing skills to attempt these features is an important social issue, where these skills are very important as they affect oneself in relation to others. In the classroom environment, various tools are used to teach these skills, such as traditional teaching by asking learners to learn and think in terms of words and abstractions. This kind of teaching may not suit young children as it might be difficult for them to connect what they learn, in any useful way, to images or situations in their embodied experiences in the world (Halverson 2004). Other tools include discussions and brainstorming possible solutions to moral dilemmas (Bolton 1999) and classroom games (Shapiro 1999). Allowing learners to be involved in moral dilemmas and be engaged in independent thinking helps them to express themselves through the kind of choices they make, and begin to formulate their own conceptions of rights, values, and principles by which they evaluate existing social arrangements (Eemeren et al. 1996). However, this procedure does not let the student experience making ethical decisions in a realistic context with imperfect information (Mckenzie & Mccalla 2009). This issue has been overcome by classroom games that allow the learners to experience situations and see how their decisions affect themselves and others in a real context. However, it is still difficult, if not impossible, to present various real life dilemmas that learners can face because of constraints such as time and curriculum standards (Eiriksson 1997). Moreover, learners typically only get the learning materials prepared in advance by the teacher. As a result, the learning activities are limited to what the teacher arranged and consequently it is rather difficult to adapt the learning materials to individual learners' learning requirements and demands (Kinshuk et al. 2009).

Despite the encouraging results the above tools provide for teaching ethics in classroom environments, unfortunately for some children the classroom environment is not effective enough particularly for those who do not want to be judged in public, such as shy children. These children may avoid presenting certain unethical actions or choices because this is not what it is expected from them. In addition, children differ from each other, which drives us to the importance of adaptation in the sense of providing various experiences to different children based on their personalities, needs, weaknesses and strengths. Halverson (2004) challenges teachers to provide the kind of teaching that creates a safe place for their learners and allows them to move outside of their comfort level and also challenges them to think outside of their current level of experience. Whilst it is challenging to create such an environment in classrooms, it seems computers can help with this. Although technology, especially games, is now part of our children's daily life, research on teaching ethics using computers has not yet reached its maximum.

Computers offer much in addressing the problems of classroom teaching altogether. First of all they offer the required privacy and the safe learning environments that encourage and recruit situated, experiential, and embodied forms of learning and thinking, in addition to learning at the learner's pace. They allow the presence of learning environments that have the potential to provide intrinsically motivating learning experiences that immerse and engage the learner such as educational games (Pierce et al. 2008). Educational games (Edugames) are learning environments that allow practicing by doing, and accordingly promote the acquisition of skills and knowledge in a pleasant, interactive way. They can have strong learning objectives underpinned by effective story telling that facilitates teaching in ill-defined domains, such as the ethics domain. Developing learning platforms for the ethics domain aim to help learners to move from the state of making moral judgments to the state of taking moral actions, from the knowing state to the doing state, which we consider a very important step in moral education.

Edugames can use stories as a source of inspiration and direction for moral conduct. Various moral situations can be integrated in the story context allowing the student to interact with and learn from, and hopefully transfer what is learned to the real world. What is really interesting is the fact that the game worlds can be inhabited by non-playing characters (agents) that are able to communicate with the learner as well as with each other in a realistic and believable context and can help supplying the educational process by different means.

Edugames that allow adaptation can uniquely present a personalized supportive motivational experience (Pierce et al. 2008). However, research on adaptive educational games (edugames) is still in its infancy, and there are very few formal evaluations that explicitly target the pedagogical impact of adding adaptive functionalities to educational games (Conati & Manske 2009). Edugames research has only recently started to consider developing moral reasoning through the use of these platforms.

Adaptation to individual users in computer based systems has been successfully applied in intelligent tutoring systems (ITSs). An ITS is a platform used to enrich the learner's experience where it monitors and guides the learner, evaluates their actions, and provides tailored feedback. Learner modeling (student modeling) is the core of this process, where capturing learner's knowledge and intentions underlying a learner action, known as mental states bandwidth, can allow for a high adaptation level. The bandwidth problem in student modeling deals with providing adaptation to individual learners not only based on what they do explicitly in the learning environment but also their intuitions. This problem has not yet been completely resolved in the literature. The bandwidth problem is highlighted in Chapter 2 along with problems and controversies in the field.

Riedl & Stern (2006) believe that narrative and interactivity are diametrically opposed, meaning one can have story or one can have interactivity but not both simultaneously. In their work, they offered a solution to this issue, yet without assuring the pedagogical effect on the user. Here is where we think the problem exists, the problem becomes not only concerned with narrative generation and the user's agency but also with the tracking of the learning process and providing feedback. A solution can be seen in the integration of the following four features: scripted narrative that allows tracking the learning process, dynamic generated story that allows the presence of a continuous story, evolving agents that increase the believability and realism of the environment and engages the user. Finally, the employment of a student model to provide an adaptive learning process. Based upon this view, this work presents AEINS, an edugame that allows the integration of these features in a single architecture.

This thesis taps into the areas of ill-defined domains, intelligent tutoring, and educational games. It contributes to ill-defined domains by taking a first step in developing a computer-based educational game to teach basic ethical values to young children and educate their character. This was achieved through the integration of educational games and intelligent tutoring. The main idea is centered around involving learners in interactive moral situations within which the students are active participants who are able to act and take decisions that affect their state in the surrounding environment and others. This kind of problem solving and decision making allows the learners to express themselves through resolving the conflicts present in these dilemmas and learn about basic human values including honesty and kindness in a concrete situations rather than abstract contexts.

1.2 Contribution to the State of the Art

The edugames presented in this thesis exhibit the presence of four features shown to individually increase the effectiveness of edugames environments, yet not integrated together: first, the presence of a student model that handles different information about the learner such as the acquired skills, his strength points, his weaknesses and his needs in order to provide personalized learning as mentioned previously. Second, the use of a dynamically generated narrative to obtain a continuous story according to the learner's preferences and provide the learner with high agency within the environment. The third feature is the use of a scripted narrative that constrains the learner agency at certain parts that supply education in order to enable tracking the learner's actions and their assessment. Finally, the presence of evolving pedagogical agents (non-playing characters) with human-like features. To the extent of our knowledge, no edugame has integrated all these features in a single architecture before.

The integration of these components is the contribution of this work, where it allows personalization through the use of a student model and addresses the limitations of the second and the third features through integrating both dynamic and scripted generated narratives. The dynamic generated narrative can produce a continuous story that increases the realism of the environment and acts as a mental and emotional hawk for the user. It also allows the learner to act freely and affects how the story unfolds (high agency). The use of scripted narrative to represent the educational objects restricts the learner's agency when interacting with the educational tasks (low agency) in order to allow tracking and assessment of the learner's actions. This principle is very similar to a game play where the player is exploring the game environment and at certain points he has only one path to follow, in order to force him (implicitly) to perform the required tasks. Finally, the presence of evolving non-playing characters increases the believability of the environment and can perform a recognized pedagogical role by helping in supplying the educational process. For these reasons, we argue that although each of these components is not a contribution in itself, their combination in one environment is. This thesis leads to the identification of the following research and development goals:

1. The development of a generic architecture based on learning theories. The architecture should exhibit the following:
    - The creation of a continuous generated narrative that allows the presence of evolving characters.
    - The integration of an intelligent tutor that makes use of a student model to attempt to solve the bandwidth problem and allows adaptation.
    - Addressing the learner agency versus tracking the learning process problem.
2. The use of the Socratic Method as the teaching pedagogy that helps in developing moral reasoning.
3. Solving classroom problems such as adaptation to individual learners and helping shy learners to express their beliefs.

The above items were achieved through the design of an architecture consisting of two separated but interacting levels: narrative level and tutoring level. The architecture consists of a story generator, a world model, a domain model, a student model, a pedagogical model and a presentation module. The architecture has been inspired by the learning theories of Keller ARC's Model (Keller 1987b) and Gagné's Events of Instruction (Gagné et al. 1992). AEINS story generator aims to generate a continuous story that increases the realism and believability of the virtual world, in addition to the commitment and engagement it provides. The intelligent tutor tracks the learner's actions and makes use of the student model that helps in providing an adaptive learning process to the student. In order to deal with the bandwidth problem of student models, production rules have been used in order to infer the learner's intuitions based on his actions.

The presence of a continuous story offers high user agency and makes it difficult, if not impossible, to follow the user's learning process. A solution to this problem lies in the use of hybrid narrative techniques: the dynamically generated continuous narrative and the graph structured narrative allowing two types of agencies during play time. The learner has high agency at all times when no educational targets are set, where he is able to act and influence the unfolding of the main story. The learner's agency is restricted in order to allow the intelligent tutor to track the learner and assess his actions, at times when educational targets are set. We argue that the presence of variant agencies provides a suitable solution for the agency versus tracking the learning process problem as it helps not to lose track of the learning process as is the case when employing high agency only or otherwise the learner may lose interest as is the case with having low agency only. Finally, the Socratic Method has been used as the predominant teaching pedagogy for its powerfulness in guiding the learner to reach the right conclusions without being dictated to them.

Based on this architecture, an educational game prototype, AEINS, has been implemented as a proof-of-concept. AEINS is an educational learning environment implemented in order to teach in the ethics domain, especially character education. AEINS as a digital educational games can help solve classroom problems as discussed previously in this chapter. AEINS has been evaluated using various methods: first, the game aspects of AEINS have been validated against Gee's games aspects (Gee 2004a). Second, AEINS has been evaluated intrinsically to check the implicit goals embodied by aspects of the design and to show that AEINS components are well interrelated, they are able to operate in the right manner. In addition to assessing the student model's capability in identifying the learner's misconceptions and helping the pedagogical model to choose the next educational step. Finally, empirical evaluation has been performed that provides promising results. The evaluation aimed to test AEINS for different criteria such as the technical infrastructure, its functioning, its ability to support or enable specific activities, and generate predicted educational outcomes.

Post interviews were conducted to address five different categories: technical infrastructure and its functioning, functions and features inherent in the system and its ability to support or enable a specific activity, the participant tasks, the capability for specific technology-based activities to generate predicted outcomes and finally, re-playability and self reflection. An interesting point which appeared from the post discussions with the participants was that they were able to pro-actively bridge their real identity to the virtual identity and projecting their own hopes, desires, values and beliefs onto their in-game persona. It has also been seen that this success in bridging the real identity to the virtual identity allows the learners to discover certain skills they possess or at least know that they have the capacity to use these skills and may also learn about their limitations. The final contribution can be seen in addressing the classroom problems mentioned earlier, and providing a safe exploratory environment for children.

1.3 Thesis Outline

Chapter 2 introduces the application domain and the current existing problems, in addition to the AI technologies that will be used in the educational game development phase along with a critical review of the literature. From the conclusions of Chapter 2, goals have been constructed in designing an edugame for character education. Managing to achieve these goals through the designed architecture is discussed in Chapter 4. Based on this architecture, an edugame prototype, AEINS, has been implemented. Description of the implementation of each of AEINS modules and how they deliver their tasks can be found in Chapter 5. The thesis results from the intrinsic and empirical evaluations are considered in Chapter 6. Finally, thesis discussion, lessons learned and suggestions for future work will be highlighted in Chapter 7. Our hope is to be able to generalize our results to inspire the design of educational games in ill-defined domains.

1.4 Summary

Ethics is a challenging domain that requires building up skills in order to achieve educational progress. Several tools have been previously implemented in classroom environments. Some show limitations such as traditional teaching and discussions. Others offer a step forward by enabling learning by doing, such as classroom games. However enabling learners to experience real-life dilemmas in the classroom environment has proven to be very difficult.

This research aims to extend the current state of the art in using computers to teach in ill-defined domains by following the ‘learning by doing’ paradigm using interactive narrative and intelligent tutoring techniques in an edugame environment. Narrative is recognized as a valid support for learning because it helps make sense of experience, organize knowledge and increase motivation (Dettori & Paiva 2009). Intelligent tutoring allows the presence of a learner model (student model) that is considered a key element in the adaptation process (Brusilovsky 1994; Abraham & Yacef 2002).

The main idea is centered around having a continuous story to engage the learner and the presence of evolving characters with whom the learner can build emotional relations. learners are offered high agency in a dynamically generated interactive narrative, where they are able to act and their actions may violate the generated story affecting how the story unfolds. At the time that educational objects are activated, the learner's agency becomes constrained in order to preserve the educational targets. Intrinsic and empirical evaluation are used in a discussion of the achievements and limitations of this research.

CHAPTER 2

Background

2.1 Overview

The previous chapter presented ethics as the domain of interest and highlighted the difficulties encountered in classroom environments while teaching in this domain and how computers could offer a solution. It also stated the main contribution of this work and highlighted the main goals. This chapter aims to provide detailed background of the areas involved in this research, including: intelligent tutoring systems, ill-defined domains and educational games. In the following sections, we bring together the various modules and attributes of these AI educational environments and the most relevant critiques, suggestions and general issues relating to the design, implementation and evaluation of these environments, especially narrative-based educational games. This facilitates a critical review of the literature on the use of edugames. It also strongly influences the development of the main methodology adopted in this work. Towards the end of this chapter, the research vision that influenced the implementation of the educational environment is presented.

2.2 Artificial Intelligence Educational Environments

Since the 1950's, the idea has been developed that the computer can be used by the student to learn independently and that computer programs can teach the student. This is based on the belief that students learn best when they gain knowledge through exploration and active learning and are able to learn at their own pace. Many educational environments have been developed that either do not employ any AI techniques or others which try to make benefit of what AI techniques can offer.

Artificial intelligence (AI) is the area of computer science focusing on creating machines that can engage on behaviors that humans consider intelligent. Many problems in AI instantiated in reasoning, planning, learning, perception and robotics require the agent to operate with incomplete or uncertain information. AI can provide tools that helps to address these problems, such as Probabilistic methods for uncertain reasoning, machine learning and search and optimization techniques. In recent years, AI-supported educational systems (AIED) have greatly advanced both as research tools and teaching applications, example applications are: intelligent tutoring systems (ITSs) and artificial intelligence educational games (AI edugames).

The application of AI techniques in educational systems enriches the learning process. It always the presence of the intelligent tutor, the intelligent characters that can assist the learner and guide him in the learning process. The AI techniques provide the chance to stretch the boundaries of educational technology to attempt not only well-defined domains but also ill-defined domains. he following sections present the various modules and attributes in ITSs and edugames in addition to the work done in these areas, especially in ill-defined domains.

2.3 Intelligent Tutoring Systems (ITSs)

Providing a personalized learning experience based on the presence of a student model is the main job of intelligent tutoring systems. Intelligent Tutoring Systems (ITSs) are those educational systems that provide individualized instruction. They provide beneficial one-to-one instructions automatically and cost effectively. They also enable the participants to practice their skills by carrying out tasks within highly interactive learning environments (Maragos & Grigoriadou 2005). The ITS executes knowledge tracing that builds a model and generates hypotheses about the student proficiency in the skills being taught (Magerko & Stensrud 2006). It would then use the model to provide customized instruction and problem selection to that particular student's perceived pedagogical needs. As a student interacts with the learning environment, the system executes model tracing that generates hypotheses linked to the student's strategies to solve a problem (Magerko & Stensrud 2006). Based on the developed model, context sensitive feedback can be provided, if a student commits an error. The central components of an ITS are: the domain model (expert knowledge), the student model (learner model) and the pedagogical model (teaching strategy) (Urban-Lurain 1996).

2.3.1 Domain Model

The domain model is a main component of tutoring systems. The domain model in ITSs is a dynamic model where a set of rules are implemented by which the system can *reason*. ITSs have their roots in expert systems research (such as medical diagnostic or electronic troubleshooting systems) and have the ability to generate multiple correct sets of solutions, rather than a single idealized expert solution. In ITSs, knowledge can be contained in frames that act as partial ordering mechanisms for the domain concepts and provide enough flexibility to the pedagogical model to pick certain frames considering the dependencies on other frames and the current student model.

2.3.2 Student Model

Student modeling is an important aspect of providing adaptivity in ITSs. It involves creating an individual model for every student. This model aims to identify the current knowledge of the student, adapts the curriculum sequence accordingly and helps him/her in navigating through the educational material. Student modeling remains at the core of ITSs research. Although some authors are questioning the goal of student modeling either because of technical limitations (McCalla 1992) or larger philosophical grounds (Sack et al. 1994), this is still an area of active research.

To provide higher adaptivity, mental states bandwidth should be attempted in the student model. Bandwidth is a parameter for categorizing student models (Vanlehn 1988). It is defined as the amount and quality of information and student reasoning that the student inputs provide to the student model. There are three categories of bandwidth. From the highest to lowest bandwidth category, they are:

Mental state: student input shows both the knowledge and intentions underlying a student action.

Intermediate state: student input includes the intermediate step used to derive the answer to a question or problem.

Final state: student input includes only the final answer.

Each category is intended to include the information in the category beneath it. The higher the bandwidth, the easier it is for a student model to infer relevant features of the current student state. However, higher bandwidth also entails more work for the student in the interface, and therefore can interfere with student motivation for using the system. According to O'Shea & Self (1983), a good student model should tell us more than what the student knows, it should tell us something about what he is doing and thinking. Gathering diagnostic information presents a challenge for ITS designers. It is quite a challenge to obtain data that truly represent the student cognitive state and/or reflect the student's intention. This can be the reason that most current implementations attempt only the final and intermediate states as will be shown later in this chapter.

2.3.3 Pedagogical Model

The pedagogical model in ITSs considers student motivation, mood and cognitive processes in making instructional decisions in the domain. Learning can be viewed as successive transitions between knowledge states and the purpose of teaching is accordingly facilitating the student's traversal in the space of knowledge states (Wenger 1987). In this case, the pedagogical model's role is to adapt instruction (problem selection, problem difficulty, topic area, choice of activity, choice of help type, and availability of help) following a model of human tutoring expertise that balances motivational and cognitive goals and supports the transition to a new knowledge state.

As can be seen, ITSs offer one of the most important aspects in education that is adapting to different learners' needs and strengths through the presence of a student model. However,e ducational games have advantage over intelligent tutoring systems in that the former tend to generate a much higher level of positive engagement, thus making the learning experience more motivating and appealing (McGrenere 1996). The next section provides reasons for the choice of educational games as the desired learning environment.

2.3.4 Related Work on ITSs

Intelligent tutoring systems (ITSs) have been utilized successfully in well-defined domains (Canfield 2001; Melis & Siekmann 2004; Vanlehn et al. 2005). Recently, there is a growing interest in pushing the boundaries of intelligent tutoring architecture to be utilized in ill-defined domains. Lynch et al. (2008) found that many existing ITSs are still appropriate to be used in ill-defined domains, yet lack sufficient flexibility to account for the additional characteristics existing in these domains such as: lack of definitive answer, the answer is heavily dependent upon the problem's conception and the problem solving requires both retrieving concepts and mapping them to the task (Lynch et al. 2006).

Despite the challenges provided by ill-defined domains, many ITSs were developed in this area. For example, the ACLS system developed to help enhance cultural discussions (Ogan et al. 2008). The system provides feedback to individual students based on five predefined dimensions of good cultural discussion. In the domain of ethics and citizenship, analyzing ethical dilemmas using diagrams has been discussed in Lynch et al. (2008), their study focuses mainly on the analysis of different ethical dilemmas. An ITS system that teaches the analysis of bioengineering ethics cases through framing has been developed (Goldin et al. 2006). The system presents the users with an ethical dilemma that has been authored and analyzed by another user, and the users have to review and give feedback. The system filters out any inapplicable feedback and rephrases the peer reviewed ones (writing skills) through system-generated feedback.

With respect to teaching pedagogies, the Socratic Method has been applied previously in the CIRCISM-TUTOR system that teaches how the cardiovascular reflex system that stabilizes blood pressure functions (Kim 1989; Yang et al. 2000). They show that applying the Socratic Method positively influences the learning process. Furthermore, CATO (McBurney & Parsons 2003) and LARGO (Ashley et al. 2007; Lynch & Ashley 2009) systems use the case based reasoning method in order to reify the argument structure through using tools for analyzing, retrieving, and comparing cases in terms of factors. Finally, ALES is an ongoing project that employs intelligent tutoring to enhance argumentation skills (Abbas & Sawamura 2008, 2009). Empirical evaluation has yet to be done to test the ALES's educational outcomes.

2.4 Knowledge Representation

Knowledge representation is an area in artificial intelligence which uses a symbol system to represent "a domain of discourse" . The fundamental goal of knowledge representation is to represent knowledge in a manner as to facilitate inferencing (i.e. drawing conclusions) from knowledge. With knowledge representation, we need to be able to encode information in the knowledge base without significant effort and to be able to understand what the system knows and how it draws its conclusions. There are many representation techniques such as semantic networks, frame and rules, which have originated from theories of human information processing.

A semantic network is a simple representation scheme which uses a graph of labeled nodes and labeled directed arcs to encode knowledge. This representation is characterized by the presence of formal definitions, being easy to visualize and its efficiency in space requirements where objects represented only once and relationships are handled by pointers. The inheritance feature can propagate between various nodes however, sometimes, this inheritance (particularly from multiple sources and when exceptions in inheritance are wanted) can cause problems. More problems occur when facts are placed inappropriately.

Another form of knowledge representation is the frame representation. A frame represents an entity as a set of slots (attributes) and associated values. A frame can represent a specific entry, or a general concept. Frames are implicitly associated with one another because the value of a slot can be another frame. The frame representation offers more natural support of values then semantic nets (each slots has constraints describing legal values that a slot can take) and inheritance can be easily controlled. However, frame representation has no associated reasoning/inference mechanisms. Both semantic nets and frame share the lack of standards about node and arc values and slot-filler values, consecutively.

The inference mechanisms are associated to other kinds of knowledge representation, such as rules. Rules are more expressive than frames and semantic networks. Their power lies in their ability to describe entities without making any particular assertions about them and making descriptions from other descriptions using a very small set of operators.

2.5 Interactive Narrative

> *"Stories are connections to the past and yet carry us into the future; they speak of relationships, of human connections, and to what gives quality to our lives."*
>
> *(Simpson 1998)*

In the last decades, there has been a significant growth in deploying narrative in education. Drama and narrative have been used in classrooms for primary and secondary school curricula, both in isolation and as a support for other subjects (Bolton 1999; Bayon et al. 2003). Stories help children to approach knowledge about human personal problem-solving, social interaction, values and morals (Trabasso et al. 1984), and additionally tightening human relationships (Simpson 1998). The more cohesive, logically and causally, the individual story elements are, the easier for the child to understand, organize and store these events in a memory representation that allows them to retain that knowledge for other purposes (Trabasso et al. 1984). In addition it has been shown that role playing and discussions can help students translate their knowledge and beliefs into actions and can enable them to see that their decisions affect other people and things (Elliott et al. 2002).

Interactive narrative presents learners with interesting and interactive story-like experiences. Narrative is defined, in our work, as a sequence of individual events or actions that are coherently generated to form a structured story that allows the presence of evolving non-playing characters whose personalities evolve during the story course. Interactive narrative has proven to be successful in creating enriching experiences for its users, sparking problem-solving skills, individual and group decision-making skills, and encouraging pupils to develop strategies to deal with different issues in different disciplines (Bayon et al. 2003).

Interactive narrative characteristics encourage researchers to use it in computer-based environments. Different techniques have been used to generate narrative such as dynamic planning at run time or more structured narrative in the form of branched graphs. Interactive narrative was used for entertainment (Mateas & Stern 2003; Barber & Kudenko 2007) and for education (Prada et al. 2000; Riedl & Stern 2006; Magerko & Stensrud 2006; Aylett et al. 2007; Hodhod & Kudenko 2008). Within educational game environments, they can be viewed as rich generated stories that allow the transfer some educational concept(s) or skill(s) to the student whilst the student is seen as an active participant in the construction of his own knowledge.

The research area of both entertaining games and educational games appreciate the use of narrative in their platforms because of the rich worlds they can provide. In this thesis, we are interested in narrative-based educational games. However because of the influence of games research on educational games and the importance of considering games characteristics and aspects in developing educational games, the next section discusses various game aspects and game theories considered in our work.

2.6 Agents as Human-like Characters

Agents are defined here as entities that can perform a task or a set of tasks in addition to performing pedagogical roles. Agents can take the role of human-like characters if provided with the shape, personality and abilities of humans. AI helps to provide autonomous agents with a way of thinking through knowledge representation and the use of rules. They can be autonomous to the extent that their action choices depend on their own experience, rather than on knowledge of the environment that has been built-in by the designer (Russell & Norvig 1995). They can have abilities like moving, talking, feeling and reacting to the external world. The human-like characters provide agents with the power of believability and increasing the realism of the inhabited world.

Pedagogical agents allow communication and interaction in learning environments (Giraffa & Viccari 1998). They can have a set of normative teaching goals, plans for achieving these goals and associated resources in the learning environment (Thalmann et al. 1997). Animated pedagogical agents, especially life like characters, have significant motivational benefits, play an important pedagogical role by acting as virtual learning companions (Maragos & Grigoriadou 2005), increase problem solving effectiveness by providing students with customized advice (Lester et al. 1997) and can have a strong positive effect on students' perception of their learning experience (Agents & Evaluation ped). Agents can also have different roles to support education, for example observing the students' actions and assessing them, in addition to providing feedback, explanations and demonstrations to the learner (Hospers et al. 2003; Abbas & Sawamura 2009). Moreover, emotional agents can be used to support the student system interactions and provide human-like tutoring (Nkambou 2006; Neji et al. 2008).

2.7 Why Educational Games?

Educational Games are a type of serious games. Serious games are those games designed for a strong purpose other than pure entertainment. Although serious games can be entertaining, their main purpose is to train, investigate, or advertise. Educational games are those games that have been specifically designed to teach people about a certain subject, expand concepts, reinforce development, understand an historical event or culture, or assist them in learning a skill as they play. They include board, card, and video games. Another type of educational games is the educational computer games (edugames). Edugames compose of two fundamental characteristics: gaming that leads to fun and learning that leads to acquire skills and transfer of knowledge. Generally, games are entertaining environments that either have predefined goals set by the designer or those that allow the player to set his own goals. Both cases are concerned with achieving internal goals in the game. On the contrary, edugames are mainly concerned with providing a learning experience with educational outcomes that, hopefully, could be transferred to real life. Gaming and fun in edugames is a way and not the aim to provide an intrinsically motivating experience to the student player. The following subsection presents how the various games' features contribute in making games engaging, enjoyable and self satisfactory.

2.7.1 Entertaining Computer Games

Games are highly motivating in nature. They contain constructive aspects such as challenge, fantasy, control, and curiosity that engage the player. Accordingly, researchers have started to investigate the utilization of games to assist learning (McGrenere 1996; Klawe 1998). Klawe (1998) considers games only effective if the interaction is monitored and directed by teachers, or if the games are integrated with other more traditional activities such as pencil-and-paper exercises. Other researchers believe that effectiveness is related to the features, preferences and behaviour of a particular user (McGrenere 1996). If edugames manage to adopt and utilize the successful aspects of games and consider educational theories through their design, they can act as standalone platforms.

Prensky (2000) has pointed out various game characteristics and their role(s) in the game environments. These characteristics can be transferred to the educational game environments and still perform the same role(s). These characteristics are:

- Games are a form of *fun*. That gives us *enjoyment* and *pleasure*.
- Games are a form of *play*. That gives us *intense* and *passionate involvement*.
- Games have *goals*. That gives us *motivation*.
- Games have *rules*. That gives us *structure*.
- Games are *interactive*. That gives us *doing*.
- Games are *adaptive*. That gives us *flow*.
- Games have *outcomes* and *feedback*. That gives us *learning*.
- Games have *win states*. That gives us *ego gratification*.
- Games have *conflict / competition / challenge / opposition*. That gives us *adrenaline*.
- Games have *problem solving*. That sparks our *creativity*.
- Games have *interaction*. That gives us *social groups*.
- Games have *representation* and *story*. That gives us *emotion*.

It can be seen that games have characteristics that help to engage and motivate the player. Some games have fixed goals and others use/employ player-derived goals which derives motivation. In edugames it is important to have these goals aligned with the learning goals. In other words, in order to succeed in the game you must succeed in learning the educational material. Furthermore, games have rules that tell the player how the game is played (what constitutes a valid action or invalid action) or (what action can help the player in achieving the goals and what actions will hinder him from achieving these goals). In edugames, these rules can be extended to allow the player's interaction with the tutoring component(s) that is embedded in the edugame environment preserving the player's immersion.

Games can be designed to cater to the player's needs, interests and abilities. People both have differences and similarities to each other, and the game's design needs to reflect that. Feedback is an important aspect in games and it has an invaluable role in learning too. It acts as an implicit guidance that informs the player about his current skills' level and may also gives be advise on how to develop those skills require improvement. Feedback can be provided by different means in the form of sound and/or objects added to or removed from the screen or implicitly within the game story context. Good design should foster freedom, immersion, and flow in order to avoid frustration and not hinder the learner from achieving their goals without overwhelming the player with information or commands (Junqi et al. 2009). Challenge is a very important attribute that exist in successful games through their competitive environments and the deliver of optimal level of challenge. This should be considered in the design of the learning objects and the tasks in the edugame environments in order to provide engagement, immersion and motivation.

2.7.2 Educational Computer Games (Edugames)

Edugames are an increasingly popular paradigm embedding pedagogical activities in highly engaging, game-like interactions (Conati & Manske 2009). Edugames have advantage over intelligent tutoring systems in that the former tend to generate a much higher level of positive engagement, thus making the learning experience more motivating and appealing (McGrenere 1996). Players can learn while engaged in an entertainment activity (Maragos & Grigoriadou 2005). The fundamental goal of edugames should be that the player must master the content to master the game. In other words, success in the game must be conditional to learning. This issue can be a difficulty in itself where learning how to play the game does not necessarily imply learning the target instructional domain. For this reason, the learning objectives should be tightly coupled with the game elements. Moreover, adaptation should be accomplished on the game level as well as the educational level to autonomously tailor the interaction to the specific needs of each individual player.

Since the 1970s various edugames started to emerge and some of them claimed to have educational effectiveness. However, little formal evaluation of the actual pedagogical values of these games has been published (Randel et al. 1992). Studies on the use of games in education (Randel et al. 1992; Laurel 1993; Murray 1998; Tan et al. 2005; Amory et al. 1999; Shaffer 2005b; Gee 2004b; Gómez-Martín et al. 2004; Shaffer 2005a; Gee 2003) have proven that games motivate learners to develop their knowledge while they put it into practice. Games became a strong supplement to teaching by virtue of their concrete experiences leading to learning. In other words, instead of being taught about topics students engaged with these topics and play them out, thereby creating their own experiences and receiving feedback on their specific actions in a safe environment (Gómez-Martín et al. 2004). It has been shown that edugames encourage the growth of logic and acquisition of skills and help in the construction of knowledge in a pleasant way (Dillenbourg et al. 1996).

2.7.3 Evolution of Edugames Research

Egenfeldt-Neilson (2005) classifies the evolution of the edugames research area into three stages: The first stage is when edugames research perceived the use of computer games as a direct way to change behaviours through repeated action. The theory claims that users can learn by practising skills and contents through reinforcements and conditioning. Later on edugame research put the spotlight on the relation between the computer game and the player. In this stage differentiating between learners and taking into account different ways of learning were taken into consideration. In the latest generation, research focuses on the context of computer games and how they facilitate learning environments. Church (1999) considered the lack of a common design vocabulary the main factor in the slow development of game design. This has also been the case for educational games, where efforts are still made in order to reach a common design methodology (Junqi et al. 2009).

2.7.4 Related Work on Edugames

Educational games are games that make learning processes more engaging and attractive to learners. They have been specifically designed to teach people about a certain subject, expand concepts, reinforce development, understand an historical event or culture, or assist them in learning a skill as they play. Although we are mainly interested in interactive narrative-based edugames, we found that it is worthwhile to extend our review to other non interactive narrative-based edugames which can contain other features of interest, such as student modeling and pedagogical agents.

2.7.4.1 Non interactive Narrative Edugames

Educational games have utilized intelligent tutoring either through employing a student model to personalize the learning process through providing feedback and hints such as How the West Was Won (Burton & Brown 1976) and Mito (Millan et al. 2005) edugames, or by providing advice on strategy and tactics for better play such as in the Wumpus (Goldstein & Carr 1977) or by managing the order of presentation of the educational material such as in JVM (Gómez-Martín et al. 2004). Prime Climb (Stacey et al. 2002) is another edugame that uses a student model to identify some of the students' misconceptions. However the model found difficulty in judging an incorrect click (answer) in a principled way, where the students were motivated to answer incorrectly to see the cartoon character falling down and lost the interest in reaching the top of the mountain (Conati 2002).

Adaptation using sub-games design has been proposed by Ecotoons2 edugame to provide several different computer-based games (Carro et al. 2002). Each game is associated with specific learning goals. For example, adding or subtracting numbers and the type of users the game is intended for. Betty's Brain offers adaptation through using the learning by teaching paradigm (Tan et al. 2005). Although it does not have a student model, the agent failure to solve the required problem means the student himself is not able to. In this case the student is forced to re-teach her in order to help her to solve the problem. Another edugame is S.C.R.U.B, a mini-game that is designed to teach principles about ways of preventing the spread of microbial pathogens (Magerko et al. 2008). S.C.R.U.B tries to adapt to the student's personality: explorer, achiever or winner.

Pedagogical agents have also been employed to serve the educational process by providing hints and feedback either based on an existent student model such as in Prime Climb (Stacey et al. 2002), JVM (Gómez-Martín et al. 2004), or without relying on a student model such as in the Lincoln game (Leon & Fisher 2006), Betty's Brain (Tan et al. 2005), ToonTalk (Kahn 1999), and TALENT (Maragos & Grigoriadou 2005).

More edugames have been developed that are based on solving various levels of tasks that serve the educational targets in order to achieve the game goals such as: Monkey Wrench Conspiracy (Prensky 2000), Spion textual adventure edugame to teach the German language (Culley et al. 1986), RoboCode an edugame to teach some Java programming techniques (Hartness 2004), CeeBot-4 an edugame to teach programming (CeeBot4 2008).

2.7.4.2 Narrative-Based Edugames

Narrative is classified into two fundamental types (Riedl & Young 2006): linear and branching narrative. In the former type, a sequence of events is narrated from beginning to ending without variation or possibility of a user to alter the way in which the story unfolds or ends. In this type of narrative, all users experience the same story and each user will experience the same story during successive sessions. In contrast, a branching narrative consists of choice points where a decision must be made by the user in order to progress the story forward. The main problem with this kind of narrative is combinatorial explosion of content that arises at increasing the number of edges coming out of the decision points. The solution is either to constrain the number of choices available to the player, or to offer the player many choices but only a small set of them actually affect the storyline (Magerko 2006).

Both types constrain the user interactivity, however planning in dynamically generated interactive narrative allows the user to have enough agency and interactivity to alter the storyline. This type of planning requires more flexibility in designing the story space. One way to implement this type of planning is to use the AND/OR trees as a general framework (Magerko 2006) or to use planning (Riedl & Young 2006). For example, Mott & Lester (2006a) used planning that proved efficiency with sufficient application knowledge. A Strips planner has been used by Thomas & Young (2007) with conventions added to the descriptions of the planning operators and literals to describe the world conditions. According to Riedl & Young (2006), planning is efficient and is able to generate different narratives for different users, and also different narratives for the single user on subsequent play turns. In other words, it generates a new plan for every possible way the user can violate the original story plan. This technique enhances the user's sense of control in the narrative environment (Riedl & Young 2006).

Narrative-based educational games have been the subject of increasing attention. Work done in this area mainly focuses on embedding pedagogical activities in highly engaging, game-like interactions. There are various features used in edugames that mean to increase the effectiveness of these platforms such as: scripted narrative, dynamic generated narrative, evolving characters and student modeling. The following subsections aim to show how the existing edugames have employed these elements and what can be the advantage of the integration of these four features together in a single architecture.

Scripted Narrative

Different ideas have been proposed on the kind of interaction between the learning objectives and the game narrative content. Some edugames used scripted narrative in order to have control of the learner's experience. According to Riedl & Young (2006), scripted narrative is not as adaptive as a planned narrative because it limits the learner's freedom in the environment and requires an extensive amount of authoring work (Figueiredo et al. 2008). However, a scripted approach to interactive narrative can be seen as a 'must' to allow for learner assessment and automated guidance (Lane et al. 2007). A further interactive drama prototype is TIME that has been developed in the field of medicine portraying a situation in the life of a virtual patient (Harless 1986). StoryTeller is an edugame developed in the literacy education domain (Bradford et al. 1999). The narrative in Storyteller is pre-defined by the children at the beginning of the play causing them to follow well-defined scenarios.

Scripted narrative has been used by the BAT ILE edugame used to help learning binary arithmetic and logic gates (Waraich 2004). In BAT ILE, the impact of the student's actions on the narrative is not obvious and a dramatic story is missed. The scripted approach has been used by the game-like environment ELECT BiLAT, a culturally sensitive negotiations simulator that trains high ranking military officers to achieve their military objectives in the field (Lane et al. 2007). The tactical Language Trainer System (TLTS) is an edugame that teaches trainees proper verbal, body language and cultural skills for different languages (Johnson et al. 2004).

Dynamic Generated Story

Many edugames exhibit the presence of a dynamically generated story that allows the production of various stories each time the game is played. This kind of narrative is more adaptable than scripted narrative, where the student actions are recognized in affecting the story as it unfolds. However these edugames do not take full advantage of the storytelling potential seen in interactive drama applications. For example, Mimesis edugame was developed to help middle school students to learn specific physical concepts (Thomas & Young 2007). Mimesis has the learning tasks represented in interactive narrative plans, where each group of learning tasks is designed in a way that leads to one or more educational goal(s). Each learning task is a contained story in itself. Crystal Island is another edugame developed in the microbiology domain (Mott & Lester 2006b; McQuiggan et al. 2008). Predefined tree of contingency plans resulted from offline narrative replanning of partially-ordered plans has been used by the IN-TALE edugame developed for military training skills (Riedl & Stern 2006).

Other edugames contain scenes or plots that generate a story as a sequence of events within which the learning objectives exist. For example, the FearNot! edugame developed to promote awareness about bullying behaviour in schools (Bayon et al. 2003; Aylett et al. 2007) and the TLCTS edugame developed to help people to acquire communicative skills in foreign languages and cultures (Vilhjalmsson et al. 2007). TLCTS uses pre-authored descriptions of scenes, which identify characters, stage settings, and possible dialog exchanges between characters. A quite similar example is the ISAT edugame developed for interactive training (Magerko & Stensrud 2006). Conundrum is another edugame that allows learners to experience ethical decision making in realistic scenarios (Mckenzie & Mccalla 2009). In conundrum, ethical situations are encoded as acts and a sequence of scenes lead to a certain conclusion. Although these edugames manage to generate various stories based on the user actions, they have not taken full advantage of storytelling potential of games seen in interactive drama applications, such as the presence of a story arc and/or evolving virtual agents. Evolving virtual agents can achieve more than simply being single virtual guides and virtual tutors, their role could be extended to interact with each other as a set of characters to present a dramatic storyline. In addition, the agents could serve as all sorts of sparring partners for players to interact with, such as representing the bad guys or companions who ask for help (Weiß & Müller 2008). These properties allow for highlighting of the relationships among the narrative elements of the continuous story, which is considered a key point for provoking active thinking and supporting meaning construction (Dettori & Paiva 2009).

The use of dynamic generated narrative in edugames succeed in varying the generated stories to the user, yet they miss the coherence existing in one continuous story. The presence of a continuous story allows the existence of narrative that 'glues' the generated learning objects together to form one continuous coherent story and preserve the dramatic tension. Another advantage in the presence of a continuous story lies in its ability to engage the learner and capture his attention through the presence of evolving agents whose personalities evolve over the course of interaction with the game. Some edugames manage to have a continuous story such as the IN-TALE edugame (Riedl & Stern 2006) and the TEATRIX edugame (Prada et al. 2000). The IN-TALE edugame performs an offline re-planning to avoid delays of computation resulting in a tree of contingency plans. At run time, when a user action threatens a causal link, the system looks up the appropriate branch in the tree of contingencies and starts executing the new narrative plan. TEATRIX is a learning environment designed to help children and their teachers in the whole process of collaborative story creation. In Teatrix, the narrative emerged from the children and the autonomous agents' interactions to form one continuous coherent story. However, this kind of generated story is not enough to ensure that the trainee is exposed to dramatic and pedagogically relevant situations in an appropriate and contextual order (Riedl & Stern 2006). The 80 days edugame (Law & Rust-Kickmeier 2008), currently under development, in the Geography domain aims to improve adaptive technologies, especially digital storytelling and to shape the learning experience. It also provides technological approaches to reduce developments costs for digital educational games through the development of an authoring tool.

Evolving Non-Playing Characters (Agents)

Generally speaking, Narrative environments are characterized by their rich worlds that allow the presence of stories within which life-like non-playing characters (agents) can be created and are able to act affecting how the stories unfold. It also allows the characters' personalities to evolve based on the surrounding circumstances, their actions and others' actions. Evolving agents increase the engagement and the realism existing in the game. FearNot! shows particular interest in the use of evolving characters during the game course (Figueiredo et al. 2008).

Student Modeling

Adaptation to individual student's needs can be seen as an advantage in any learning environment. The student could benefit from having some form of tutorial guidance when playing educational games as they tend to perform better in more structured pedagogical activities (Conati & Manske 2009). Some edugames have recognized the importance of employing a student model such as BAT ILE (Waraich 2004), TLTS (Johnson et al. 2004), ISAT (Magerko 2006), IN-TALE (Riedl & Stern 2006), Mimesis (Thomas & Young 2007), TLCTS (Vilhjalmsson et al. 2007), ELECT BILAT (Lane et al. 2007) and ELEKRA (Pierce et al. 2008).

2.8 Summary on Educational Games

From the above literature review, it can be seen that non narrative based learning environments are able to deal with well-defined domains, where these environments do not have the characteristics that allow them to deal with ill-defined ones. However, narrative-based learning environments allow dealing with ill-defined domains through the use of narrative and its ability to accommodate tacit knowledge and transfer it.

The non-narrative based edugames contain background stories that act as an engaging factor but does not generated based on the student's actions. Within interactive narrative-based edugames, either dynamic generated narrative is used that loosely allows control over the student's learning experience or scripted narrative as an alternative to achieve greater control on the student's experience. Some developed edugames consider the evolution of the agents' characters inhabiting the environment over play-time. Others use intelligent tutoring components such as pedagogical model and/or student model.

The reviewed systems can be classified according to their student models and the extent they attempt the bandwidths levels of student modeling discussed in Subsection 2.3.2. Some systems attempted the final state bandwidth, such as Wumpus (Goldstein & Carr 1977) and Prime Climb (Stacey et al. 2002). Others were able to attempt the intermediate states bandwidth are: How the West Was Won (Burton & Brown 1976), ToonTalk (Kahn 1999), the AquaMOOSE edugame (Elliott et al. 2002), TLTS (Johnson et al. 2004), JVM (Gómez-Martín et al. 2004) and TLCTS (Vilhjalmsson et al. 2007). Finally, for the highest mental state bandwidth, the ISAT edugame allowed the presence of hypothesized information in the skill and knowledge models, however the current edugame prediction does not make use of this information (Magerko & Stensrud 2006).

Until this point we have considered educational theories that can be applied to the field of teaching in ill-defined domains using computer-based systems. As mentioned, there are some problems encountered in the previously implemented systems, in addition to the obstacles/difficulties existing in the classroom environments. This motivated us to develop a system that adopts these theories and tackles the existing problems. Table 2.1 and Table 2.2 visualize the reviewed edugames' main features.

From the table below the following can be observed: the developed edugames in ill-defined domains either use scripted narrative or dynamic generated narrative. Not all edugames make use of student model despite its importance in providing a personalized learning process. Attempting the high bandwidth in student modeling has not been fully covered by the literature. Systems that use kinds of teaching moments do not have a connecting story between these teaching moments. Evolving agents have been considered in just a few systems. It can be seen that no system allows the combination of all these aspects despite the advantage(s) each component can provide either on the entertaining side or on the educational one.

From the literature review done, it has been noticed that the above games neither make use of any educational theories to guide the design of the games' environments (before the game implementation) nor the design of the learning objects and their presentation to the learner.

Until this point, an overview of the different areas we are interested in has been presented. An architecture that processes the shortcomings in the currently developed educational games is our aim; the combination of scripted narrative and dynamic generated narrative in order to provide a balanced edutaining (entertaining-educating) experience, the use of a student model in order to provide adaptation and personalized learning process and the existence of non-playing characters who are evolving over the play-time. We argue that although each of these components is not a contribution in itself, their combination in one environment is.

Table 2.1: Summary Table

Edugame Name	Linear story	Scripted story	Dynamic Generated Story	Continuous Story	Student Modeling	Pedagogical Agent(s)	Evolving Agents	Evaluation
How The West Was Won	•				•			•
WUMPUS	•			•				•
AquaMOOSE	•							
Prime Climb	•				•	•		•
Betty's Brain		•				•		•
JVM		•			•	•		•
Lincoln	•					•		
Monkey Wrench Conspiracy		•			•			
Talent		•			•	•		•
Ecotoons		•			•			
MITO	•				•			
Robocode								
Toontalk	•					•		•
CeeBot-4		•						
S.C.R.U.P					•			

Table 2.2: Summary Table (cont.)

Edugame Name	Linear story	Scripted story	Dynamic Generated Story	Continuous Story	Student Modeling	Pedagogical Agent(s)	Evolving Agents	Evaluation
ELECT BiLAT		•		•				
FearNot!			•				•	•
Mimesis			•		•	•		
TEATRIX		•						•
BAT ILE	•				•			•
In-TALE		•		•				•
Story Teller				•				•
TIME		•						•
Crystal Island			•					•
ISAT		•						•
TLCTS			•		•			•
Conundrum		•						
TLTS			•		•			•
ELEKTRA		•	•		•	•		•
80 days			•	•				
AEINS		•	•	•	•	•	•	•

2.9 Chapter Summary

This chapter provides definitions for ill-defined domains, character education, Socratic Method, evolving agents and interactive narrative. The chapter presents design approaches for edugames and highlighted the importance of underpinning the edugame design with educational theories. The main features of the various edugames have been summarized, upon which the main points to be addressed through this research have been highlighted and our hypothesis has been shaped.

As seen from the review, edugames exhibit the presence of four features shown to individually increase effectiveness of edugames environments, yet not integrated together. First, the presence of a student model that handles different information about the student, such as the acquired skills, his strength points, his weaknesses and his needs in order to provide personalized learning as mentioned previously. Second, a dynamic generated narrative approach that aims to provide the student with high agency within the environment and generates a story according to the student preferences. The third feature is the use of scripted narrative that constrains the student agency at certain parts that supply education in order to allow tracking of the student's actions and assessment of them. Finally, the presence of a continuous story that engages the student and allows the presence of evolving non-player characters. To the extent of our knowledge, no edugame has integrated these features in a single architecture before.

The integration of these components together is the contribution of this work, where it allows personalization through the use of a student model. The combination of the second and third attributes addresses the limitations existing in both. The use of dynamic generated narrative allows the student to act freely and affects how the story unfolds (high agency). The use of scripted narrative to represent the educational objects restricts the learner's agency when interacting with the educational tasks (low agency) to allow tracking of the learner's actions and assessment of them. This principle is very similar to a game play where the player is exploring the game environment and at certain point he has only one path to go through, in order to force him (implicitly) to perform the required tasks. Finally, the presence of a continuous story with evolving non-playing characters engages the learner by increasing the realism and believability of the environment. Evolving agents can also perform a recognized pedagogical role by helping to supply the educational process. For these reasons, we argue that although each of these components is not a contribution in itself, their combination in one environment is. The next chapter will present the educational theories and the theoretical background that influenced the work done in this research. The next chapter will elaborate on the educational theories role in influencing and guiding the design and the implementation of various AI learning environments.

CHAPTER 3

Background

"Only education is capable of saving our societies from possible collapse, whether violent, or gradual"

Jean Piaget

3.1 Overview

Up until this point, a literature review has been done that raises some issues regarding the lack of educational theories that provide a framework for guiding the design and implementation of the computer-based educational games. Before tapping into the technical features and listing design goals, it might be useful to present the theories that affected our decisions and then justify the choices made. In addition to elaborating on the different and most important features that exist in educational theories and could assist the student player in not only achieving the internal goals of the game but also the external goals of imparting education.

The chapter starts by discussing how educational games can act as situated learning environments and the usage of moral dilemmas in moral development and in fostering character education.

3.2 Situated Learning and Learning theories

Situated learning is learning that takes place in the same context in which it is applied. Lave & Wenger (1991) argue that learning should not be viewed as simply the transmission of abstract and decontextualised knowledge from one individual to another, but a social process whereby knowledge is co-constructed; they suggest that such learning is situated in a specific context and embedded within a particular social and physical environment. In these environments, knowing is not separable from doing (situated cognition). Learning must involve more than the transmission of knowledge but must instead encourage the expression of effectivities and the development of attention and intention (Young 2004) through rich contexts that reflect real life learning processes (Lave & Wenger 1991). In situated theories, the term 'representation' refers to external forms in the environment that are created through social interactions to express meaning (language, art, gestures, etc.) and are perceived and acted upon in the first person sense.

Knowing, in situated learning, emerges as individuals develop intentions through goal-directed activities within cultural contexts which may in turn have larger goals and claims of truth (Young et al. 1997). This can occur in both discovery learning as well as open inquiry learning (Mandrin & Preckel 2009). Discovery learning is an instruction style by which the learners are led to discover a predetermined outcome. The predetermined goal usually consists of finding some general principle by studying specific situations. According to (Bruner 1967), discovery learning has many advantages where it encourages active engagement, promotes motivation and promotes autonomy, responsibility and independence. It also fosters the development of creativity and problem solving skills and allows a tailored learning experience. This theory is closely related to Jean Piaget work.

Inquiry learning allows the learners explore a new field in order to acquire a better understanding in this field (Mandrin & Preckel 2009). However, No knowledge has determined in advance to be acquired. Many learning theories exist can support this kind of learning, for example Gagné's events of instruction, Keller's ARCS Motivational model, and Bloom's taxonomy that have been found to be the most appealing templates to be used in game design principles, in addition to Reigeluth's Elaboration Theory (Gunter et al. 2006).

Gagné has developed *events of instruction* which serve as a guide for developing and delivering a unit or units of instruction. His described nine events are: Attention gaining, objective setting, invoking of prior learning, presentation of new material, created scaffolding, provision of practice, feedback, assessment, and retention-and-transfer of new knowledge to a real-life situation.

According to Keller (1987a), motivation is a necessary but not sufficient condition needed to ensure that learners actually learn something. His ARCS model is represented using the four following classes: Attention, confidence/challenge, relevance and satisfaction/success. Gaining attention is a learning prerequisite while relevance is about what is taught and how it is taught. Confidence is expectancy for success, and finally satisfaction is about how people feel about their accomplishments. Keller's model is intended to be incorporated in accordance with instructional models like Gagné's.

Bloom has identified six levels within the cognitive domain, from the simple recall or recognition of facts, application at the lowest levels, through increasingly more complex and abstract mental levels such as application and analysis, to the highest orders which are classified as synthesis and evaluation (Bloom & Krathwohl 1956). An adapted version of Bloom's taxonomy has been developed that uses the following terms: remembering, understanding, applying, analyzing, evaluating and creating (Anderson & Krathwohl 2001). The top two levels have been essentially exchanged from the old to the new version where creativity and evaluation has changed their places. The updated version goes well with this research assumptions that consider creation/synthesis the highest ranked cognitive operation.

Reigeluth's Elaboration Theory is designed for making scope and sequence content in a way that will optimize attainment of learning goals (Reigeluth et al. 1980). More cognitive strategies are those aim to force the player to use strategies invented by the designers in order to achieve goals and allowing the player/learner to be in control (Gunter et al. 2006). This last strategy component is an obvious requirement for all games since without it a game becomes a non-interactive computer program.

Gunter et al. (2006) believe that designing an educational game is much more difficult than designing an entertainment game in that not only must intellectual control of the design elements that lead to a fun and engaging game be maintained, but also planning instructional elements that lead to educational game experience must be reached. They suggest that the educational game design should be reviewed to ensure it follows Gagné's nine events and Keller's Arcs model. Additionally, the structure of the game progression should be verified against Bloom's mastery level theory to ensure players have the opportunity to master the basics before being asked to perform advanced tasks. More learning theories defined by various researchers have been presented in Jarvinen & Holopainen (2005), the main features of these theories have been summarized in Table 3.1.

Table 3.1: Game Design

Game Design Features	Researchers
Representation, interaction, conflict, and safety. Interactivity is the most important aspect of games.	(Crawford 1984)
Decision making, goals, opposition, managing resources, game tokens, and information. Decision making is the most integral feature of games.	(Costikyan 1994)
How data is represented and what kind of algorithms are used. How player inputs affect the game systems' behaviour over time. Ability to describe players' emotional responses while interacting with the game	(Hunicke et al. 2004)
Identify and collect key elements and aspects that make current good games work.	(Church 1999)
Interactivity, storytelling and narrative.	(Adams & Rollings 2003)
Players, objective, procedures, rules, resources, conflicts, boundaries, and outcomes.	(Fullerton et al. 2004)
Rules to be used in the different design phases are: an imperative statement of the rule. a description of the domain of the rule. rules that take precedence over the rule. rules over which the rule takes precedence. description of examples and counter examples.	(Falstein 2002)

Table 3.1 shows that interaction, conflict, decision making, storytelling, narrative, controlled players, and rules are all important aspects that should be considered to develop a successful game. These aspects have been considered in setting the design goals of the developed educational game as will be seen in Chapter 4.

3.3 Ill-Defined Domains

Ill-defined domains are those domains that exhibit one or more of the following characteristics:

- Cannot be described in a finite set of production rules (Scandura 2003).
- Components of problem spaces are not fully specified. In particular, the problem descriptions lack a precise definition of a concrete and visualized goal-state (Ormerod 2006).
- Lack of defined rules that help in progressing in the solution path from the initial step to the final step (Ormerod 2006).
- Each case of knowledge application involves the concurrent interaction of multiple conceptual structures such as schema or organizational principles, each of which is individually complex. The interaction of these structures varies substantially across cases nominally of the same type, producing across-case irregularity (Ogan et al. 2006).
- Different decisions can be defended based upon different criteria and it often depends on how the solver conceptualizes the situation (Lynch et al. 2007).
- Lack consistent, unambiguous, and generalizable solutions (Lane et al. 2007).

Learning in ill-defined domains is more complex than in well-defined domains. In the former, knowledge is incomplete which may increase the need to use heuristics to solve the domain problems, in addition to improve skills. Within well defined domains such as maths and physics there exist procedures and methods to investigate and validate the correctness of a problem answer. The student working on such problems can check the correctness of his answer by checking the appropriate rules. In contrast, ill-defined domains lack the formal methods that can justify an answer. Good solution can only be evaluated by members of the problem-solving community to check the validity of this response (Voss & Post 1988) or is the one that is most viable and most defensible (Leader & Middleton 2004).

Various aspects should be considered while teaching in ill-defined domains, such as: firstly, encouraging students to think critically (Avner et al. 1980). Secondly, helping students to employ a rich base of shared knowledge and beliefs held by a community in order to evaluate and communicate knowledge claims (Shin & McGee 2003). Lastly, encouraging students to draw analogies as this can play an important role in transferring ill-defined problems into well-defined ones. This idea follows (Simon 1973) and his explanation of the architect's design process: "During any given short period of time, the architect will find himself working on a problem which, perhaps beginning in an ill structured state, soon converts itself through evocation from memory into a well-structured problem."

In conclusion, ill-defined domains can be seen as challenging domains that require innovative methods in order to help teaching in these domains. We are interested in the ethics domain, especially character education that fosters core ethical values in addition to supplementary values that promote ethical, responsible, and caring young people.

3.4 Moral Development

Jean Piaget is a philosopher well known for his pedagogical studies, he explored the implications of his theory to all aspects of cognition, intelligence and moral development (Piaget 1928). Piaget described the four development stages of children as follows:

Sensorimotor stage where the child is able to differentiate self from objects and note the characteristics of the action and its effects.

Preoperational stage where the child learns to use language and to represent objects by images and words. He is able to identify objects through single feature.

Concrete operational stage where the child Can think logically about objects and events. He is able to identify objects through several features.

Formal operational stage where the child can think logically about abstract propositions and test hypotheses systematically. he starts to use constructed knowledge to create still more complex objects and to carry out still more complex actions.

Many of Piaget's experiments were focused on the development of mathematical and logical concepts. The theory has been applied extensively to teaching practice and curriculum design in elementary education, for example (Bybee & Sund 1982; Wadsworth 1978). Piaget's ideas have been very influential on others, such as Lawrence Kohlberg.

3.4.1 Kohlberg's Stages of Moral Development

> *"A moral is a message conveyed or a lesson to be learned from a story or event."*
>
> *(Daeg de Mott 2001)*

Initial educational efforts employing Kohlberg's theory were grounded in basic Piagetian assumptions of cognitive development. For Kohlberg, the right is what must be universally valid across societies. Kohlberg's theory consists of a sequence of qualitative changes in the way an individual thinks, as follows (Kohlberg 1984):

Punishment and obedience avoidance of physical punishment and deference to power

Instrumental exchange exchange of favors or blows. "You scratch my back, I'll scratch yours."

Interpersonal conformity right is conformity to the behavioural expectations of one's society or peers. Good behaviour is that which pleases or helps others within the group.

law and order respect for rules, laws and properly constituted authority.

Prior right sand social contract moral action in a specific situation is not defined by reference to a checklist of rules, but from logical application of universal, abstract, moral principles.

Universal ethical principles an individual who reaches this stage acts out of universal principles based upon the equality and worth of all human beings.

Kohlberg's six stages can be more generally grouped into three levels of two stages each: pre-conventional, conventional and post-conventional. The pre-conventional level consists of the punishment and obedience orientation stage (How can I avoid punishment?) and the self-interest orientation (what's in it for me?). The conventional level consists of the interpersonal accord and conformity stage (social norms)(The good boy/good girl attitude) and the authority and social-order maintaining orientation stage (law and order morality). Finally, the post-conventional level consists of the social contract orientation stage and the universal ethical principles (principled conscience). Kohlberg used moral scenarios that have been referred to as Kohlberg's dilemmas and was interested in how people would justify their actions if they were put in a similar moral crux. According to Kohlberg, if children get engaged in enough independent thinking they will eventually begin to formulate conceptions of rights, values, and principles by which they evaluate existing social arrangements (Crain 1985).

Although Kohlberg's work inspired lots of follow-up work (Colby et al. 1983; Lind 1985; Duriez & Soenens 2006), there has been criticism of Kohlberg's theory of moral development and his methods. Critics claim that Kohlberg's stages were derived exclusively from interviews with males thereby failing to capture the distinctly female voice on moral matters (Crain 1985). The use of hypothetical situations skews the results because it measures abstract rather than concrete reasoning. Other criticisms are to do with empirical matters, such as the problem of invariant sequence (stages cannot be skipped), the prevalence of regression (regress backward in stages), and the relationships between thought and action (Crain 1985). Despite the criticisms, this does not affect the fact that Kohlberg's dilemmas are well designed moral stories that involve the participant in a moral reasoning process. Accordingly, we have chosen some of Kohlberg's dilemmas to use in our work, side by side, with other moral dilemmas authored specifically for school children.

Kohlberg established the Moral Judgment Interview in his original 1958 dissertation (Kohlberg 1958). During the roughly 45-minute tape recorded semi-structured interview, the interviewer used moral dilemmas to determine which stage of moral reasoning a person used. The dilemmas were fictional short stories that described situations in which a person had to make a moral decision. The participant was asked a systemic series of open-ended questions, like what they thought was the right course of action, as well as the justifications for certain actions if they were right or wrong. Only the form and structure of the replies were scored and not the content itself. Over a set of multiple moral dilemmas an overall score was derived (Colby & Kohlberg 1987). Based on that score the current moral reasoning state was mapped to one of the moral development stages.

As can be seen from above, Kohlberg's theory takes values as a critical component of the 'right'. Whatever the 'right' is, for Kohlberg, it must be universally valid across societies (known as "Moral Universalism") (Kohlberg 1971). However, it is worth mentioning that this opinion does not deny the ill-defined nature of the moral dilemmas, it only provides a way that could be used to define what the 'right' is. Yet, as described in Section 7.2.2, it could be possible to divide the whole moral dilemma (main problem) into sub-problems, where each is less ill-defined and could be addressed as a well-defined problem. In this case, answers to these subproblems could be evaluated under the umbrella of the "Moral Universalism" idea suggested by Kohlberg..

According to Piaget (1932), "the child is someone who constructs his own moral world view, who forms ideas about right and wrong, and fair and unfair, that are not the direct product of adult teaching and that are often maintained in the face of adult wishes to the contrary." This is an important point that should be considered when teaching children about ethical values. Teaching children about ethics cannot be done by dictating our definitions of 'right' and 'wrong' to them, instead they learn as a result of their construction of their own moral world view. Therefore, providing the children with a safe environment wherein they can experience situations that foster their moral reasoning, could be seen as a plus.

3.5 Character Education

Character education is an important branch of the ethics domain. It is an ill-defined area that does not contain explicit right or wrong answers to its problems. It holds core ethical values such as caring, honesty, fairness, responsibility, and respect for self and others. Effective character education promotes these values along with supportive performance values such as diligence and perseverance that form the basis of good character (Lickona et al. 2007). Different methods have been used to teach these values as shown previously in Chapter 1. Involving students in role playing and to put themselves in another's shoes are quite successful techniques. These educational methods allow self reflection and, in it, education is centered on themes and concepts and the connections between them, rather than isolated information (Kelly 2003).

Teachers encourage students to think and explain their reasoning instead of memorizing and reciting facts. They guide the students through discussions to help them recognize what is good and what is bad. In doing so, the Socratic Method is used. However, the limitations of these methods arise from the classroom constraints mentioned in Chapter 1. The classroom teacher would not be able to deal with every single child in the class and to adapt the rest of the story according to the individual misconceptions raised by each of them. Therefore adaptation to individual students in classrooms can be thought of as a very difficult task if not impossible.

3.6 Socratic Method

The Socratic Method is is a form of inquiry and debate between individuals with opposing viewpoints based on asking and answering questions to stimulate critical thinking and to illuminate ideas. It is dramatic, entertaining and triggers lively classroom discussion. According to this model, the teacher asks a series of questions that lead the students to examine the validity of an opinion or belief. The Socratic Method is a powerful teaching method because it actively engages the learner and encourages critical thinking, which is just what is needed in teaching ethics, values, and other character issues. This is a very important issue as it allows appropriate number of choices during ill-structured and authentic investigations that lead to the development of inquiry skills (Avner et al. 1980). Lynch et al. (2008) have shown that even in domains where it is impossible to make sharp distinctions between good and bad solutions due to the lack of ideal solutions or a domain theory, the solution differences are meaningful. An analogy can be drawn where the students' different answers to a Socratic Dialogue can be seen as meaningful and able to reflect their own beliefs and thoughts.

The Socratic Method displays its strengths when the students make a 'bad' choice. Through discussion, students should then be forced to face the contradictions present in any course of action not based on principles of justice or fairness. This method requires a delicate balance between letting the students make decisions and demonstrating the limits in their reasoning. Finally, 'raising the ante', which is defined as raising the stakes and introducing consequences, is a tactic followed if the student sticks with the unethical choice. For example, if we would like learners to investigate the effects of stealing, we could pose the problem of shoplifting and ask what they would do if they were the owners. In summary, the Socratic Method helps students to think critically, solve problems non-violently, and make choices based on what is right instead of what they can get away with.

The use of the Socratic Method in moral dilemmas seems as an adequate technique, especially with young children and adolescence, for its ability to encourage critical thinking as mentioned previously. It allows the children to figure out any course of unethical choice or action by themselves and consequently to learn through self experience. It also helps in preventing the fantasy world from delivering wrong/un-true knowledge by presenting the suitable argument and negative consequences for any unaccepted action. The next sections provide examples of moral dilemmas and how they can be used in our work, in addition to the role of interactive narrative as a successful technique in delivering tacit knowledge culminating in ill-defined domains.

3.7 Chapter Summary

This chapter discussed the effectiveness of situated learning and problem solving strategies and why and how could they be employed in educational games' environments. It highlighted the concepts and theories behind this research and discussed the different moral development stages introduced by Piaget's and Kohlberg's.

Character education is a challenging area that requires quite clever pedagogies that raises curiosity, challenge and enhances problem solving skills. The Socratic Dialogue has been chosen for what it can offer, as it aims to force the student to discover for himself any course of contradiction present in his action(s). The next chapter will elaborate on designed architecture and will illustrate how the architecture has addressed the design aspects.

CHAPTER 4

Proposed Model and Architecture

4.1 Overview

Thus far, this thesis has motivated rigorous empirical research on educational games especially narrative_based ones. The idea of this chapter is centered around developing an innovative educational game architecture that allows the presence of individual elements that each has shown effectiveness in edugame environments but has not yet been aggregated in a single architecture. These elements are: a continuous dynamic generated story, a scripted branched narrative, a student model, and pedagogical evolving non-player characters. The chapter also aims to discuss the different possibilities and choices incorporated in the decision making process related to the representations of the different modules.

4.2 Design Goals

Requirements for successful educational games as suggested by Amory et al. (1999) are:

1. The edugame must present an engaging story to the student.
2. The edugame should have sufficient stimulation to engage learners in knowledge discovery.

3. The edugame should provide optimum level of challenge; not too easy, not too long, not too short, not too difficult, not illogical.
4. The relationship between the educational needs and game elements should be recognized.
5. The educational material should be integrated with the game story, where game objects are associated with educational outcome(s).

This list of features has been extended in this research to include:

6. The edugame design must be based on learning theories.
7. The edugame should include one or more intelligent tutoring components in order to provide a personalized learning process and resolve the player's misconceptions within the learning environment.
8. The edugame must provide students with opportunities for personal discovery through problem solving.
9. The developed edugame should be evaluated with respect to games aspects and its ability to provide educational outcomes (evaluation phase).
10. The educational outcomes should be measured according to Bloom's taxonomy (evaluation phase).

4.3 Proposed Architecture

In the previous chapter we have motivated the need for an edugame design that is able to: (1) satisfy the above goals. (2) allow a balanced user edutaining experience (educational entertaining experience). (3) Provide a personalized learning process. With this view, the architecture shown in figure 4.1 has been designed. The architecture consists of two separate but mutually interacting levels: the tutoring level and narrative level.

4.3.1 Tutoring Level

The tutoring level aims to engage the learners in an adaptive learning process and to interact with the learner based on an understanding of the learner's behaviour in order for the educational process to be as effective as possible. This level consists of four components: a domain model, a student model, a pedagogical model (*seventh goal achieved: the presence of an intelligent tutor components*), and a presentation model.

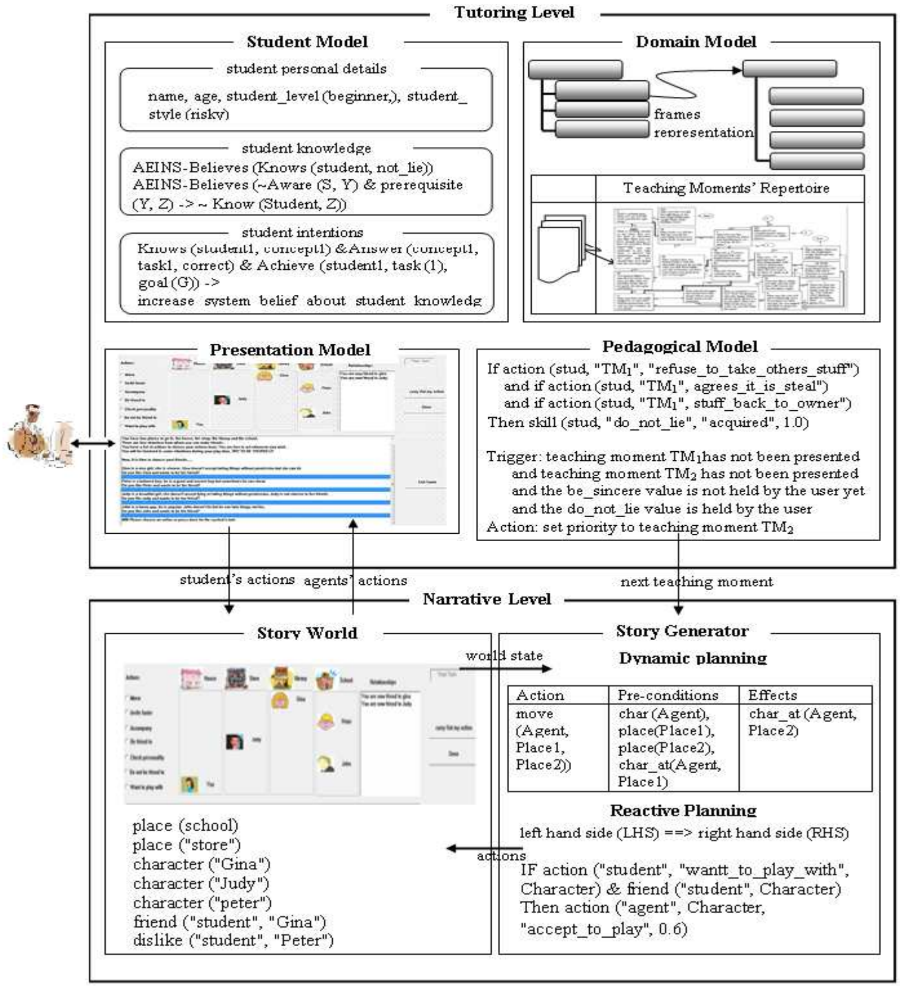


Figure 4.1: The various modules of the architecture

4.3.1.1 The Domain Model

The domain model is a main component of tutoring systems; it consists of the educational concepts and their relationships; dependency upon each other. In the character education domain, there are no natural relations and rules that guide the conceptual view of the domain and inform the design of a computational model. In addition, concepts in this domain can be merely seen as skills that should be practiced in order to allow progression in the education process.

To represent the domain model, knowledge representation techniques should be used in order to define the concepts and their relationships and dependencies. Since there is no curriculum sequence that can allow us to validate and/or verify these kinds of relationships, experts' opinions are needed. The frame knowledge representation seems suitable for this task for the following reasons: firstly, it allows no costly search processes where all the facts and properties connected with a concept are located in one place; secondly, frame structures are well-suited for the representation of schematic knowledge. Each frame has its own name and a set of attributes, or slots which contain values; for instance, the frame for trustworthy moral virtue (root concept) might have slots that corresponds to sub-concepts (sub-skills) that should be mastered in order to consider the main concept (skill) mastered such as be-honest and not-lie values. Lastly, the frame representation provides a flexible model as it allows partial ordering of the dependencies and relationships between the domain concepts. In this way, it leaves 'room' for the pedagogical model to choose the next concept to present the student with based on the current student model, see figure 4.2. However, the frame representation lacks the presence of associated reasoning/inference mechanisms, as mention in Section 2.4. Therefore rules could be integrated to overcome this through their ability to provide direct inference mechanism (start from well-known results, such as the axioms and the premises then apply inference rules successively until arriving to the required goal in question).

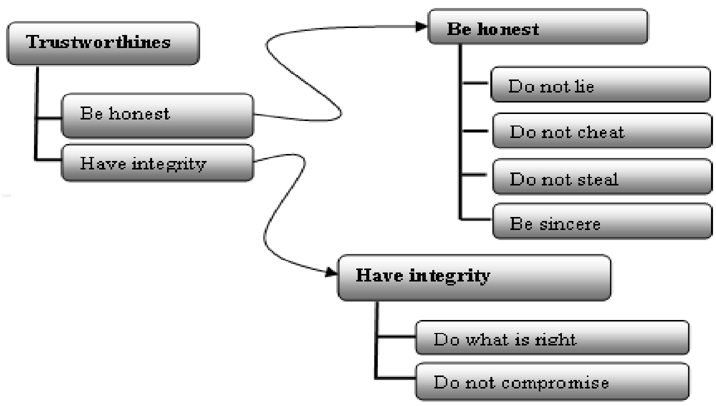


Figure 4.2: Domain representation

The domain model should contain exercises that engage the user with the domain concepts in a pleasant engaging way. Following the characteristics of the domain, moral dilemmas can act as suitable exercises. Each moral dilemma can be referred to as a teaching moment. Every teaching moment can be imagined as non-interactive story presentations interleaved with user-decision points that allows the story to progress forward. In other words, every node is a distinct situation of the world and the directed edges link decision points with each other or leads to an end (Magerko 2006), see figure4.3. The story beats can be seen as decomposable sub-problems that represents a sub-task of making a decision about components of a particular type. For example, helping a friend to shoplift. The aggregation of all the sub-tasks leads to solving the main task in question (Simon 1981).

Keller (1987b) defined Attention, one condition of curiosity, as 'capturing the interest of learners and stimulating the motivation to learn'. Training and exercises in AEINS are provided in a similar context, for example if the student fails to show that his beliefs towards certain misconception (wring value) have been altered then the next teaching moment will focus on the same misvalue. It has been shown that by providing a familiar context, learners are able to better activate their prior knowledge (Anderson et al. 1977). In addition, the text of the teaching moments is written to be engaging and students can interact with them. For instance, after reading a later sentence, a new interpretation emerges that leads the student to reread a prior sentence to check (get feedback on) that interpretation (Koedinger & Aleven 2007). When needed, during the interaction with a teaching moment, some questions are worded from the perspective of the learner to provide a meaningful context and facilitate the activation of prior knowledge. This technique has shown its usefulness in the learning process (Anderson & Pichert 1978). Moreover, the teaching moments design should allow unexpected ends to raise the student's curiosity (Mergel 1998).

The student interaction with these teaching moments satisfies problem based learning condition that satisfies partially the second design goal: 'sufficient stimulation to engage learners in knowledge discovery' and satisfy the eighth design goal: 'provide students with opportunities for personal discovery'. The exercises should be authored in a way that fits naturally within the edugame elements alomg with various various difficulty levels in order to attempt different student educational levels; novices and experts, to provide an optimal level of informational complexity (Piaget 1928) as can be seen in Figure 4.4. This partially addresses the third design goal: 'provide optimum level of challenge'.

In figure 4.4, The concepts in the domain model are connected to a teaching moments' repertoire. Each concept is mapped to more than one teaching moment where each provides certain level of challenge. In this way, the suitable teaching moment would be presented to the learner according to his current skills.

4.3.1.2 The Pedagogical Model

The pedagogical model adapts instruction (problem selection, problem difficulty, topic area, choice of activity, choice of help type, and availability of help) following a model of human tutoring expertise that balances motivational and cognitive goals. The pedagogical model should include the knowledge tracing model (Koedinger & Aleven 2007)

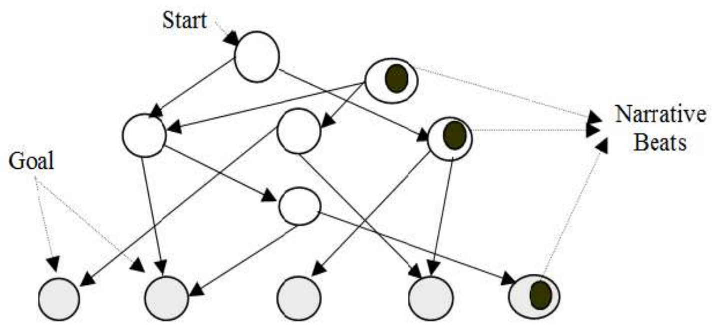


Figure 4.3: Representation of structured narrative

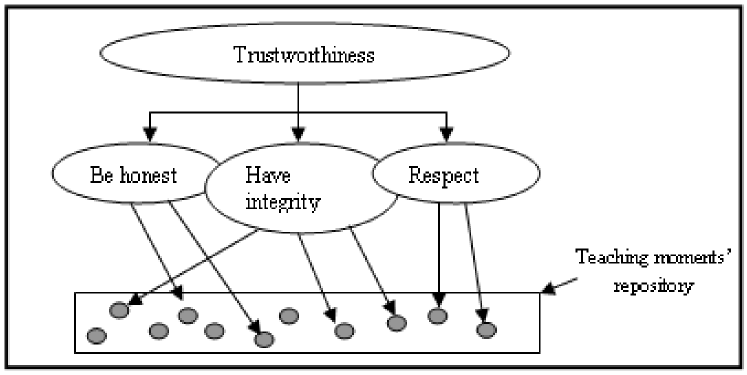


Figure 4.4: Mapping of the moral values to the exercises repository

in order to interpret each student's actions as they work through problem scenarios. The results of the tracing model can be used to provide the individual students with personalized feedback and to guide the selection of the problems relevant to the individual student's needs. Furthermore, the model should be able to evaluate the student's level of mastery of the knowledge components, concepts and skills, in a curriculum unit.

As discussed before in Chapter 2, development in ill_defined domains is merely a change in the way a person thinks, and is not necessarily the case of acquiring more knowledge. Since it is difficult for children to express their thoughts and beliefs the same way adults do, allowing them to act can be seen as the appropriate substitute. Accordingly, the pedagogical model can assess the student on these bases. The model should be able to track the student's actions, assesses the student's skills and updates the student model accordingly.

Rule chaining can act as the suitable representation method that allows the pedagogical model to apply specific cognitive operations to reason about the student and the teaching process. The modularity of rules simplifies the task of updating the knowledge base. Individual rules can be added, deleted, or modified without drastically affecting the overall performance of the system (Buchanan & Shortliffe 1984). A rule representation of the model can be of the following form.

```
Trigger:  teaching moment TM1 has not been presented
   and teaching moment TM2 has not been presented
   and skill2 is not held by the user yet
   and skill5 is held by the user
Action:  set priority to teaching moment TM2
```

The above representation denotes that if (a) a specific pattern of teaching moments (TM_1 and TM_2) has not been presented to the student yet and (b) the student holds certain values (e.g. sincere) and does not hold others (e.g do not lie), the action part of the rule executes (teaching moment TM_2 has priority over teaching moment TM_1). If several rules have been satisfied, sometimes this results in having more than one teaching moment suitable to be presented next to the learner. In this case, one of the teaching moments is chosen randomly.

The pedagogical model decisions consider the student's needs, weaknesses and strengths in order to provide an environment that is neither too complicated nor too simple with respect to the student's existing knowledge as suggested by Malone & Lepper (1988).

4.3.1.3 The Student Model

The student model is a crucial component that mainly aims to guide an adaptive learning process based on the student current skills. This satisfies partially the third design goal: 'provide optimum level of challenge'. It involves creating an individual model for every student. The student model should include demographic data such as name, gender, and age. It should also include the level of mastering individual concepts, indications about the student misconceptions. For example, an incorrect application of a certain skill and whether this has been remedied at any stage during the game. Moreover, the model should also have indication(s) of where the student's strengths and weaknesses lie in relation to the game (for instance, making decisions in unanticipated situations).

Production rules have been chosen to represent the student model for its power in allowing for compact knowledge representation and high levels of automation as well as flexibility to adapt to rapidly changing information. An example of capturing the student's learning skills via rule representation can be as follows:

```
student_acquired (skill1, CF1) & student_acquired (skill3, CF2)
& student_not_acquired (skill4, CF3), goal(G))-> learned_concept
(main_skill1, ''held'', Z)
```

CF_1, CF_2, CF_3, CF_4 can act as confidence factors that can be used to compute the whole rule confidence Z.

Finally, in order to attempt the high bandwidth (mental states bandwidths), other rules that can construct new information about the student using existing ones may be used as follows:

```
student_knows (concept1) & Answer (concept1, task1, correct) &
student_achieve (task1, goal(G))-> increase_system_belief_of_
skill1 and skill2
```

This representation denotes that if the student knows $concept_1$ and the student answers the related task correctly and the student is able to achieve the required goal, then the system should increase its belief about the student's knowledge on $skill_1$ and $skill_2$. This kind of information enriches the student model, and helps the pedagogical model to provide a personalized learning process.

4.3.2 Narrative Level

The narrative level aims to engage the learner in a continuous story, where he is able to act and affect the unfolding of the story. The narrative level consists of two components: a story generator and a world model.

4.3.2.1 The Story Generator

As mentioned previously in Subsection 2.7.4.2, there are different types of narrative; linear, branching and dynamically generated narrative. Both branching and dynamically generated narrative allow various experiences to the user. However, it can be seen that the branching narrative drawback lies in constraining the user's agency and that of the dynamically generated narrative lies in the difficulty of tracking the learning process.

For the purpose of this research, the edugame story should allow high agency to the user and in the same time allow tracking the user's actions when an educational theme is presented. Allowing high user agency and tracking the learning process in parallel seemed as the bottle neck in designing the story generation module. A solution to this problem can be seen in the integration of more than one narrative technique in order to balance the user agency and track the learning process during the play time course. Planning, such as STRIPS, can be used to dynamically generate different stories at run time based on the student's actions. First goal achieved through presenting an engaging story to the student. In the same time the story generator should be able to integrate more structured narrative, (see figure 4.3) that employs educational material without affecting the student's experience. This actually allows the achievement of the fifth goal: 'integrating educational material to game story'. It will be also useful to allow the agents inhabiting the world to employ reactive planning in order to appear more realistic and believable.

This allows the partial achievement of the second design goal: 'sufficient stimulation to engage learners in knowledge discovery'. An example of the world model representation is as follows:

```
place(‘‘house’’)
place(‘‘library’’)
character(‘‘Gina’’)
character(‘‘Judy’’)
char_at(‘‘Gina’’, ‘‘house’’)
friend(‘‘student’’, ‘‘Gina’’)
personality(‘‘Gina’’, ‘‘honest’’, ‘‘not_responsible’’)
```

4.3.2.2 The Presentation Module

The presentation module handles the flow of information and monitors the interactions between the user and the system and vice versa. Keller's ARCS model (Mergel 1998) has been chosen for its suitability to games in designing the edugame interface in a way that helps to partially address the sixth design goal: 'edugame design should be based on learning theories'. This module can address the four classes of the ARCS's model: Attention, Relevance, Confidence/Challenge, and Satisfaction/Success (Mergel 1998) to enrich the module's design. Gaining and keeping the learner's attention can occur through the presence of a graphical interface and non-playing characters. Relevance could be provided through supplying a world similar to the student's real world by allowing them to interact with similar situations that might face them in real life. The presentation module should provide a facility that allows the student to view the history of the game play in order to help with self reflection and self assessment. For example, reasoning about previous actions that lead to the current situation (e.g., losing a friend). It is also valuable to present and engage the learner in activities with unexpected ends, which raise his/her curiosity and lead to satisfaction.

4.4 Chapter Summary

This chapter provides the goals set for having successful educational games and gives an idea about how these goals were tackled by the proposed architecture. Achieving the first goal: 'the presence of an engaging story to the student' has been achieved directly through the presence of dynamic interactive narrative. Whereas, goal 6: 'the design should be based on learning theories' has been achieved through considering Gagné's nine events and Keller's ARCS model. In addition, goal 5: 'the educational material should be integrated with the game story' has been achieved through presenting the teaching moments to the learner in narrative form as part of the main game story. Moreover, goal 8: 'providing students with opportunities for personal discovery' has been addressed through the problem solving of the teaching moments and the exploration of the game environment.

Other goals were achieved by considering them in more than one element in the design, for example Goal 2: 'the edugame should have enough stimulations to engage learners' has been considered in the teaching moments design by providing curiosity that helps to engage the learner and has been also considered in the world model through the presence of non-playing characters. Goal 3: 'provide optimum level of challenge' was achieved through the presence of a student model that provides adaptation to the student's level and the existence of various teaching moments that attempt different levels of the student's skills. Goal 7:'the edugame should include one or more intelligent tutoring component' has been tackled through the presence of an intelligent tutor modules represented in the domain model, student model and pedagogical model. Goal 4: 'the relationship between the educational needs and game elements' was addressed through the presence of non-playing characters that inhabit the game world and help in supplying the educational material. In addition, the proposed design couples learning and gaming where game levels were achieved through progressing in the learning process. A summary on how the goals have been achieved by the various edugame components is shown in figure 4.5.

It can be perceived that achieving goal 6: 'the edugame design must be based on learning theories' can contribute to achieving goal 10: 'the educational outcomes should

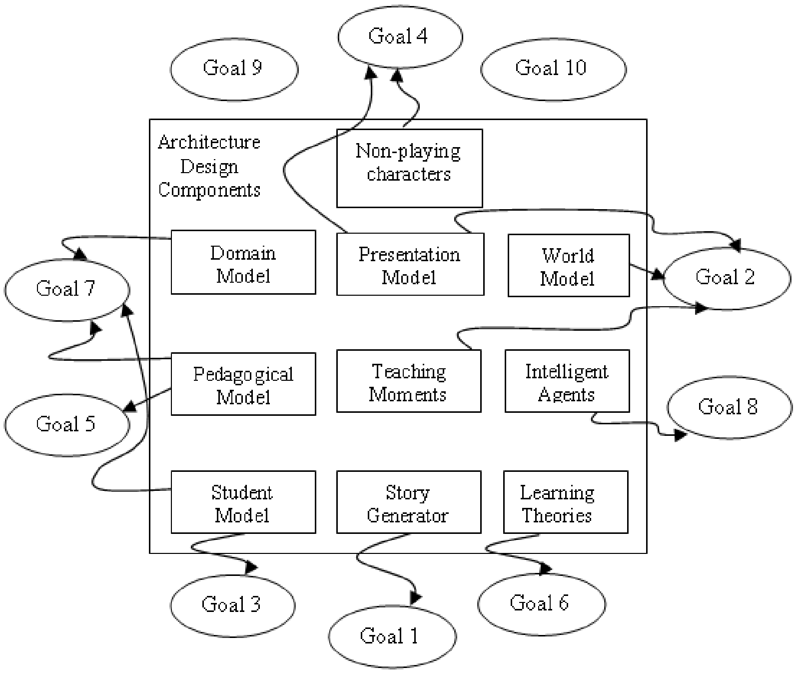


Figure 4.5: Summary of goals achievement

be measured according to Bloom's taxonomy' at the evaluation phase. Goal 9: 'the developed edugame should be evaluated versus games aspects and its ability to provide educational outcomes' can be also achieved in the evaluation phase by verifying the implemented prototype to Gee's games aspects.

The proposed architecture in this chapter manages to incorporate hybrid narrative generations and an intelligent tutor that can track the students' actions and assess them. A frame representation has been selected to structure the domain model as it offers clear visualization of the domain concepts and facilitates the pedagogical model job in choosing the appropriate educational content. A rule representation has been found useful in capturing the student's knowledge and behavior. A model of how the intended edugame should work has been presented. The next chapter will show how the presented architecture will be used to implement an edugame prototype for the empirical study.

CHAPTER 5

Implementation

5.1 Overview

In the previous chapter, we proposed an architecture that was able to achieve the design goals set based on the literature and our view. General descriptions and expectations of each module have been displayed and discussed along with the considered choices. Thus far, this thesis has motivated rigorous empirical research on educational games, especially narrative_based ones. The proposed architecture makes a contribution in the educational games area. The contribution has been shown in the integration of hybrid narrative and intelligent tutor to allow the presence of a continuous story and evolving agents. The integration addresses the learner's agency versus tracking the learning process problem that exists in educational games. This chapter presents the implementation and the interaction between the different modules of AEINS and shows how the AEINS manages to engage, support and encourage the learner by considering his needs, strengths and weaknesses.

5.2 AEINS

AEINS is an Adaptive Educational Interactive Narrative System that has been implemented based on the architecture described in Chapter 4. The main aspect of AEINS is its ability to integrate a hybrid narrative technique and an intelligent tutor that makes use of a student model. AEINS aims to provide an adaptive learning environment that engages the student and allows knowledge discovery through problem solving. The AEINS architecture is shown in Figure 5.1.

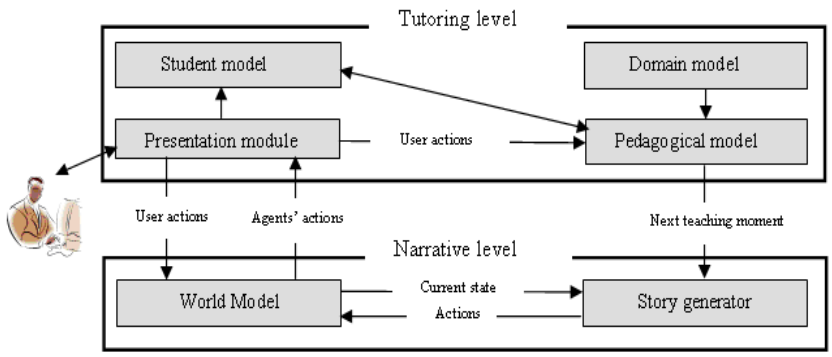


Figure 5.1: AEINS architecture

AEINS is implemented in order to help teaching 8-12 year old students about basic moral virtues. Each virtue corresponds to one or more skills needed to be practised by the students. Skills development is judged through the student's interaction with AEINS. AEINS uses problem based learning techniques following the constructivist approach to learning. Problem-based learning is a learner-centered approach, which is grounded in cognitive theories and focuses on putting students in real-world problem situations that can enhance the students' motivation (Haith-Cooper 2000) and helps them in identifying what to learn and develop in order to solve the problem (Gordon & Brayshaw 2008).The inquiry existing in this procedure helps the creation of the learner's knowledge based on his interpretation and processing of what is received (Lo et al. 2008).

Problems in AEINS are designed in a way that facilitate exploration and experience of different moral actions, in addition to the presentation of new insights allowing the students to see the consequences in a safe environment. The inquiry provided through the use of the Socratic Method allows the students to discover for themselves what knowledge gaps and deficiencies they may have, along with skills they may need to develop. AEINS is able to provide support through providing feedback implicitly within the environment. For example, if the student accepts to lie to in favour of his friend, AEINS highlights the point that although friendship is important it should not be a reason for the student to undertake such unethical action. AEINS starts presenting the learner with bad consequences such as losing a friend or being told of as a kind of punishment in order to help him recognize the presence of a misconception (gap).

5.2.1 How AEINS works?

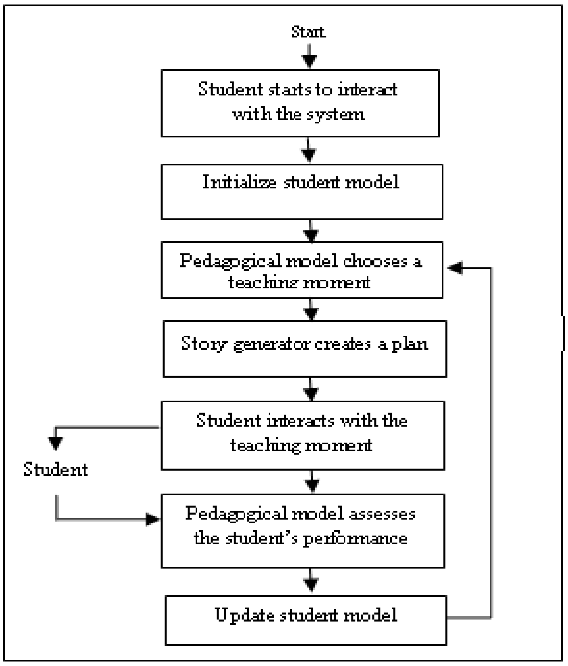


Figure 5.2: The game model

Based on the designed architecture, an edugame is planned to be developed. In 2004, Gee published a condensed list of principles of learning that should be built into good computer and video games (Gee 2004a). The principles are categorized under three main themes: Empowered Learners, Problem Solving and Understanding. The developed edugame should be evaluated against these aspects. The more aspects are achieved the higher the prototype can be considered to be a successful game. This will be discussed in detail later in this thesis, see Section 6.5. Moreover, Gagné's nine events (Gagné et al. 1992): attention gaining, objective settings, invoking of prior learning, presentation of new materials, created scaffolding, provision of practice, feedback, assessment and retention-and-transfer of new knowledge to real life can be followed to inform the design of the edugame.

A model of the game is imagined to work as shown in figure 5.2. The game starts by presenting the game world to the student and gives a brief introduction about the world. Since there are no default skills that could be assigned to the student, the game initializes the student model by allowing the student to choose his friends from a group of children, each child has his own personality, in order to assess the student's primary skills and start the tutoring path. This way has been chosen over asking direct questions to the student such as ‘are you an honest person?’ or ‘are you a sincere friend?’. The direct questions provide bias to have ’yes’ as an answer to these questions. In addition, it is always easier to judge people than judging ourselves. In the light of these findings, an indirect method employed in choosing friends with certain personalities has been chosen. This method implicitly reflect the beliefs of the student, for example if the student agrees to be friend to a character who lies, this means he accepts and agrees on the lie principle in itself even if he is not a liar himself. Accordingly, we think that the student needs to see the consequences of lying and recognize that it is not good to even accept friends who lie.

The next step is for the pedagogical model to choose the suitable teaching moment, based on the domain model and the current student model. To present the teaching moment, the teaching moment preconditions should be satisfied. The teaching moment tag is sent to the story generator, which in turn produces the suitable plan, set of actions, that should be taken to satisfy the required preconditions (narrative goals).

The student is free to act and may violate the generated plan. The story generator role is to respond to the student’s actions through the story world by allowing the inhabitant agents to act and revise the plan accordingly. Once the preconditions are satisfied, the teaching moment begins and the student starts interacting with it through the presentation module and gets engaged in a conversation that evolves depending on the student’s actions and choices. The pedagogical model assesses the student performance and updates the student model accordingly. The cycle continues as shown in figure 5.2.

5.3 Domain Model

The domain model consists of moral virtues with each corresponding to one or more skills that need to be practised and mastered. The domain knowledge is built using the concepts provided by Elkind & Sweet (1997) and represented in hierarchal frames, see Figure 5.3. Due to the lack of our experience on the educational and philosophical side of the ethics domain, Professor Helen Haste, Emeritus Professor of Psychology, has been consulted. Profesor Haste agreed that the represented model is quite a clear representation of what one might call common sense and popular views. She added that the model can be used by all means as a basis for developing our game.

The ethics domain has an ill-defined nature, therefore building a conceptual model seems a very difficult task. Dependency and relationships between concepts seems im-

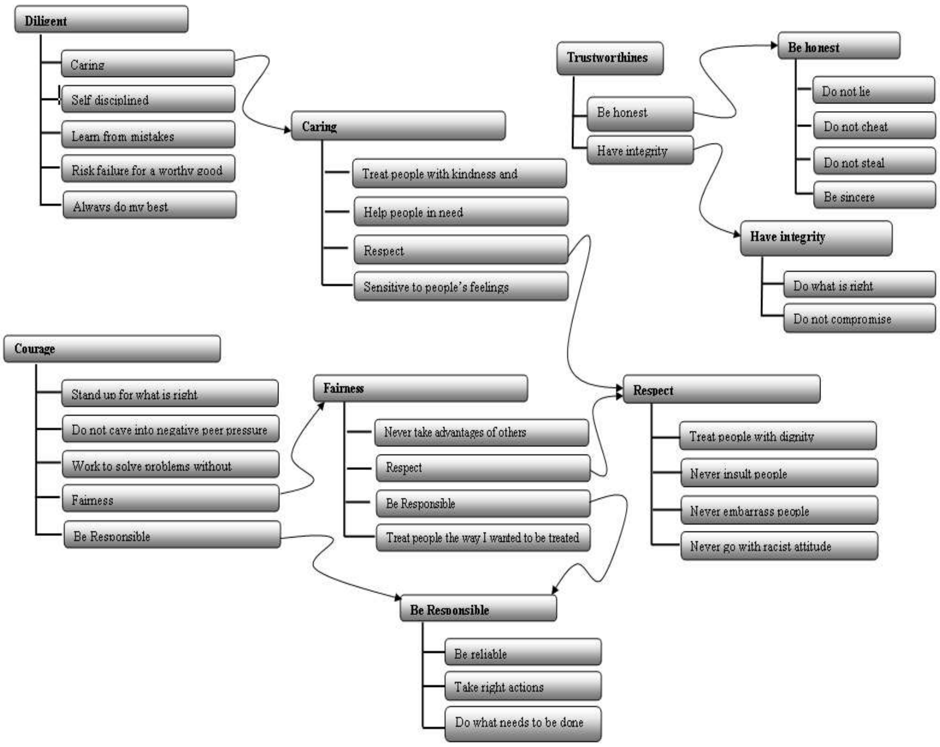


Figure 5.3: AEINS domain model

possible to define, on the other hand inheritance can be found as one attribute that can help in conceptualizing the ethics domain. This bias the choice to frame representation, which also raise the lack of inference mechanisms associated to this representation, as discussed previously in Section 2.4. Rules can provide a powerful reasoning mechanism that can be attached to the frame representation leading to a quite useful knowledge representation structure. Moreover, the frame knowledge representation provides partial order hierarchy that partially restricts the delivery of the curriculum sequence. This property gives the chance to the pedagogical model to vary the presentation sequence based on the current student model. Figure 5.3 shows that some skills need to be practised in order to achieve higher skill levels. For example mastering the fairness value requires mastering trustworthiness and be_responsible values. The second part of the domain model comprises of a teaching moments repertoire.

The teaching moments can be thought of as a variety of ethical problems that require tough decisions. The idea behind the current design of the teaching moment is based on analyzing moral dilemmas and transforming them to a story graph structure, then specifying the decision points that reflect the specified skills. Such nonlinear scenario structure can arouse users' curiosity and offer uncertainty for challenging the attainment of its goal, hence motivating users to learn (Lo et al. 2008). While designing the teaching moments, we took into account that they should emphasize good models and examples, hopefully, after which the students could model their own behaviour. Ideas from Kohlberg's dilemmas and other moral situations designed specifically for school students were used to author the teaching moments. Analyzing these situations and transforming them into graph structures is not a straight-forward process. Actually, it can be considered as the bottle neck in the system development phases.

The opinions of educational experts were necessary at this stage to make sure that the decision points identified reflect the skills needed to be acquired. Their opinions and feedback helped in refining the teaching moment scenarios. The idea of developing an authoring tool has been considered, but not as part of this thesis. After modifying the teaching moments, the implementation took place. The authored teaching moments vary in their length between long and short in order to provide diversity to the student. Such diversity was intentional for the sake of surprise and unexpectedness that help in engaging the student. Although the various branches of every teaching moment are hand coded, each teaching moment exhibits variability through allowing different characters and places to be incorporated in the teaching moment depending on the story world state. Each teaching moment represents a part of the whole story and focuses on a certain concept (moral value) in a way that the concept mastery is established within. A full graph representing moral dilemma (teaching moment) can be seen in Figure 5.4. Currently the implemented repertoire contains 8 teaching moments. Examples of the teaching moments can be seen in Appendix A. For illustration, character names and places have replaced the variables in the presented teaching moments.

5.3.1 Kohlberg's Dilemmas

Moral scenarios have been utilized in computer based systems in order to help students to develop their skills in analyzing the ethical dimensions of a particular context. For example, Winter & McCalla (1999) built a game for exploring ethical decisions for the ethics class at the University of Saskatchewan. The moral scenarios were designed as binary trees, where there was also only one possible outcome for each choice. Another game is Conundrum (Mckenzie & Mccalla 2009) which uses ethical scenarios to challenge a learner's preconceived notions about the consequences of their ethical choices. Evaluation of both systems showed promising results about using this kind of moral scenarios in developing ethical reasoning. Kohlberg's dilemmas and other moral dilemmas especially designed for school children have been used in AEINS as the teaching moments. An example of transforming a Kohlberg's dilemma to a teaching moment is as follows:

"Gina was a twelve year old girl. Her mother promised her that she could go to a special rock concert coming to their town if she saved up from baby-sitting and lunch money to buy a ticket to the concert. She managed to save up the fifteen dollars the ticket cost plus another five dollars. But then her mother changed her mind and told Gina that she had to spend the money on new clothes for school. Gina was disappointed and decided to go to the concert anyway. She bought a ticket and told her mother that she had only been able to save five dollars. That Saturday she went to the performance and told her mother that she was spending the day with a friend. A week passed without her mother finding out. Gina then told her older sister, Louise, that she had gone to the performance and had lied to her mother about it. The elder sister, Louise, wonders whether to tell their mother what Gina did."

Example of the interview questions from Kohlberg's to his student:
1. Should Louise, the older sister, tell their mother that Gina lied about the money or should she keep quiet?
2. In wondering whether to tell, Louise thinks of the fact that Gina is her sister. Should that make a difference in Louise's decision?
3. Does telling have anything to do with being a good daughter?

This dilemma has been transformed to a graph structure story with interleaved decision points. The unfolding story depends on the student's actions at these points.

Kohlberg's dilemmas as a teaching moment
Your little sister Gina wants to talk to you; she seems to have a big secret
Gina is ready to tell you her secret;
Gina is telling you that their mum asked her to to save money to buy the school clothes which costs 25 pounds. Gina saved the money but she bought a concert ticket for 20 pounds and told her mum that she saved 5 pounds only. Gina is asking you not to tell anyone and if mum asks you, you should not tell her the truth..
Your friend John heard the conversation between you and your sister accidentally; he is approaching you.
John said that he is sorry as he heard what Gina said by accident. John is asking if you think you should tell your mum that your sister lied about the money?
Learner (taking the role of the elder brother/sister): yes
John is wondering if you think that by telling your mum this makes you a good son?
Learner: yes
John is also wondering if by telling your mum you have betrayed your sister's trust?

Learner: no
Gina is very angry and said that she will not be your friend anymore. Do you insist to disagree with Gina?
Learner: no
Gina is glad because you agreed to lie for her sake. John thinks this a big mistake and you will be in a big trouble when your mum knows. Do you agree with John?
Learner: yes

As seen the dialogue tries to emphasize the wrong beliefs and encourage the good actions. The moral agent follows the Socratic Method in order to either help the student to evaluate the moral dilemma from different perspectives, as in Kolberg's example, or present opinions and asks questions in order to lead the student to discover himself any contradiction(s) present in any course of action not based on moral principles. The dialogues continue until the story ends with either a negative reward or a positive one based on the computation model of the student's actions. The student model is updated after each student's action, however it is only used by the pedagogical model after the dilemma ends.

Providing feedback was a real challenge. It was not adequate to have feedback of the following forms 'your answer is right' and 'your answer is wrong.', which may distract the student and decreases his engagement level. As we discussed previously, the narrative environment offers the chance for the feedback to be tailored within the context of the story. So the consequences of the student's interactions with the teaching moment are implicitly provided within the story as it unfolds. This kind of feedback is referred to as formative feedback. Based on the student's actions, the system is able to present the student with more than one possible outcome for the dilemmas. For example, the above situation will end with the sister 'Gina' getting upset from the student and the mother punishing 'Gina'. If the student chooses not to tell their mother, a guilty feeling may accompany him and/or he may choose to advise the little sister not to repeat such an action again. Through this experience, the student will get the chance to reason more deeply about those dilemmas and see what outcome(s) satisfies him most. Therefore, extending the student model to include the student's beliefs reflected via his interaction with the system can help to evaluate what the student has learned from the activity.

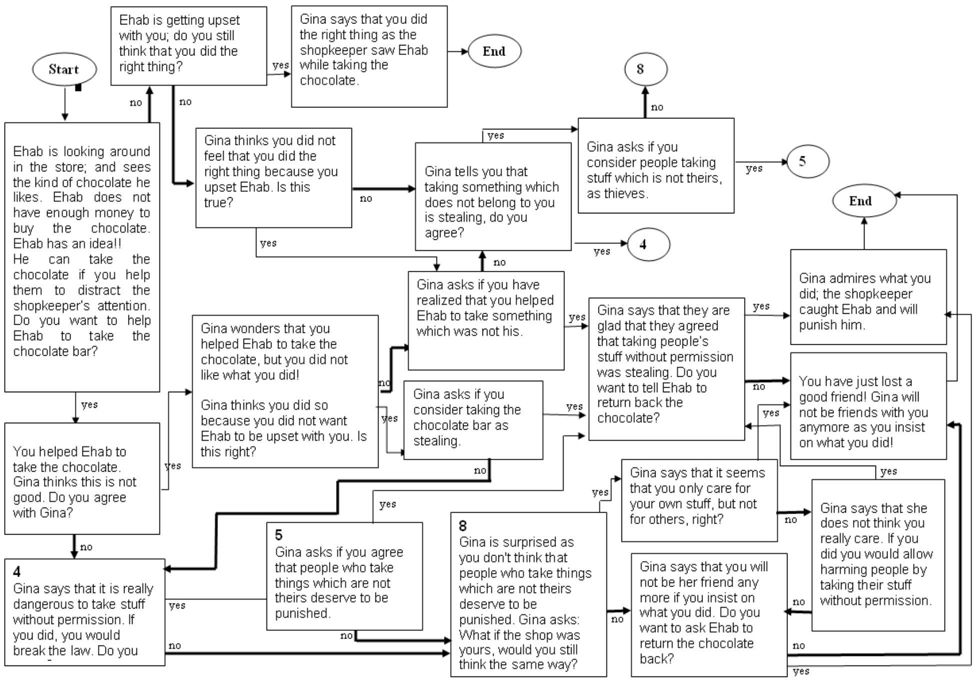


Figure 5.4: Graph representation of a teaching moment

5.3.2 Teaching Moments

Deciding on the appropriate teaching moments has been done with the help of the children's educational expert Dr. Hanaa Mohamed [1] who assisted in the design and the choice of the appropriate decision points and the different branches for each teaching moment. A repertoire of teaching moments has been built where the teaching moments could only be selected for presentation by the pedagogical model. A graph representation of a teaching moment is shown in Figure 5.4. Each teaching moment has certain prerequisites that must be fulfilled before its execution. The first set of prerequisites are educational prerequisites, the second set is narrative prerequisites. An example of these two sets for the teaching moment presented in Figure 5.4 is as follows:

Educational Prerequisites for teaching moment$_1$:

```
If not (acquired_value (‘‘Trustworthiness’’))
   and if not (acquired_value (‘‘do_not_steal’’))
Then suggested_TM (‘‘dilemma’’, ‘‘TM1’’)
```

[1] Hanaa Mohamed, Educational Psychology Department, Faculty of Education, Fayoum University, Egypt & a Ph.D. holder from the Psychology Department, University of York, UK.

```
If not (acquired_value (‘‘Trustworthiness’’))
   and if acquired_value (‘‘do_not_steal’’)
Then suggested_TM (‘‘dilemma’’, ‘‘TM2’’)

If not (acquired_value (‘‘Trustworthiness’’)
   and if not (acquired_value (‘‘do_not_lie’’))
Then suggested_TM (‘‘dilemma’’, ‘‘TM3’’)
```

The educational prerequisites are used to determine the suitable teaching moment to present to the student according to the student model, see Section 5.5. They infer the student's current skills and his misconceptions. If firing the rules resulted in more than one dilemma that could be presented to the student, there are judging rules that prioritize one dilemma over the other. These rules are part of the pedagogical model, see Section 5.4.

```
If not_presented (‘‘dilemma’’, ‘‘TM1’’)
   and if not_presented (‘‘dilemma’’, ‘‘TM2’’)
   and if not(acquired_skill (‘‘does_not_agree_to_take_other’s_stuff’’))
Then prioritize (‘‘dilemma’’, ‘‘TM1’’)

If not_presented (‘‘dilemma’’, "TM1’’)
   and if not_presented (‘‘dilemma’’, ‘‘TM2’’)
   and if acquired_skill(‘‘agree_to_take_other’s_stuff’’)
   and if not(acquired_skill (‘‘convinced_steal_is_bad’’)
Then prioritize (‘‘dilemma", ‘‘TM2’’)
```

Narrative prerequisites for dilemma 1

```
If at_the_shop (‘‘student’’)
   and at_the_shop (char(X))
   and at_the_shop (char(Y))
   and friend (‘‘student", char (X))
   and char_personality (char (X), not(value_hold(‘‘steal’’)))
   and friend (‘‘student1’’, char (Y))
   and char_personality (char (Y), value_hold(‘‘steal’’))
Then present (‘‘dilemma", ‘‘TM1’’)
```

The narrative prerequisites aim to present the dilemma only when the world conditions are suitable. These prerequisites are sent to the story generator, as the desired world state. In other words, to accommodate the teaching moment in the whole story, the world should satisfy the preconditions of this teaching moment. This is very important in order to obtain a coherent storyline.

The post-conditions for the teaching moments are not coded as those for the strips actions, see Section 5.6. They depend on the student actions and choices. There are rules working on these actions and which update the state of the world accordingly. At the end of the student's interaction with the teaching moment, the resulting changes in the world are the postconditions of the teaching moment.

The interaction of the student with the teaching moments is monitored and evaluated by the cognitive tutor and has the following structure:

- The teaching moment begins with a specific theme to act as a starting point or trigger for learning;
- The student is asked about his opinions through a series of questions;
- The student's answers are evaluated and arguments are presented to help the student to examine the validity of his opinion or belief;
- If the student agrees with a desired ethical choice, the teaching moment ends;
- If the student sticks to an unethical decision, the system raises the stakes;
- If the student keeps sticking to the unethical choice, another teaching moment is chosen and the above steps are repeated.

5.4 Pedagogical Model

Research suggests that students benefit from being encouraged to consider a collection of evidence and coordinate their theoretical ideas with supporting or contradictory evidence as they engage in argumentation (Koslowski 1996; Bell & Linn 2000). In addition, students must have opportunities to choose among different options and to reason about the criteria lead to the chosen option (Kuhn 1993). AEINS follows these approaches in designing the pedagogical model. The pedagogical model considers the student's model history and the domain model in order to choose the next educational step. An example of the model is given below.

```
If action (‘‘TM1’’, ‘‘agree_to_lie’’)
   and if action (‘‘TM1’’, ‘‘insist_to_lie’’)
   and if action (‘‘TM1’’, ‘‘lie_for_friend_sake’’)
   and if action (‘‘TM1’’, ‘‘agree_lying_is_bad’’)
Then skill (‘‘do_not_lie’’, ‘‘acquired’’, 0.5)

If action (‘‘TM1’’, ‘‘refuses_to_lie’’)
   and if action (‘‘TM1’’, ‘‘insists_not_to_lie’’)
   and if action (‘‘TM1’’, ‘‘knows_lying_is_bad’’)
Then skill (‘‘do_not_lie’’, ‘‘acquired’’, 1.0)

If action (‘‘TM1’’, ‘‘not_take_other’s_stuff’’)
   and if action (‘‘TM1’’, ‘‘agrees_it_is_steal’’)
   and if action (‘‘TM1’’, ‘‘take_stuff_back_to_owner’’)
Then skill (‘‘do_not_lie’’, ‘‘acquired’’, 1.0)
```

The confidence factor attached to each rule is the rule confidence factor. Confidence factors lie in a range between 0 and 1, 0 means there is no confidence at all about a certain rule and 1 means that the system is 100% sure about this rule. Any number between 0 and 1 represents the extent of trusting this rule. For example, if the confidence factor is 0.5, this means that system is 50% sure that the student is holding a certain principle.

Other types of rules work on choosing certain teaching moments over others when more than one teaching moment is applicable for presentation. An example of these rules is as follows:

```
Trigger:  teaching moment TM1 has not been presented
   and teaching moment TM2 has not been presented
   and the be_sincere value is not held by the user yet
   and the do_not_lie value is held by the user
Action:  set priority to teaching moment TM2
```

5.5 Student Model

Student modeling is considered a key component for edugames to successfully adapt to individual users in an appropriate way. It aims at identifying students' characteristics, needs, and situation in an automatic way, using students' behaviour and actions in order to automatically infer the relevant information (Graf et al. 2009). A reliable student model is necessary, but getting enough information about a learner is quite challenging (Graf et al. 2008). For example, dealing with the student's mental state. Attempting this high bandwidth state is important as it can lead to better student modeling, and accordingly achieve better adaptation. AEINS builds a model of the student's learning process by observing, recording and assessing the student's actions and choices from the generally accepted ethical views. The model is currently a simple form of the overlay model represented in the form of rules; the model assumes that the student knowledge is a subset of the expert's knowledge. The system aims to expand the student knowledge until it turns out to be the same as the expert's. The model assumes that the student has no other beliefs than that of the experts and there are no other misconceptions that the pedagogical model does not know about. Accordingly, a bug model is not considered as a part of the developed student model.

The student model consists of three parts: the first part is concerned with the student's personal details, the second part deals with the student knowledge and the third part with the student intentions.

Student personal details

This component reflects the level of the player while playing (ex: beginner, advanced), in addition to the objects he tends to collect and handle in solving his tasks or those objects he likes more (ex: dolls, guns, games ...etc). This component can also include the style of the player whether he plays safe or risk aversive ...etc

Student knowledge

Explicit beliefs of the system towards the student knowledge can be expressed in this form:

```
AEINS-Believes (student-aware (trustworthiness))
AEINS-Believes ( ~(student-aware (responsibility))
```

The pedagogical model can expand the student model by making use of the information in the domain model to infer more knowledge about the student. For example, if the domain model contains the information prereq (do_not_lie, honest), which means that it is conditional to acquire the do_not_lie value in order to fulfill the honest value and if the student model contains the information ~(student-aware (honest)) (~denotes 'the negation of') the pedagogical model can make use of this information in order to infer more information about the student. The general rules takes this form:

```
AEINS-Believes (student-aware (Y) & is_prereq (Z, Y)) ->
AEINS-Believes (student-aware (Z))
AEINS-Believes (~(student-aware (Y)) & is_prereq(Z, Y)) ->
AEINS-Believes (~(student-aware (Z)))
```

Inference rules that infers the progress of the student in the learning process, based on his actions, are structured as follows:

```
IF skill (``student'', ``do_not_lie'', ``acquired'', CF1)
   and IF skill (``sincere'', ``acquired'', CF2)
   and IF skill (``do_not_steal'', ``acquired'', CF3)
   and IF skill (``responsible'', ``acquired'', CF4)
THEN concept-learned (``honest'', ``held'', Z)

IF skill (``do_not_steal'', ``acquired'', CF1)
   and IF skill (``insist_not_steal'', ``acquired'', CF2)
   and IF skill (``agree_steal_is_wrong'', ``acquired'', CF3)
   and IF skill (``do_not_steal'', ``acquired'', CF4)
THEN concept-learned (``do_not_steal'', ``held'', Z)

IF skill (``support_his_friend'', ``acquired'', CF1)
   and IF skill (``courage_in_facing_problems'', ``acquired'', CF2)
   and IF skill (``do_what_is_required'', ``acquired'', CF3)
THEN concept-learned (``have_integrity'', ``held'', Z)
```

The above representation denotes that if the student acquires the above mentioned skills with confidence factors CF_1, CF_2, CF_3, CF_4 respectively (CF_i values are obtained by the pedagogical model), then the rule confidence factor can be determined using the combination function: min (CF_1, CF_2, CF_3, CF_4). Confidence factors are based on rough guesses of of experts in the domain, rather than being based on actual statistical knowledge.

The confidence factor of the rule will be combined with the confidence factors of the premises to obtain an evaluation of the confidence factor of the conclusion. The calculation of the conclusion confidence factor is calculated as follows (Drakos 1993; Buchanan & Shortliffe 1984):

- For conjunctive premises (premises connected with and operator) associated with confidence factors (CF_i) and so is the conclusion (Z). The rule certainty confidence= min(CF_i)*Z
- For disjunctive premises (premises connected with or operator) associated with confidence factors (CF_i) and so is the conclusion (Z). The rule certainty confidence= max(CF_i)*Z
- For premises associated with confidence factors (CF_i) and the conclusion is not. The rule confidence factor= $CF_1+CF_2*(1-CF_1)$
- If there is another rule drawing the same conclusion, the certainties are calculated using the individual rules (say CF_1 and CF_2), then combine them to get a total certainty of ($CF_1 + CF_2 - CF_1*CF_2$). The result will be a certainty greater than each individual certainty, but still less than 1.

Student intentions

This component contains knowledge about the student's intentions. According to the information fed from the pedagogical model, such knowledge is constructed using this general representation:

```
Knows (student, concept_1) & Answer (concept_1, task_1, correct) & Achieve
(student, task(1), goal(G))-> increase_system_belief
_about_student_knowledge
```

This kind of inference rules enriches the student model by allowing inference about the student intentions. This allows the consideration of other implicit aspects rather than those explicitly inferred from the student's actions. This information allows the pedagogical model to act out intentions in the future planning of the learning process. For example, the pedagogical model might express the intention of providing the learner with more activities on a certain concept because it believes that the student's degree of expertise required to move further in the learning process has not been achieved.

The structure of the student model and the representation rules were reviewed by the cognitive scientist, Robert Hausmann [2], who agreed upon the rules structure and representation. According to his experience, he primarily approved the ability of these

[2] Robert Hausmann, Cognitive Scientist at Carnegie Mellon University, U.S.A.

rules to infer the student's knowledge and accordingly the ability of the model to provide the required personalization.

Based on the student model, AEINS is capable of providing a summary report at the end of the interaction with the learning environment. The report displays the different skills the student has. It also shows the teaching moments the student interacted with and the values held and not yet held by the student, associated with confidence factors.

5.6 Story Generation in AEINS

The story in AEINS is generated not as part of a learning objective but rather as a step of making contact. It serves the purposes of transitioning between objectives and increasing causal relatedness, thus improving cohesiveness (Niehaus & Riedl 2009). AEINS uses planning for story generation because it is more variable than the other types and able to generate different narratives for different users, and also different narratives for the single user on subsequent play turns. In other words, for every possible way the student can violate the story plan, an alternative story plan is generated. Similar to the work of Barber and Kudenko (2007), a STRIPS-like representation planning algorithm is used that selects a story event to be executed based on a set of authored story actions, see Table 5.1.

action name	*preconditions*	*postconditions*
move(Y,Z)	place(Y), char_at(student,Y)	place(Z), char_at(student,Z)
invite(X,Y,Z)	char(X), place(Y), char_at(X,Y)	place(Z), char_at(X,Z)
make_friend(X,Y)	char(X), char(Y), like(X,Y)	friend(X,Y)
play_with(X,Y)	friend(X,Y)	enjoy_play_time(X,Y)
do_not_be_friend(X,Y)	dislike(X,Y)	not_friend(X,Y)

Table 5.1: Example of the story world operators

The problem with the STRIPS planner that it sometimes provides an improper action-reaction. This problem happens when there is a need to prioritize the latest student action in order to provide a direct logical reaction to it before continuing with the execution of the rest of the plan. When this does not happen, an improper action-reaction problem occurs. Assume the following scenario: an agent goes to the shop, the user chooses to follow the agent to the shop, the user steals something from the shop, and the user flatters the agent. The planner could execute a sequence of actions before the execution of an action that can be considered as a response to the user's flattery action. Here is where we think the problem lies; the user is expecting a reaction to his last action especially in the kind of actions that are in the form of an invitation or a request. Such way of actions execution can lead to the user's boredom and frustration in addition to losing interest in the environment.

A solution has been found in creating a reactive planner that provides direct reactions to the user's actions. The presence of a reactive planner in AEINS offer the agents the opportunity to act according to the latest student's action instead of only basing the action choice on the whole past history of the narrative, as the STRIPS planner usually does. Imagine the following situation, the planner picks 'be_friend_to' and 'move' actions to be executed. Luckily, the student follows the plan and chooses to 'be_friend_to' one of the agents. In normal planning this will lead to the execution of the move action automatically. Through the use of the reactive planner, the agent responds first to the 'be_friend_to' invitation then the reactive planner hands over the role to the STRIPS planner to continue the execution of the original plan. We argue that this kind of prioritizing the latest user's action increases the believability of the agents and keeps the sense of realism of the world. It is worth to mention that the reactive planner does not interfere with the original plan. In other words, the reactive actions can not invalidate the original STRIPS planner, see Figure 5.5.

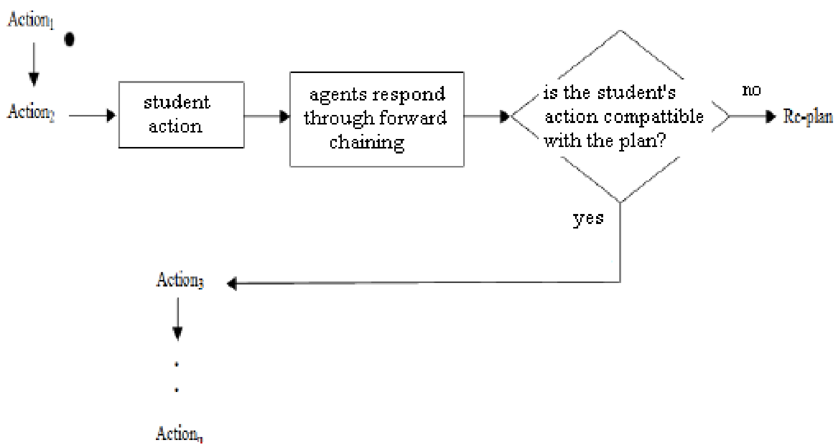


Figure 5.5: Plan execution flowchart

The reactive planner is used by the non-playing characters (agents) and uses the same actions representation as the STRIPS planner with an increment of one more parameter denoting the suitability cost. The suitability cost (#N) is an integer that guides the agent to choose the most suitable response action to the current student action. An example of two action operators for the reactive planning is shown in Table 5.2. The N

action name	*preconditions*	*postconditions*
reply_friendship(Agent, student, N_1)	like(Agent, student)	agree_to_be_friend & friend(Agent, student)
respond_to_play(Agent, student, N_2)	not(current_TM(TM_2)) & friend(Agent, student)	accept_play_invitation

Table 5.2: Example of the reactive planner operators

value changes dynamically during run-time through forward chaining rules based on the story events. The advantage of using forward chaining rules within the reactive planner is that it allows the reception of new data and can trigger new inferences, which makes the engine better suited to dynamic situations in which conditions are likely to change. For example, as the relationship between the student and the agents inhabiting the world evolve over time, agents' reactions towards the student need to suit the current conditions of the world. The more the action is a logical response to the student actions the more the story is believable.

The forward chaining rules are of the form:

```
left hand side (LHS) ==> right hand side (RHS).
```

The LHS is a collection of conditions which must be matched in working storage for the rule to be executed. The RHS contains the actions to be taken if the LHS conditions are met.

The general execution cycle is:

- Select a rule whose left hand side conditions match the current state.
- Execute the right hand side of that rule, thus somehow changing the current state.
- Repeat until there are no rules which apply.

The simplest algorithm to find a goal is to select the first rule whose conditions match the premises. However, this algorithm may miss the best solution (best action) that can exist in later rules. Another algorithm is to check all the rules and choose the best solution among them. The second algorithm seems to be more practical and allows for better chances in finding the best solution.

When the user performs an action that requires an agent's response, this response is selected from a set of pre-authored actions based on the associated value #N. For example, if the student asked one of the agents to be his friend, the N value of 'reply_to_friendship' action will dominate the N value of 'respond_to_play' action according to a pre-defined relation matrix. The matrix highlights which behaviours should be active in which contexts. For example, if the user's last action is asking to be friend to one of the agents (non-playing characters), then the 'reply_friendship' reactive action will be prioritized over other reactive actions such as 'respond_to_play'. 'reply_friendship' is nondeterministic action where it can provide different postconditions based on the current state of the world. For example, the agent will accept the user's friendship if they already like each other, otherwise the agent will not accept to be friend to the user. Afterwards, the STRIPS planner continues the execution of the original generated plan, so for the above example the 'move' action will be executed. An example for a set of rules is shown below:

```
IF action (‘‘want_to_play_with’’, char (X))
   friend (‘‘student’’, char (X))
   Then action(‘‘agent’’, char (X), ‘‘accept_to_play’’, 0.6)

IF action (‘‘want_to_play_with’’, char (X))
   friend (‘‘student’’, char (X))
   played_before(‘‘student’’, char (X))
   Then action(‘‘agent’’, char (X), ‘‘accept_to_play’’, 0.8)

IF action (‘‘want_to_play_with’’, char (X))
   not(friend (‘‘student’’, char (X)))
   Then action(‘‘agent’’, char (X), ‘‘refuse_to_play’’, 0.7)

IF action (‘‘want_to_play_with’’, char (X))
   not(friend (‘‘student’’, char (X)))
   played_before(‘‘student’’, char (X))
   Then action(‘‘agent’’, char (X), ‘‘refuse_to_play’’, 0.5)

IF action (‘‘invite_to_house’’, char (X))
   friend (‘‘student’’, char (X))
   Then action(‘‘agent’’, char (X), ‘‘accept_invitation’’, 0.6)
```

At the level of story generation, the story generator uses STRIPS planning for the dynamic generation of narrative in run-time where every user's action that can violate the plan, can be accommodated by re-planning. Extending the STRIPS planner through the use of the reactive planner has had its effect on the user's experience as it provides a more realistic and dramatic story. An example that illustrates the narrative generation can be seen in Figure 5.6.

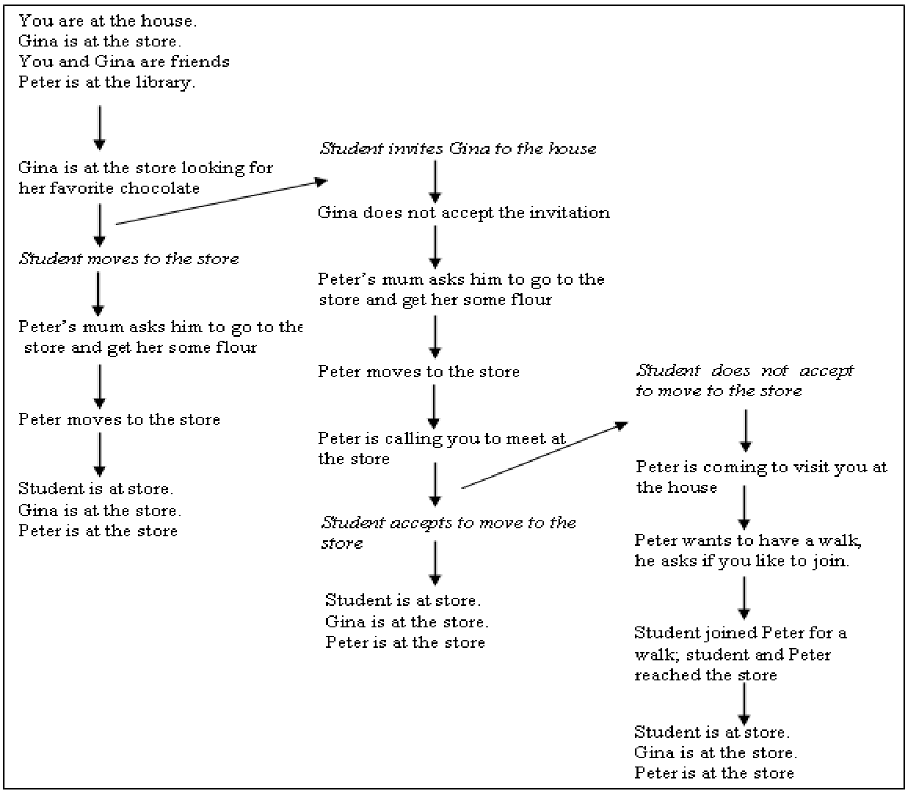


Figure 5.6: Example of the generated narrative

In Figure 5.6, the first row represents the current story world and the last row represents the goals to be satisfied. The left column shows the first plan the story generator produces, the actions in italic are assumed learner's actions. If the learner's action does not satisfy the first plan, another plan is developed; the second plan in the middle column. Again if the learner's action violates the plan, a third plan is developed; the plan in the right hand most column. This continues until the goals (teaching moment narrative preconditions) are satisfied.

5.6.1 Agency in AEINS

As seen from the previous section, the integration of the dynamically generated narrative and the scripted narrative allows AEINS to propose two types of agency, see Figure 5.7. The first kind is complete free agency by which the student is able to influence and

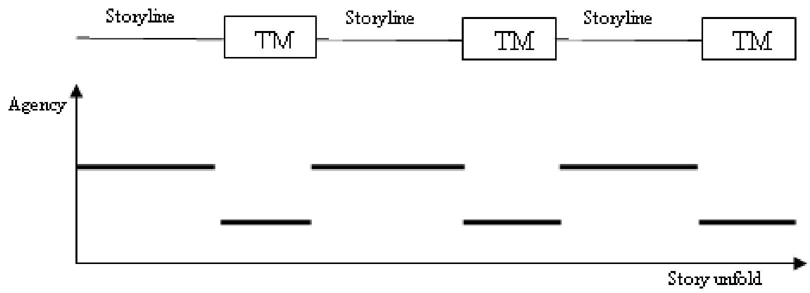


Figure 5.7: AEINS agency

control the direction of the story (i.e., before reaching or after finishing a teaching moment). The second type is restricted agency, which exists in the entire interaction within a teaching moment; the teaching moments use a simple branched-planning approach designated by decision points where the student has to act. Restricting the agency to preserve the educational targets is acceptable because the teaching moments themselves are relaxed by varying the places and characters that can participate in their worlds. AEINS's main aim is to allow students to move from the *making moral judgments state* to the *taking moral actions state*, from the knowing state to the doing state, which we consider a very important step in moral education. The following subsections introduce the AEINS working model and how the various architecture components are utilized in AEINS.

By the end of the whole experience, the learner would have experienced some emotional and moral complexities. According to Freeman (2004), this kind of experience, especially when theses complexities develop over the course of a game-like environment, can leave the player with a better and deeper understanding.

5.7 Story World in AEINS

The game nature of AEINS allows the existence of non-playing evolving characters (pedagogical agents) and objects in the AEINS story world. The purpose of pedagogical agents is not to perform tasks for users or to simplify tasks, but rather to help users learn how to accomplish tasks (Sklar 2003). They aim to increase problem solving effectiveness by providing students with customized advice (Lester et al. 1997). The pedagogical agents in AEINS are semi-autonomous agents, where on one hand they are able to act and react according to their state and the current world state. On the other hand, the story generator can dictate to them, when required, what to do in order to preserve the coherence and dramatic tension of the whole story.

With reference to section 2.6, Agents should be implemented with the mentioned features in mind, especially those properties that allow them to be life-like characters as those recommended by Giraffa & Viccari (1998), for instance having mobility to go to different physical places, be flexible and accept other agents' interventions, being characters with personalities, have social ability via some kind of agent communication language, act pro-actively and have some kind of reactivity. Each agent is implemented as a set of rules that describe the character personality, which consequently control the character behaviour. The following agents are inhabiting AEINS world and introduced to the user in the following way:

- Gina is a nice girl, she is sincere. Gina does not accept taking things without permission but she can lie,
- Peter is a beloved boy, he is good and sincere but sometimes he cheats,
- Judy is a beautiful girl, she does not lie or take things without permission. Judy is sometimes not sincere to her friends,
- John is a funny boy, he is popular. John does not lie but sometimes he can take things that are not his.

All the agents should share the same basic knowledge base to support interacting with the world and the other agents. The main advantage of having more than one agent is to have the freedom to portray agents who do not share the learner's goals, they can be used to provide negative examples (Thomas & Young 2007). For example, friend("student", "Gina") states that the student is currently a friend of Gina, character_personality("Peter", "can_cheat_in_exams") states that the agent Peter holds the moral of cheating in exams.

On the other hand, The non-playing agents can also act according to the moral goals and can give positive examples or help the student to stay on the right track. The agents' characters can also evolve whilst the story ends based on their actions and the students actions to help with the mental and emotional engagement of the student. The AI of the non-playing characters is represented in the form of rules, these rules can be modified during the story as a result of certain actions. For example, a character who is a friend to the student can become an enemy as a result of a student action. Or a holder of unethical moral virtue character can change to be a holder of a good moral virtue as a result of some interactions with the surrounding world as follows: friend("student", "Gina") and character_personality("Peter", "can_cheat_in_exams") can change as a result of the student action "refuse_to_help_Peter_to_cheat" to ~friend("student", "Gina") that means that the student and Gina are not friends any more and accordingly Peter personality can change as a kind of recognition to the fact that cheating is wrong to the following: ~character_personality("Peter", "can_cheat_in_exams") where ~negates the rule to be read as follows: "Peter would not cheat in exams".

The student and the agents are responsible for the story unfolding where it is generated based on their actions. When it is time to present a teaching moment, the currently involved agents in the main story will take the corresponding roles (that fits their current personalities and relationship to the student). If a role exists that still needs to be occupied or an agent is not capable to take that role, the story world with the assistance of the story generator will allow the inclusion of another agent smoothly through the narrative. Once the scene is set, the teaching moment starts.

As mentioned previously, the predominant teaching pedagogy is the Socratic Method. The holder of good moral virtue uses the Socratic Voice to provide discussion, hints and feedback to the student. The text dialogue produced encourages the student to think critically in order to solve the discrepancies encountered in the moral situation(s) they are facing. When the teaching moment ends, the student, along with the agents, is free to act again influencing how the main story unfolds. The story world receives the required actions to be executed by different agents and pass this information to the presentation module to be displayed to the student. An example of the story world representation is as follows:

```
place(‘‘house’’)
place(‘‘library’’)
place(‘‘school’’)
place(‘‘store’’)
character(‘‘Gina’’)
character(‘‘Judy’’)
character(‘‘Peter’’)
character(‘‘John’’)
friend(‘‘student’’, ‘‘Gina’’)
dislike(‘‘student’’, ‘‘Peter’’)
char_at (‘‘Gina’’, ‘‘house’’)
char_at (‘‘Peter’’, ‘‘school’’)
char_at (‘‘student’’, ‘‘house’’)
current_actor(‘‘Gina’’)
current_actor(‘‘Peter’’
character_personality(‘‘Peter’’, ‘‘sincere_to_his_friends’’)
```

```
character_personality(''Peter'', ''can_cheat_in_exams'')
```

5.8 Presentation Module

AEINS presents the learner with an interface that allows him to choose a playing-character to represent himself in the game, and then start the game whenever he is ready, see $figure$5.8.

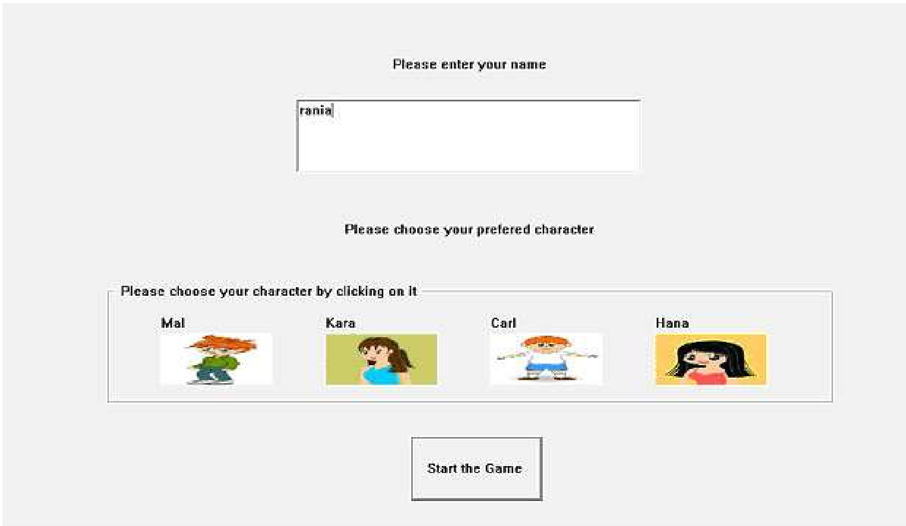


Figure 5.8: AEINS introduction form

To interact with the story, AEINS offers a point and click GUI as shown in Figure 5.9 where the student is able to take actions, such as move, invite, make friend and so on. The game starts by introducing the characters in the world to the student and asks him to choose his friends. Based upon his choices the student model is initialized. Afterwards, the student can allow the game to act or he can choose to act. The student is able to choose whom he wants to interact with and the places he wants to move to by clicking on the corresponding pictures. For example, the student can choose the *'invite'* action and then clicks on *'Ziad'*'s and *'house'*'s pictures. The end result will be 'invite Ziad to my house'. Ziad has the freedom to accept or reject the student's invitation according to the rules that describe the non playing-characters actions.

The GUI provides a multi-line text box that allows the whole experience to be listed in front of the student during play time. The student is able to review his past actions and other characters' actions at any time. The teaching moments are also presented as part of this text, where the student interacts with them through check boxes and buttons, the

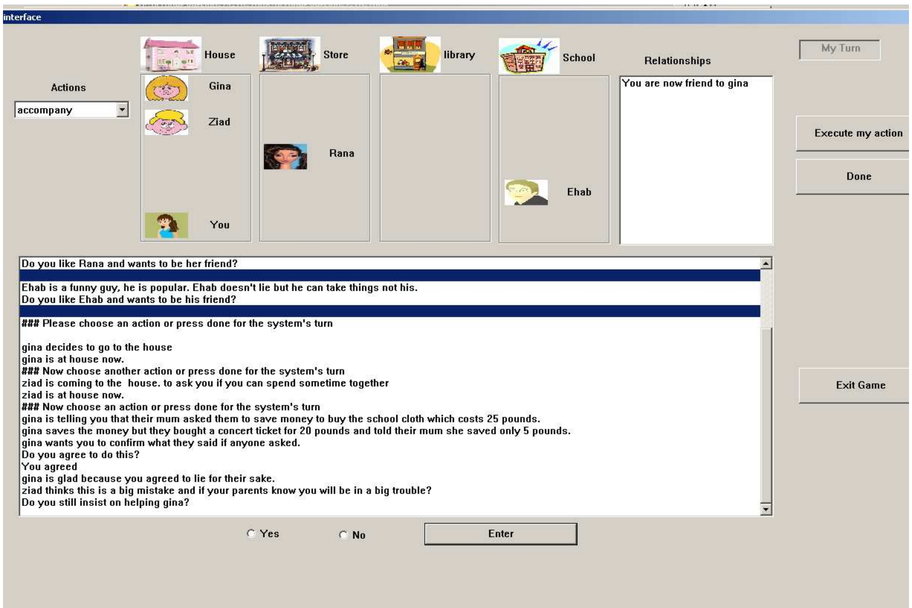


Figure 5.9: AEINS interaction interface

story unfolds according to the student actions and choices leading to the end scene of the teaching moment. These scenes are designed in a way that provides implicitly positive or negative feedback based on the current student model. This forces the student to make conscious choices in terms of ethics. This kind of feedback is referred to as summative feedback and it corresponds to positive and negative rewards in game play. Providing feedback as part of the story maintains the motivation and flow, where usually adapting a game to enhance its educational benefit endangers its intrinsic motivation and flow (Pierce et al. 2008).

5.9 Learning Theories Employed in AEINS

Keller's ARCS model has been considered in the design of the teaching moments as discussed in section 4.3.1.1 and the presentation module as discussed in Subsection 4.3.2.2. Gagné's nine events considered in the implementation of AEINS are: Attention gaining, objective settings, invoking of prior learning, presentation of new materials, created scaffolding, provision of practice, feedback, assessment and retention-and-transfer of new knowledge to real life. Attention gaining has been satisfied through the use of graphical interface, and the problem solving style of learning provided in the AEINS environment. Each teaching moment in AEINS started with part of a situation followed by a series of interactive questions. Setting the objective is not handled as in traditional tutoring, however it is implicitly accompanied with succeeding in the game that will happen only through succeeding in the educational process. Invoking prior learning has been tackled in designing the teaching moments, where some teaching moments forces the student to recall and apply previous acquired skills in order to solve the current problem.

Presentation of new materials has been achieved partially through the meaningful organization of the content, however the presence of variety of media, such as audio and video is missed in AEINS. Created scaffolding is one point we think AEINS achieved successfully in the teaching moments' design, in addition to the presence of non-playing characters that help in supplying the educational material, act as the source of Socratic Voice and provide feedback. Provision of practice is present in AEINS through problem solving, i.e. solving the conflicts in the teaching moments. Feedback is implicitly provided in AEINS either in the form of formative or summative feedback as discussed in Section 5.3.1. Assessment is done for the student's actions and choices whilst interacting with the teaching moments. Retention-and-transfer of knowledge to real life situations is one of AEINS aims. Enhancing retention is achieved through the repetition of learned concepts but in various contexts to avoid boring the student. As will be discussed in Chapter 6, the evaluation shows some evidence on the possibility of knowledge transfer that the student may use in his real life.

5.10 A Typical Student-System Interaction Scenario

This section presents a typical scenario that the children might have encountered playing the game, showing the role of the characters, different modules' roles and some typical teaching moments. The system interaction is in normal font. The student's actions are in bold. Comments and illustrations are italicized.

At the very beginning the system allows the learner to enter his name and pick a character to represent him/her in the game world. Then the system greets him/her and presents a brief introduction about the game world.

Hi Rania! This is your world, please have a look around!
You have four places to go to: the house, the shop, the library and the school. There are four characters with whom you can make friends. You have a list of actions to choose your actions from. You are free to play whenever you are ready.

Now, it is time to choose your friends.....

The system presents the characters by name and personalities
The user has to choose a categorized yes/no answer, as no free text is allowed in the current version of AEINS

Gina is a nice girl, she is sincere. Gina does not accept taking things without permission but she can lie Do you like Gina and want to be her friend?

yes
You like Gina. You and Gina are friends now.

Peter is a beloved boy, he is good and sincere but sometimes he cheats. Do you like Peter and want to be her friend?
no
You do not like Peter. You and Peter are not friends.

Judy is a beautiful girl, she does lie or take things without permission. Judy is sometimes not sincere to her friends. Do you like Judy and want to be her friend?
no
You do not like Gina. You and Judy are not friends.

John is a funny boy, he is popular. John does not lie but sometimes he can take things that is not his. Do you like John and want to be his friend?
yes
You like John. You and John are friends now.

After the student chooses his friends, the student model is initialized according to these choices. The following facts are now asserted in the student model (~denotes 'not'):

```
current_student(Rania)
playing_char(Carl)
AEINS_believes (stud_aware (cheat))
AEINS_believes (stud_aware (sincere))
AEINS_believes ( ~stud_aware (do_not_lie))
AEINS_believes ( ~stud_aware (do_not_steal))
```

Based on the above information and that of the domain model, the student model infers new facts as follows:

```
AEINS_believes (~stud_aware (do_not_lie) & is_prereq (do_not
_lie, honest)) -> AEINS_believes (~stud_aware (honest))
AEINS_believes (~stud_aware (honest) & is_prereq (honest, trust-
worthiness)) -> AEINS_believes (~stud_aware (trustworthiness))
```

The student model is updated by adding the new drawn facts to the current model.

Based on the current student model, the pedagogical model chooses a teaching moment:

```
If not (acquired_value (''Trustworthiness''))
   and if not (acquired_value (''do_not_steal''))
   and expertise_level_is (beginner)
Then suggested_TM (''dilemma'', ''TM1'')

If not (acquired_value (''Trustworthiness''))
   and if not (acquired_value (''do_not_lie''))
   and expertise_level_is (beginner)
Then suggested_TM (''dilemma'', ''TM2'')

Trigger:  teaching moment TM1 has not been presented
   and teaching moment TM2 has not been presented
   and the be_sincere value has not been held yet
Action:  set priority to teaching moment TM1
```

It is worth at this point to remind the reader that every teaching moment has two kinds of prerequisites: educational and narrative. The educational prerequisites have been satisfied from the above rules leading the pedagogical model to choose the teaching moment (TM_1) to present to the student.

It is now time to satisfy the narrative prerequisites that allows the teaching moment to be presented as a part of the continuous story.

The pedagogical model send the teaching moment id to the story generator that fetches the narrative preconditions for the required dilemma. These prerequisites are as follows:

```
at_the_shop (''student'')
and at_the_shop (char(X))
and at_the_shop (char(Y))
```

```
and friend (``student'', char (X))
and char_personality (char (X), not(value_hold(``steal'')))
and friend (``student1'', char (Y))
and char_personality (char (Y), value_hold(``steal''))
```

The story generator considers these prerequisites as the current goals and generates a plan that allows the story to unfold from the current world state to the goals state.

Now AEINS asks the learner to either act or allow AEINS to act.

Please choose an action or press done for the system's turn.

The learner chooses to act, he chooses to invite someone to his house (this is done by choosing one of the actions: the student chooses "invite home".

The system now asks the user to choose whom he wants to invite and then press the "carry my action button."

Now CLICK on whom you want to invite to your home. Then press CARRY OUT MY ACTION button.

The learner chooses to invite Gina (this is done by clicking on Gina's picture.)

You chose to invite Gina.

Since the agents inhabiting AEINS world are semi-autonomous, they are able to reply directly to the student's latest action through the reactive planner. The reactive planner chooses the highest preference action for the agent. Based on the current status of the student and the agent the following action executes.

Gina accepts your invitation.
Gina is at your house.

AEINS asks the learner to either act or allow AEINS to act

Now choose another action or press done for the system's turn.

The learner chooses to allow AEINS to act (this is done by pressing the done button.)

As it is AEINS turn to act, the STRIPS-like planner executes the first action in the previously generated plan. Since Gina is already involved in the story and exhibits the required properties required by the narrative prerequisites, the story world does not need to introduce a new character at this stage.

Gina: I am going to the store now.
Gina is at the store.

AEINS asks the learner to either act or allow AEINS to act.

Now choose another action or press done for the system's turn.

The learner chooses to allow AEINS to act. To satisfy one of the goals, the story world introduces Judy that satisfies the required conditions.
Judy: I like you and want to be your friend, do you agree?
yes.
You agreed to be friend to Judy.

AEINS asks the learner to either act or allow AEINS to act.

Now choose another action or press done for the system's turn.

The learner chooses to allow AEINS to act: As the narrative preconditions still miss the presence of another agent with the student at the required place, the following action will be executed.

Judy: I am the store, do you want to come and join me?
yes.
You agreed to join Judy.

AEINS asks the learner to either act or allow AEINS to act.

Now choose another action or press done for the system's turn.

The narrative preconditions of the teaching moment have now been satisfied, the learner and two friends of his are all at the store.
Since the preconditions and actions are represented by variables, this allows different

characters to join the learner in the future.
The teaching moment starts as follows:

Gina is looking around in the store and they saw the kind of chocolate they like.
Gina has no enough money to buy the chocolate
Gina has an idea!! they can take the chocolate if you helped them to distract the shop_keeper
Gina: Could you please help me and distract the shopkeeper's attention? I really want that chocolate bar.
yes.
You agreed.

AEINS reflects on the user's action by stressing on his chosen action.

You helped Gina to take the chocolate.

AEINS recognizes that the learner's attitude is not a desirable one. Therefore, Judy, the one who holds the do_not_steal principle, will start the Socratic Dialogue in this dilemma aiming to guide the student to figure out why his action was not right.

Judy: I do not like what you did, this is not good. Am I right?
no.
You disagreed.

The teaching moment unfolds according to the student's answers to Judy. Judy will follow the Socratic Dialogue and raise the ante when necessary as follows:

Judy: It is really bad to take stuff that is not ours without permission. You will be a law breaker, do you agree?
no.
You disagreed.

Judy: I am surprised as you do not think that people who take things which are not theirs deserve to be punished. I wonder what if the shop was yours, will you still think the same?
no.

You disagreed.

Judy: It seems that you only care about your own things and not about others, am I right?
no.
You disagreed.

Judy: I do not think you do really care. If you do you would not harm people by taking their stuff without their permission. Am I right?
no.
You disagreed.

Judy: I will not be your friend any more if you insist on what you did. Now, do you want to tell Gina to return the chocolate back?
yes.
You agreed.
Judy: I admire what you did. As you see, the shopkeeper caught Gina and punishes her for what she did.

The teaching moment ends at this point and the pedagogical model assessed the student's actions as follows:

```
If action (``TM1'', ``agree_to_steal'')
   and if action (``TM1'', ``insist_on_stealing'')
   and if ~action (``TM1'', ``agree_steal_is_bad'')
   and if ~action (``TM1'', ``take_stuff_back_to_owner'')
Then skill (``do_not_steal'', ``acquired'', 0.2)
```

The value 0.2 is the system's confidence of the gained skill, which is lower than a pre-specified threshold in this example. Based on this information the pedagogical model updates the student model by asserting the following rule(s):

```
skill (``do_not_steal'', ``not_acquired'', 0.8)
```

According to the updated student model, the student has misconceptions with the do_not_lie value (old piece of information from the instantiated student model at the beginning of the game) and the do_not_steal value (new information from the updated model). Based on this information the pedagogical model can choose either a teaching moment that deals *with the same value (do_not_steal) or a teaching value that considers the (not_lie) value as follows:*

```
If not (acquired_value (‘‘Trustworthiness’’))
   and if not (acquired_value (‘‘do_not_steal’’))
   and presented (TM1)
Then assess_student_skill_level (‘‘do_not_steal’’)

assess_student_skill_level (‘‘do_not_steal’’)->
   skill (‘‘do_not_steal’’, ‘‘not_acquired’’, X) and X > 0.7
Then suggested_TM (‘‘dilemma’’, ‘‘TM5’’)

If not (acquired_value (‘‘Trustworthiness’’)
   and if not (acquired_value (‘‘do_not_lie’’))
Then suggested_TM (‘‘dilemma’’, ‘‘TM3’’)
```

It is worth to mention that these are non-deterministic rules where more than one solution can be obtained. According to the fired rules, two teaching moments are suggested: TM_3 and TM_5. The current pedagogical model chooses randomly one of the teaching moments to present. The chosen teaching moment id will be send to the story generator to construct a new plan.

Now AEINS asks the learner to either act or allows AEINS to act.

Please choose an action to perform or press done for the system's turn.

AEINS continues interacting with the learner based on the student model.

5.11 Summary

This chapter illustrates the implementation of AEINS and how each model is represented. The bottleneck in developing this system was the collection of the domain knowledge. The frame representation provides a favourable feasibility in the mutual interaction between the domain model and the pedagogical model. Although the current student model is an overlay model, it succeeds in dealing, to a large extent, with the bandwidth problem and was able to generate a functional student model.

AEINS uses two narrative techniques, dynamic generated narrative through STRIPS like planning and graph planning, this integration allows students freedom in influencing the story unfolding and at the same time helps in preserving the educational targets through tracking, assessing and guiding each of the student's actions. AEINS used the Socratic Method as its teaching pedagogy because of its capability of forcing the learner to face the contradictions present in any course of action that is not based on principles of justice or fairness. The AEINS interface has been implemented considering the attributes advised by other researchers in the field.

CHAPTER 6

Evaluation

6.1 Overview

This chapter gives detailed results from all of the evaluations of AEINS. The goal of evaluation is to identify issues and effects of the developed architecture and have a better understanding of the implemented platform from the participants' perspectives. In order to investigate the different aspects present in AEINS, more than one evaluation method has been used. For the purpose of this study, intrinsic and empirical evaluation have been performed. On the intrinsic front, we introduce some properties that should arguably hold in order to achieve this thesis contribution. Empirically, we constructed an edugame platform to be tested by children who are post interviewed. Interviews as an evaluation method, have been chosen for their ability to get in-depth information from the participants.

The chapter starts with the listing of the thesis goals and moves the reader through the various evaluation methods considered in the evaluation of AEINS. Towards the end of this chapter, results from experiments with human participants are discussed along with a study on the participants' log files. Finally, a discussion of findings and drawbacks encountered in AEINS are presented.

6.2 Thesis Goals

The contribution of this thesis lies in the integration of four features shown to individually increase effectiveness of edugames environments, yet not integrated together: first, the presence of a student model that handles different information about the student such as the acquired skills, his strength points, his weaknesses and his needs in order to provide personalized learning as mentioned previously. Second, a dynamically generated narrative approach that aims to provide the student with high agency within the environment and generates a story according to the student's preferences. The third feature is the use of scripted narrative that constrains the student agency at certain parts that supply education in order to allow tracking the student's actions and assess them. Finally, the presence of a continuous story engages the user and allows the presence of evolving non-player characters. Based on this architecture an educational game, AEINS, has been implemented and applied to character education as a proof of concept.

AEINS is intended to be evaluated for the following aspects: design goals, games' features, technical features, social aspects, educational outcomes and adaptation. Evaluation in the context of learning technology can be described as a process through which the information about usability of a system is gathered in order to improve the system or to assess a completed interface, and the evaluation methods are procedures for collecting relevant data about the operation and the usability of the system (Oliver 2000). When a novel learning technique is proposed and implemented, it is necessary to compare it with other similar techniques, if possible, to gauge how it improves on previous results (Karpov et al. 2006). To the extent of our knowledge, AEINS is the only edugame developed to teach children in the ethics domain and the only educational game that combines the following features: graph generated narrative, dynamic generated narrative, evolving agents and a student model in a single architecture. Therefore, a comparison study to other exact architectures could not be done. However, on the parts level, the utilization of the individual aspects in AEINS can be compared to work done by other researchers who made use of the same aspects.

6.3 Evaluation of Design Goals

Evaluation of any system is the way to prove its effectiveness. In order to evaluate AEINS's design goals, formative and summative evaluation could be followed. Formative evaluation seeks to identify aspects of a design that can be improved (Malone & Lepper 1988). It is typically conducted during the development or improvement of the system. Due to the nature of AEINS design, it was not feasible to approach the formative evaluation as it was not possible to try the system before it was completely developed. This is due to the fact that any informative output would only be presented to the user after at least one interaction cycle between AEINS's modules. For this reason, intrinsic evaluation was the suitable method to use as it is concerned with design goals and is interested in the implicit goals embodied by aspects of a design, and makes value judgment about these goals, as would be detailed later in Section 6.4. On the other hand, summative evaluation has been approached to provide information on the system's efficacy (the system's ability to do what it was designed to do) (Malone & Lepper 1988). So by looking at how the learner's did, it helped to know whether the system teaches what it is supposed to teach. This has been approached using the interviews evaluation method as will be discussed later in section 6.6.5.3.

AEINS has been tested for its longest learning path. The designer tried the system in order to test for code coverage and make sure that the system 'works right'. It was intentional to interact with AEINS in a way that initialized the student model with all the moral virtues assigned as 'not mastered' and during the interaction course with AEINS, there was no indications that the learner was involved in concept formation. In other words, the designer showed persistent misconception while interacting with the teaching moments. Based on that attitude, the pedagogical model meant to present all the dilemmas related to the misconceptions. In conclusion, AEINS successfully provided the longest learning path when required.

6.4 Intrinsic Evaluation

The intrinsic evaluation checks that all the design goals have been met and that AEINS is able to provide what it is supposed to provide, see Section 4.2, in addition to making value judgment about these goals (Carroll et al. 1992). The design goals are intended to be satisfied through the implementation of the architecture's various modules. AEINS is able to generate a continuous engaging story which the student can interact with and affect how it unfolds (goal 1 addressed). Having a game world where the student can see the effect of his actions on himself and others is a stimulant, in addition to designing the exercises as interactive teaching moments (goal 8 addressed) which take part in the main story construction (goal 5 addressed). Moreover, the world is inhabited by non-playing characters with whom the student can interact in a realistic and believable way (goal 2 and goal 4 are satisfied). Providing the adequate level of challenge (adaptation) is achieved through the presence of the student model and various levels of teaching moments (goal 3 addressed). The edugame considers the learning theories of Gagné and Keller in the design and implementation phases (goal 6 partially addressed), and uses Bloom's taxonomy as a gauge for the educational outcomes (goal 6 to be fully addressed). The inclusion of a domain model, a student model and a pedagogical model in the edugame environment addresses goal 7. Goal 9 and goal 10 have been achieved through the empirical evaluation as will be discussed later in this chapter.

Moreover, the intrinsic evaluation aims to verify that the following goals have been achieved:

1. The development of a generic architecture based on learning theories. The architecture should exhibit the following:
    - The creation of a continuous generated narrative that allows the presence of evolving characters.
    - The integration of an intelligent tutor that makes use of a student model to attempt to solve the bandwidth problem and allows adaptation.
    - Addressing the student agency versus tracking the learning process problem.
2. The use of the Socratic Method as the teaching pedagogy that helps in developing moral reasoning.
3. Solving classroom problems such as adaptation to individual students and helping shy students to express their beliefs.

The first part considers the architecture design, which is based on the idea of using interactive narrative and problem based learning that suits many ill-defined domains like those mentioned previously. It is generic in the sense that it can be utilized in any system that aims to teach in ill-defined domains such as ethics and citizenship, history, English literature or social behaviours. In addition, educational theories, such as Gagné's nine events, see Section 5.9 have been considered during the design phase, whereas Keller's ARCS model has been considered in designing and implementing the presentation model. Moreover, the architecture manages to achieve the goals set for successful educational games, see Section 4.3.1.

One aspect of the designed architecture lies in the ability of the story generator to produce a dynamic continuous story at run time, which allows the interleave of graph structured narrative(s). The continuous story allows the presence of the non-playing characters whose personalities evolve and change as the story unfolds. The evolving characters help in providing realism and believability to the story and help in supplying education to the student especially through the use of the Socratic Voice. The evolving characters also help to engage the student emotionally to the edugame virtual world.

The second aspect would be verified in Subsection 6.8. The third aspect deals with the agency problem in the existing edugames where the generated narrative in these edugames is either produced by continuous planning and loses some aspects of the educational process (e.g., keep track of the learning process and assess the learner) or is produced by graph planning that constrains the learner's freedom in order to maintain the educational goals. AEINS succeeds in overcoming this by integrating both graph planning and continuous planning approaches to generate the story in AEINS, which is a unique feature of AEINS. The former has been used in structuring the teaching moments and the latter was used to generate the story that links the teaching moments together and forms a long continuous story.

The second part deals with the teaching in AEINS. AEINS follows the constructivist teaching approach, where it is not merely teaching the participant about a process or concept undertaken by an ethics teacher, but rather allows him to experience the process directly. AEINS has strong learning objectives underpinned by effective storytelling, where it uses stories and interactive narrative as a source of inspiration and direction for moral conduct. Learners are involved in moral dilemmas that help them to express their own characters through problem solving, decision making, and conflict resolution present in these dilemmas. This kind of problem solving and decision making allows the learner to learn about basic human values including honesty and kindness. The following contribution of AEINS lies in the use of the Socratic Method as its teaching pedagogy in order to help the learners to discover for themselves what knowledge gaps they may have, along with skills they may need to develop. The ability of AEINS to provide learning and/or develop the students' moral reasoning will be discussed in the empirical evaluation section.

The final part is concerned with solving real-life classroom teaching problems. These problems are tackled through using computers in general and using AEINS in particular. AEINS succeeds to overcome the classroom problems, where it offers learning at the participant's pace, the required privacy and the safe environment within which children can explore. It allows the inclusion of many different dilemmas that the child can interact with and learn from. Most importantly it offers adaptation that provides personalized teaching and feedback. Moreover, the learner is able to interact with the virtual environment, receiving reactions during the interaction course and afterwards about what has happened; form his own hypothesis and re-interact with the environment, seeing what effect he or she gets and finally treats this effect as feedback and accepts or rethinks his or her original hypothesis. By doing this, AEINS helps the learners to move from the state of making moral judgments to the state of taking moral actions, from the knowing state to the doing state, which we consider a very important step in moral education.

Although results from the intrinsic evaluation partially confirm the hypothesis of the thesis, empirical evaluation is still needed to fully judge the contributions of this thesis. The next section evaluates AEINS against various game aspects.

6.5 Game Aspects in AEINS

Gee (2004a) published a condensed list of 13 principles of learning that should be built into good computer and video games. According to Gee, the stronger any game is on more of the features on the list, the better its score for learning. Following the definitions provided in this list, this section describes the extent AEINS managed to achieve Gee's principles.

6.5.1 Empowered Learners

6.5.1.1 Co-Design

Good games gives players a feeling of control over the game, they are actively creating part of their experience, having an effect on the virtual world they are inhabiting, and influencing their playing experience. In other words, the player feels significant impact, due to his actions, on the tasks he is attempting and how he approaches them.

In AEINS, this principle is well attempted. The student can take actions that influence how the story unfolds. In addition, the teaching moments' settings allow the student to act and apply his beliefs in various situations showing the impact of the student's actions in the short term and long term in the teaching moment story. The variety of situations in which the student becomes involved and the realism in the game aim to support transfer of various basic moral skills. For example, one agent can ask the student to support his say, although they both know that it is a lie. The student has the freedom to agree or disagree with the agent. Either decision will lead to a completely different story line and consequently different endings, where endings in this case are considered as summative feedback for the student, mainly based on his actions.

6.5.1.2 Customize

This principle addresses a more fundamental way that the player can influence game play, either by customizing the game play to fit their learning and playing styles or the game itself allows the learners to try different learning styles. AEINS does not allow this. AEINS offers a personalized story and individualized learning process, but it does not offer different learning styles such as text, graphics, or audio. It does not also consider gender or offer multiple interfaces for individual preference.

6.5.1.3 Identity

Games can provide an exceptionally strong method of fostering motivation allowing students to feel ownership by immersing players in an alternate reality where they take on a different identity. The player either becomes able to apply his own fantasies, desires and pleasures onto the character or if the character is empty the player has to create a life history for this character in the game world. In AEINS, the player chooses a character to represent himself in the virtual world and chooses friends from a group of non-playing characters (semi-autonomous agents). This character is empty where the student can build character history through his action and choices, that reflects his beliefs, in the game world. If the learner succeeds in bridging the real identity to the virtual identity in the game, he should be motivated to learn the ethical values and skills to help that character succeed.

6.5.1.4 Manipulation and Distributed Knowledge

This aspect deals with actions, where computer and video games inherently involve action at a distance. The more and better a player can manipulate a character, the more the player invests in the game world. Good games offer characters that the player can move intricately, effectively, and easily through the world and easy manipulation of the world's objects. We think AEINS has partially achieved this aspect, where the graphical user interface provided is 2D. On-screen text is used in order to interact with the game. The virtual character representing the student and other non-playing characters are able to take actions and go around the world. However, there are no physical objects that can be used by the learner for carrying out his goals, there are actions that assist him in approaching his goals. For believability and variety purposes, some actions have been developed specifically for the student and others specifically for the non-playing characters as not all people in the real world have the same personalities or capabilities. If the student is good in taking the appropriate actions, he should progress quickly in the game by facing other moral dilemmas. If he is not, the game will help them improve. This should provide learners with the required personalized learning process and allow them to learn at their own pace.

In ill-defined domains, knowledge to be acquired is more conceptual than perceptual. Accordingly, it is important to provide interaction with just the type of conceptual materials that we want students to learn. Games offer an advantage over traditional schooling where they allow connection between perception and action, which is a highly prototypical form of knowledge that can be represented by production rules of the following form: If this is the current situation, do this. Moreover, getting the learner immersed in a (simulated) environment provides a much richer context than a worksheet or other homework assignment could. This brings us to the various integration ways of games and educational materials, such as exogenous and endogenous.

According to Hastings et al. (2009), in exogenous games, the learning content is often added into a general game framework like a quiz show or a shooter game. Researchers prefer endogenous games, the content material is intimately tied in with the game play, because of their theoretical advantage in learning effectiveness. AEINS is designed as an endogenous game. From the very beginning, we were aware of the importance of having the educational tasks weaved into the games directly and progress in the game should depend only on acquiring the required skills. We created multiple stories that can smoothly integrate to the main story in which the player is put into a position where he must use the skills we are trying to reinforce. Inability to perform the skills will bring feedback and extra practice. Mastery of the skills will bring success and progress within the game.

6.5.2 Problem Solving

6.5.2.1 Well-ordered Problems

Good games provide ordered problems in a way that skills gained at solving earlier problems would help in solving further, possibly more difficult, problems later on. As known, games should provide the right level of difficulty to their users, presenting the player with complex tasks that overestimate his skills can lead him to invent solutions which do not apply to related tasks or present him with trivial tasks that underestimate his skills which can lead to frustration (Hastings et al. 2009). Presenting the right level of interaction is very important as it allows the student to apply his skills in a clever way to find some solution to the encountered problem. AEINS provides different levels of moral dilemmas that attempt various ethical concepts and reinforce good attitudes. The more the student practices and proceeds in the game the more moral conflicts will appear. Skills gained at solving simpler problems should help the learner to solve subsequent more complicated conflicts.

6.5.2.2 Pleasantly Frustrating

The problem with learning ethics is that it is not merely a matter of acquiring more knowledge. Another problem is that moral situations have no one single right answer that everyone agrees upon. However, there are generally accepted moral views for such situations especially when the problem is divided into subproblems and every single one is tackled individually as -a kind of- well defined problem. The advantage AEINS offers in this case is that student will get immediate, non-threatening feedback that indicates he is missing something important. This is done through the reactions of the non-playing characters that provide implicit feedback. When the new skill is gained, the student starts receiving positive feedback again in the context of the story itself, for example, advancing to a good end of the story.

6.5.2.3 Cycles of Expertise; Skills as Strategies

Expertise is formed in any area by repeated cycles of learners practicing skills until they are nearly automatic, then having those skills fail in ways that cause the learners to have to think again and learn anew. As mentioned through this thesis, in AEINS, each new dilemma (teaching moment) brings a new challenge that builds on previously-learned skills. Students advance between levels when a certain level of proficiency is reached. They then continue to practice those skills in the service of higher level goals. Practice helps the student automatize the new knowledge and feel pride in their growing expertise. As skills become automated, they serve as components in the higher level strategies that the students learn.

6.5.2.4 Information On-Demand and Just-In-Time

Gee sees that humans are not efficiently capable of using verbal information (words). They can use it best when it is put in use and when they feel they need it. Although most games come with some sort of manual, few players ever read them. Instead, good games provide subtle, in-game hints about what to do (Hastings et al. 2009). In AEINS, the player initially receives a brief introduction about the world and what should be done. Then the student is left to explore the environment by himself. The AEINS story helps in leading and guiding the student through the learning process. Positive and negative feedback are provided whenever appropriate, this supports the learning by connecting actions with solving goals.

6.5.2.5 Fish Tanks; Sandboxes

Fish tanks are those simplified versions of the main game that allow tutoring and practicing in order to understand the game as a whole system. AEINS has not tackled this point. With sandboxes, Gee defines the term as follows: learners are put into a situation that feels like the real thing, but with risks and dangers greatly mitigated, they can learn well and still feel a sense of authenticity and accomplishment. Sandboxes give players free rein to explore the range of choices in a game environment without feeling pressure to perform optimally or choose too quickly (Hastings et al. 2009). In AEINS, this has been attempted in the design of the teaching moments that provide realism in the game and social contexts. The game story elements are designed in a way that can motivate the student to learn the ethical skills.

6.5.2.6 Skills as Strategies

Gee found that people do not like practicing individual skills over and over in a meaningless context. They will gladly practice a set of related skills as a strategy to accomplish goals they want to accomplish. AEINS allows practicing individual skills but through providing various realistic and meaningful contexts and situations. It also provides moral dilemmas that require the learner to apply more than one skill in order to progress successfully in the game.

6.5.3 Understanding

6.5.3.1 System Thinking

People learn skills, strategies, and ideas best when they see and understand how they fit into an overall larger system to which they give meaning. The player learns most effectively when he understands his role within the system and can use that knowledge to set goals and determine actions (Hastings et al. 2009). The AEINS environment allows the student to picture himself in the virtual world and how he fits in it, in addition to how his actions affect himself and others. An AEINS story is generated in a way that gives the student this type of system within which he can learn and practice ethical and moral skills. It was designed to provide the student with the conceptual connections required for learning with understanding.

6.5.3.2 Meaning as Action Image

Humans do not usually think through general definitions and logical principles. Rather, they think through experiences they have had. It is the person's own experience that gives words their meanings. Gee's opinion is that games can reach marvellous effects if they succeeded to tie words and concepts to actions in the world. In other words, by linking perception to action, the conceptual learning is strengthened and the student's experience is enriched. As we have discussed before, the AEINS design is all about situating the learning and use of ethical skills within a rich context that enables the player to learn with deep understanding. AEINS is designed to help the student learn not just the actions that are required, but also the perceptual conditions in which they apply.

6.6 Empirical Evaluation

Several evaluation approaches could be followed to evaluate AEINS, such as comparative, quantitative and qualitative evaluation approaches. This section describes the different approaches considered to evaluate AEINS and discusses the choices of certain approaches over others.

Comparative evaluation is considered one of the most classical approaches in evaluating computer based learning systems. It is a comparative study between classical teaching versus computer-based teaching. We intended to conduct Comparative evaluation, but it was not possible due to the presence of limitations related to recruiting teachers and working with schools. Nevertheless, we plan to apply it in future work in order to give more insight about the role of AEINS in educating children about moral virtues

Quantitative and qualitative approaches have been distinguished and thereby defined on the basis of the type of data used (numeric or textual; unstructured or structured), the logic employed (deductive or inductive), the type of investigation (confirmatory or exploratory), the method of analysis (statistical or interpretive), the approach to explanation (process theory or variance theory) (Bazeley 2004).

Quantitative evaluation was considered using the closed questions method, but was not applied for the following reason: although closed questions could be easily analyzed, they were not utilized as they restrict the respondent's responses by supplying alternative answers and the responses could be hard to interpret. Besides, this type of evaluation supports more generalizable conclusions and tries to explain the variance of the dependent variable(s) generated through the manipulation of independent variable(s) (variable-based), which is not the case in this study.

Qualitative evaluation was more related to the real usage of AEINS where the object of the study is the individual participant (case-based). This type of evaluation could be approached through several methods including focus groups and interviews. Gena (2005) mentioned that qualitative methods of evaluation are seldom applied in the assessment of user adaptive systems, though for the purpose of this study the qualitative evaluation seems to be very appropriate because of the ill-defined nature of the ethics domain and the fact that the participants were children.

Focus groups is a method that brings a group of users together to discuss issues and requirements (Sharp et al. 2002). This can be very revealing where these sessions can be used to collect the user's opinions and feedback both during the requirement gathering and after the system has been used for a while. As there was no opportunity to collaborate with schools as mentioned previously, there was no chance to allow the children to interact with AEINS for quite long periods. However, this is aimed to be done in future work.

It had been decided to allow the children to interact with AEINS and then post-interviewed to collect their opinions and feedback. The interviews were semi-structured that composed of open-ended questions. This method has been considered for its flexibility, sensitivity, meaningful conclusions about specific problems and its ability to lead to specific constructive suggestions. In addition, it allowed to vary questions to suit the context and probe more deeply on interesting issues as they arise (Sharp et al. 2002). The following study provides an evaluation for the technical features of AEINS, social aspects in AEINS and the educational outcomes through a qualitative analysis of the data resulted from the post interviews with the users of AEINS.

Two more methods were also suggested to evaluate AEINS: the pre- and post-test and the Wizard of Oz methods. The pre- and post-test is a method where the students should take a pre-test, usually multiple choice test, play with AEINS then undergo another post-test. This evaluation method proposed a severe disadvantage for our study lied in the possibility of the children to relate the questions in the tests to the game play in AEINS. In other words, the children might think that their behaviour is judged by AEINS and this might affect the way they took their decisions in the game. For example, always tend to choose the right action. The Wizard of Oz is a low-fidelity prototyping method that assumes the existence of a software based prototype (Sharp et al. 2002). In this method, the user interacts with the emulated system without being aware of the fact that an experimenter is the one who is responding to him not the computer. This evaluation method might help evaluating the user's beliefs but would not help to assess the different aspects of AEINS, which would not serve the purpose of this study.

6.6.1 The Study

A study was conducted with a total of 20 participating children. The study was based on allowing the participants to interact with AEINS in subjective experiences as it is these experiences that need to be captured. The following is a detailed description of the format of the study in addition to a detailed description of the participants.

6.6.2 Study Design

A full study has been completed to test AEINS for different criteria such as the technical infrastructure, its functioning, its ability to support or enable specific activities, and generate predicted educational outcomes. The study was conducted on a group of children aged 8 to 12 years to test the hypothesis of building an educational game that is able to provide individualized and personalized learning in the ethics domain, and able to develop new thoughts of the participants. Comprehensive log files are automatically generated by AEINS that detailed every action taken within the game. A CRB clearance has been extracted for this purpose.

In designing this study, it was determined that the best approach was to rely on a qualitative research method that produces a description, usually in non-numeric terms ideal for eliciting users' thoughts. Since the participants were children, the use of in-depth, open-ended interviewing seemed the appropriate method to capture the interviewees' experiences and getting into their thoughts on the program being evaluated. It helped the participants to express their program experiences and judgments in their own terms. The resulted data consist of verbatim quotations with sufficient context to be interpretable.

In each assignment, the participant was left to explore and interact with the system at their own pace. The children were monitored during their interaction with AEINS to see if one of the following appears: engagement, losing the feeling about the outside world, boredom, or entertainment. The participants were then post-interviewed, the interviews were directed, focusing on the system's different aspects Appendix A and providing a questionnaire Appendix C which was designed to gain feedback from the participants about the way they perceived the game. All discussions were recorded in order to be analyzed later.

6.6.3 Participants

Twenty participants were assigned to play with AEINS over a number of games. Their age was between 8 and 12 years (15 male, 6 female), with an exception of one participant who was a 7 year old. They were all children from schools in York who were recruited through personal contacts and voluntarily agreed to use AEINS after taking their families permission. Table 6.1 shows that the participants were of different origins and had different cultural backgrounds. The children speak English as their second language, however they were all at the average level of the language skills required for their ages in their classes.

Table 6.1: Participants' background information

participants	Gender	Home Country	Age
P1	M	Korea	11
P2	F	Fiji	9
P3	F	Fiji	8.5
P4	F	Fiji	12
P5	M	Egypt	9
P6	M	Egypt	11.5
P7	F	Egypt	9
P8	F	Malissia	10
P9	M	Taiwan	11
P10	M	Taiwan	9
P11	M	Egypt	10
P12	M	Egypt	8
P13	F	Egypt	7
P14	M	UK	9
P15	M	Uzbekistan	8.5
P16	M	Uzbekistan	10
P17	M	Lebanon	9
P18	M	Lebanon	11
P19	M	Malaysia	10
P20	M	Malaysta	10

AEINS is built on the universal view of the right and wrong, therefore there was no problem in recruiting children from different back grounds and different cultures as this will not affect how to use AEINS.

6.6.4 Materials and Procedures

Prior to each experiment, demographic data was collected for each participant and an informed consent form, see Appendix B, signed by their parents. The participants were interviewed individually. The AEINS environment was briefly introduced to each participant. The participants were encouraged to explore the environment themselves and provided with the required privacy. Participants were explicitly told "Try to be yourself", our intention is to encourage them to respond on the basis of their moral convictions, without regard for whether an action is good. The participants reactions during their interaction with AEINS were watched and recorded.

The participants worked at their own pace and all their actions were recorded by AEINS to be analyzed later by us. AEINS did not allow the participant to change their minds regarding their taken actions, because this is what can happen in real life. Once an action is done, there may not be a chance to redo it or revise it. In this way, the participant will experience the effects of his choices on himself and on others in a way similar to that in a real life context.

To evaluate AEINS, post interviews were conducted that focus on five different categories. The first category includes questions related to the technical infrastructure and its functioning. The second category includes questions related to the functions and features inherent in the system and its ability to support or enable a specific activity. The third category includes questions related to the participant tasks. The fourth category includes questions related to the capability for specific technology-based activities to generate predicted outcomes. And finally the fifth category includes questions related to the re-playability and self reflection. The questions in each of these categories are mapped to some other coding questions that are directly related to the research questions needed to be investigated.

We used this style in designing our evaluation, because it was difficult to face the participants with such rich questions that, according to their age range, will be difficult for them to understand. So we substituted research questions with some other questions that can easily be interpreted by the children and allow them to express themselves. The answers to these questions help in answering the main research question in a certain theme, an example of this representation is shown in Table 6.2 and Appendix C. This type of assessment allows us to cover different aspects about AEINS and the problem space by ensuring that the participants are assessed on their knowledge of the key moral issues relating to the moral situations they faced.

6.6.5 Results

According to what AEINS aims to achieve and the data provided, it has been found that it will not be interesting to tackle every single question on its own as sometimes some questions did not produce enough rich data. Instead the results are organized around the main themes reflected by the data. These three themes are: AEINS Architecture and implementation, Social aspects in AEINS, and Learning deployed in AEINS and educational achievements. All the sample comments are representative and no negative comments have been suppressed.

Table 6.2: Example of post interview analytical questions

Interview question	Coding
Question type 4: Interaction of activity and learning outcomes. These questions are related to the capability for specific technology-based activities to generate predicted outcomes. (Did activity Z help the participant to accomplish S?)	
- What do you gained from this experience? - Do you think this session can help you in your real life? - What do you think of the stories you took part in?	- Do the activities (teaching moments) result in what they aim for?

6.6.5.1 AEINS Architecture and Implementation

The AEINS interface is a simple point and click interface. However, some participants were slow at the beginning getting acquainted to the rules of the game, but after a short time they became quick and very immersed. The interface uses check boxes to handle the student's actions or choices. It allows mouse clicks to interact with the game world and multiple lines text boxes to present the story and stores every single action in the environment. This allows the learner, at any time, to go and see past actions to solve a conflict or judging certain action based on previous ones. Most of the participants referred to the interface as easy to use, one participant commented on the interface saying

> P18: "Everything is clear. The reading is quite easy, where lines are under each other, quite separate which make things clear."

It has been noticed that only a few participants struggle with using the laptop mouse such as P4 and P18, which was easily solved by attaching a normal mouse to the laptop.

Interacting with AEINS was shown to be an enjoyable experience for most of the participants, AEINS was described by P11 as an environment where you can try wrong things and see what could happen. P5 said the following about AEINS

> ".... very million times good."

and added

> "It tries to make you behave well in real life, this is your training to be good."

Another participant said

> P6: "I enjoyed finding new situations, meeting the characters and solving problems out for them."

and added

> "I like the idea of facing situations in different places"

Moreover, the story in AEINS has been described as connected by P5, fun as judged by P13 and by P6 as defined and interesting. Another participant added

> P18: "The whole story is quite organized. It is good and simple .... it gives a variety of options and characters."

The participants asked to have longer time to play with the game adding more situations to interact with and more places (enlarge the environment space) that have realistic pictures with internal views and people acting. This suggests the need for a 3D interface and a bigger world, however it also suggests that they have enjoyed playing with the game and were satisfied with the design of the current moral situations and therefore they are asking for more. In relation to this, the participants were keen to see how the current story (moral situation) will end. This is interesting, because this end represents summative feedback, which is based on all the participant's previous actions in this particular moral dilemma. There are two kinds of feedback, positive feedback in the form of praising the participant for his good attitudes and negative feedback in the form of losing something or losing a friend.

Although AEINS has combined two different techniques to generate the narrative as one of its main contributions. No participant has noticed the transfer points of one technique to another as the story was generated smoothly and successfully to accommodate the teaching moments in a seamless way without affecting the learner's experience. Accordingly, we can say that AEINS manages to compromise between giving the learner the appropriate freedom and being able to track and assess the learning process.

Use of the save facility in AEINS was admired by the participants, they all agreed on the idea of revisiting the experience, for example P6 said

> "I like saving the experience to remember what happened in case this comes to me again so I remember what I have done."

Another participant said

> P1: "I would refer back to the saved stories to check what I have chosen where I can't remember"

We argue that this a critical issue in AEINS, where revisiting the previous experiences allow self-reflection and may judge themselves on the validity of certain actions, in addition to developing or articulating new thoughts and ideas based on existing ones. We think learner's here are attempting the highest levels of the adapted version of Bloom's taxonomy, where they can evaluate actions and develop/create new ideas. This is a recognized result that needs more empirical studies to confirm.

6.6.5.2 Social Aspects in AEINS

The evaluation shows that children appreciate the social characteristic in the system, as they were able to recognize the genuine social aspects and the realism represented in the game. The analytical questions confirm this recognition. For example, participants clearly cared about the outcome as shown from the following quotes:

> P15: "The best moment was when my parents and my teacher were proud of me because of what I had done."

Another participant, P16, felt **good** when the teacher told the parents that he told the truth and he was rewarded by going on a nice summer holiday. This quote and others like

> P6: "I was **upset** when my friend said that she will not be my friend anymore." [boldface added]

shows the emotional effect of the game on the participants where they can feel good, bad, scared, surprised. Emotional engagement is another positive point AEINS provides.

It seems that AEINS was able to make them feel that they are really involved in realistic situations and consequently they were acting accordingly, which provides more evidence that the participants' were recognizing the social situation and recognizing the non-playing characters as real friends. One of the interviewees said

> P5: "I felt as if I am in a real world and these characters are really talking to me, they were very believable."

Another participant said

> P6: "I did not mean to upset my friend, I felt as if it really happened and I had lost my friend who will not talk to me ever again. I think I will be careful next time."

What was really interesting is the way the participants personalize the non-playing characters in the game. They do not only interact with them as their friends in the game but also they gave them lives and they were picturing how these characters behave beyond these moments. For example one interviewee said

> P2: "I do not like Gina when she lies, I want to tell her that this is wrong and she has to stop lying."

The interviewee added

> "If she keeps doing this now, no one will believe her in the future."

The participants also believe the non playing characters' personalities: they like some and dislike others. One participant said

> P9: "I like Peter the most, he is funny."

Another participant said

> P4: "I do not like Gina, she is not a real friend. She always asks me to do wrong things."

and

> P11: "Gina is a liar."

Another participant said

> P1: "I want to tell Judy to stop acting like a baby"

The realism present in AEINS allows the participants to think about the non-playing characters as real friends who can feel and expect certain actions from them. For example, one participant quoted

> P7: "If I choose to be on the side of one friend, the other one could become angry."

Another participant, when asked about the non-playing characters said the following:

> P6: "They rely on me. they ask me to solve their problems. They need my help."

However, when asked if any of them has behaved in a strange way , he replied

> "They are trying to make me cheat, *real friends* do not do this." [italics added]

Moreover, the participants were treating the situations as real ones and responding to them in a realistic way, for example one participant said "I found the homework situation very confusing." and when he has been asked why, he replied

> P2: "When my mum called me to see the TV, I was **scared** as I still have homework to do and the teacher will figure out the next morning." [boldface added]

One participant felt proud of herself as she supported her friend and left the football game with him when another player was unfair to this friend. Another participant was very confused in the same situation as she was torn between leaving the game and supporting her friend or *missing the fun*. [italics added]

These results reflect an important point that the learners were able to react to aspects of the domain and apply their current and potential capacities in this game. From the participants' answers, it has been figured out that most of them were not treating the game as just a game, they do respect and appreciate the difficult situations they were facing and they tried to prove themselves and use their skills in order to solve the discrepancies faced. This is very promising because this means that the actions taken in the game reflect their real beliefs and this will help us to recognize the real effect of AEINS on them. Some quotes reflect this result, for example when one participant mentioned that she does not like the homework teaching moment and when she has been asked why she answered

> P9: "I do not like doing homeworks"

Also another participant had not tried to go home at all and when asked why, he replied

> P2: "I do not like going home in general."

This shows that the children were interacting with AEINS in a realistic manner.

Although some of the children did not go that far and achieve what their colleagues achieved, we think we are heading in the right direction to tab in this educational field. Some of the children are talking this way and expressing their ideas,

> P5: "It was really nice solving my friends' problems."

> P6: "It is good to feel that your friends rely on you, and ask you for help when they need to."

This actually can be seen as recognition of abilities and skills of the participants: they felt proud when they succeeded in solving problems and supported their friends. What has been observed here is that the game is not giving certain skills but it empowers the participants to use the skills they have. It also reinforces problem solving skills where learners are forced to solve their friends' problems and helps them to think wisely about the best way to do this, for example this participant did not choose to be on anyone's side as the teaching moment required, he wants to solve the situation by another way as shown in his say

> P1: "I want to tell them not to be upset, just play, whether to lose or win there is no problem"

These results go well beyond the educational theories in Chapter 2, which state the importance of stories in transferring tacit knowledge and speak rather about relationships and human connections. In addition, being involved in stories and moral dilemmas helps in emphasizing moral behaviour and gives the chance to experience various situations and allow participants to take different roles.

6.6.5.3 Educational Achievements of AEINS

This theme is very important as it tends to show that AEINS is an effective learning environment and is able to deliver effective learning, in other words, develop the participant's reasoning process. The use of the Socratic Method as the teaching pedagogy shows success. In every teaching moment, since the voice of Socrates comes from one of the involved characters in the moral situation who exhibits certain personality characteristics, mostly one of the learner's friends, to raise the moral conflict, pushes the learner to think harder to solve the discrepancy exist in these situations. For example, from P11's log file, it has been found that the learner followed the following path in the shoplifting dilemma: agree to help his friend to take a chocolate bar without paying for it, then undertake a discussion with the good moral character, who uses Socrate's Voice, the discussion leads to a change in the learner behaviour where he admitted he did a mistake and asked his friend to return the chocolate back. Such an attitude reflects the power of the Socratic Method in forcing the learner to face the contradictions present in any course of action not based on good moral principles. In the post interview with P11, he mentioned that he made a mistake by helping Gina (the immoral character in the shoplifting dilemma) to take the chocolate. This goes well with the results obtained from the log file.

One participant likes the fact that she can interact with the teaching moments and is able to see the effect of her decisions on herself and others. This interviewee has asked to restart the game when she has been faced by negative consequences as a result of one of her choices. This shows that although the feedback was implicitly provided in the story, it manages to deliver the message (you did something wrong) which was not appropriate to be said explicitly as discussed before in Chapter 5. In the post interview, it seems that the interviewee has an explicit representation about taking stuff. This appears in her final comment:

> P13: "Taking other people's stuff is stealing and we should not take something without asking first."

We claim that the interactive teaching moments were able to provide the appropriate hints about various moral actions and situate the learners in different mental and emotional states. Moreover it allows the learner to attempt the high levels in the adapted version of Bloom's taxonomy such as Analysis, for example the participants were analyzing the situations, where conflict exists, and trying to find a solution to the current dilemma, as in these quotes

> P4: "It was difficult to take a decision as this can make my friend upset"

The participants were also relating to the real world and applying their beliefs, for example participant 17 was nearly choosing all bad actions to do, accordingly he was faced with negative consequences as a feedback. He said the following in the post interview

> P17: "I hope if there was no law."

This shows that although he chose to do the bad actions the feedback provided made him think of the law and the consequences of such actions in real life. Another interesting point raised while talking to participant 5 is that they were able to show high intellectual reasoning to provide support to their acts, for example Participant 5 does not like to disagree with his friends as they become angry with him.

> "I do not want them to stop being my friend."

and when asked if they even do wrong things, he replied

> "Yes, because everyone does wrong stuff."

However, Participant 5 does not seem to be worried about other things rather than losing a friend, we claim that some ideas transfer occurred through interacting with AEINS, the following quote supports this claim

> "I used to lie on my little sister to come out of trouble, now I think with lying I can be in a bigger trouble."

And when asked about what he is going to do now, he answered

> "Tell the truth."

The presence of the student model provides adaptation in the sense of presenting the teaching moments according to the student's recognized misconceptions. An important point to mention is that this kind of adaptation reinforces re-playability since the student is not presented with all the teaching moments existing in AEINS every time they play. Re-playability can also occur as a result of the variety of the presented teaching moments and the fact of having different branching stories in the single teaching moments. A point was raised by P16 that he would like to try different possibilities for different actions, even if only faced with the same dilemmas he faced before, so he would play daily for about 20 minutes with this game. We think with the presence of richer repertoire of teaching moments, students can spend a quite long time interacting with AEINS. Such practicing through problem solving and the ability of experiencing new things could lead to developing new insights or deeper ones.

Transferring the knowledge to the real world is the main aim of AEINS although this is very difficult to assess as it needs very long term evaluation. However, the interviews provided some insight about what AEINS has achieved in this area. It has shown that some of the learners are thinking of taking the experiences from the game to real experiments. For example, when one participant was asked about what she thinks she will take away out of this experience, she answered

> P7: "I will think about the situations I have been involved in and what can happen if I really get involved into one."

Another participant commented:

> P6: "I think this can help me solving school problems."

These quotes show the possibility of learning transfer and the sparking of new thoughts and/or deeper ones. This also fits well with Gee (2004) in that when people are faced with a new situation in the world, aspects or elements of this situation remind them of aspects or elements of experiences they have had in the past. They use these elements of past experience to think about the new situation. Sometimes they can just apply past experience pretty much as is to the new situation, other times they have to adapt past experience to be able to apply it.

Discovery is also another good point AEINS offers as it provides a safe environment for participants to explore. For example, one participant mentioned that he chose to agree with the bad friend in order to see what would happen. On the other hand, another participant thinks that doing a wrong action in the game is just a mistake, but he is aware of not taking the same action in real life. Even this participant has a certain level of awareness, choosing the wrong action in the game will lead to certain consequences that can support his opinion about not to perform the same action in real situations.

6.7 The Analysis of the log Files

Quantitative evaluation, for example using questionnaires, can provide informative data about the participants. For reliability purpose, large number of participants should exist. Because the difficulty encountered in working with schools because of their busy schedules in the period of evaluating AEINS and the difficulty in recruiting teachers because they have full time jobs and we were mainly relying on good wills, the large sample required for reliable quantitative evaluation was missing. However, on the other side since AEINS's users are children, quantitative evaluation might not seem the perfect evaluation method as it offers some difficulties such as the children bias to be kind when answering questions, the children being shy to agree on a wrong value as this might give a bad impression towards them. The best way to overcome this has been found in studying the participants' log files.

The main risk when performing experiments/evaluation for an educational game that seems to judge the participant personality lies in the fact that the participants may always try to pick the right choices as a result of being observed, for example always not to lie. In other words this means that the majority of the participants would be in the Right-Right cells. Log files were studied carefully in order to examine this theme. Fortunately, for our purposes, this is not the case as can be seen from the tables [1] below.

The rows in the tables represent the initial actions made by the students when interacting with the teaching moment. These actions could be classified as either 'right' or 'wrong'. The columns represent the final actions made by the students during the interaction, which again could be classified as either 'right' or 'wrong'. So, for example, the cell right-wrong contains the number of students who started with right choices and ended with wrong choices. In some of the teaching moments, more complex paths existed. This accounts for the division of the right-right cell into the R-R and R-W-R cells; the second of which contains the number of students who started with right actions, went on to make one or more wrong actions, but finally managed to end with a right action.

[1] R-R denotes both an initial and final Right action (student adheres to the right choices). R-W-R denotes an initial Right action, followed by one or more Wrong actions and a final Right action. W-W denotes an initial Wrong action and remain devoted to it to the end resulting in a final Wrong action. W-R denotes an initial Wrong action and final Right action

As an example of this, consider the table of choices made in Teaching Moment 1 (Table 6.3). Six students both started and ended with a right action; however of these six, two made at least one wrong action between the first and final actions. We also see that one student started with a right action but ended with a wrong action, seven students started with wrong actions but ended with right actions, and two students both started and finished with wrong actions.

Table 6.3: The participants' reasoning paths

<table>
<tr><th colspan="3">Teaching Moment I</th></tr>
<tr><th>Start \ End</th><th>Right action</th><th>Wrong action</th></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td>4</td><td>2</td></tr></table></td><td>1</td></tr>
<tr><td>Wrong action</td><td>7</td><td>2</td></tr>
<tr><th colspan="3">Teaching Moment II</th></tr>
<tr><th>Start \ End</th><th>Right action</th><th>Wrong action</th></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td>2</td><td></td></tr></table></td><td></td></tr>
<tr><td>Wrong action</td><td>4</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment III</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td>6</td><td>2</td></tr></table></td><td>1</td></tr>
<tr><td>Wrong action</td><td>7</td><td>2</td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment IV</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td></td><td>1</td></tr></table></td><td></td></tr>
<tr><td>Wrong action</td><td>1</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment V</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td></td><td>1</td></tr></table></td><td></td></tr>
<tr><td>Wrong action</td><td>3</td><td>1</td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment VI</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td>5</td><td>3</td></tr></table></td><td>1</td></tr>
<tr><td>Wrong action</td><td>5</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment VII</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>Wrong action</td><td>1</td><td>1</td></tr>
</table>

<table>
<tr><th colspan="3">Teaching Moment VIII</th></tr>
<tr><td>End / Start</td><td>Right action</td><td>Wrong action</td></tr>
<tr><td>Right action</td><td><table><tr><td>R-R</td><td>R-W-R</td></tr><tr><td>3</td><td>2</td></tr></table></td><td>1</td></tr>
<tr><td>Wrong action</td><td>3</td><td>1</td></tr>
</table>

The above tables provide interesting results. The variance in the start states between right and wrong shows that the participants' felt free in making their initial choices. On the whole the tables show that pedagogical model manages to present the student with the appropriate teaching moments that challenge the participants as more than 50% of the time the participant would go with the wrong choice.

Most of the participants take the wrong action at the start of the teaching (36 out of 71 interactions). The majority of the participants express care towards their friends to the extent they can do something which obviously seems to be wrong, however when they realize that what they did was not right they tend to change their behaviour and adhere to the right choice (31 out of 71 interactions). The rest adhere to the wrong choice even after being involved in the Socratic Dialogue (5 out of 71 interactions).

Other participants appear to pick the right choices and adhere to them to the end. It is fairly hard to exactly identify the reasons for this. It can be either a reflection of their own personalities or because of their awareness of what is expected from them in this experiment or could be they value their friendship very strongly or even just exploring the consequences of their actions (20 out of 71 interactions). Others started with taking the right action, however they seem to re evaluate their decision based on the consequences occurred, for example their friend could be upset so the participant's altered their behaviour to please their friend and stick to a wrong choice (4 out of 71 interactions).

What is also interesting is the multiple change of behaviour within the same teaching moment where the participants start with picking the right choice then alter their behaviour for their friend's sake (take a wrong action) then once again after being involved in the Socratic Dialogue they managed to discover the incorrectness/contradictions existed in their actions. Eventually, those participants mange to end with the right choice (11 out of 71 interactions).

The above results can be visualized in the charts below. Figure 6.1 shows the 50% of the time chances the participant has for their initial choice. It also clarifies that the majority of the occurrences end with the right choice. Figure 6.2 shows that the majority of participants were presented with the appropriate teaching moments that were able to challenge them based on the pedagogical model's decisions. This also indicates the validity of the student model representation that supplies knowledge to the pedagogical model. As seen in Figure 6.2, there occurred 36 initial wrong actions and 31 final right actions for those interactions. This shows that the system successfully aided around 86% of those who initially made the wrong choice to discover the contradictions in their course of actions and make the right choice at the end.

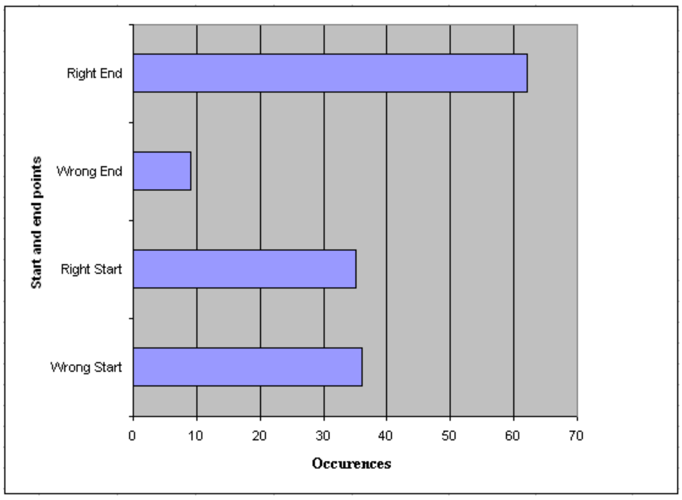


Figure 6.1: The occurrences of the right and wrong choices

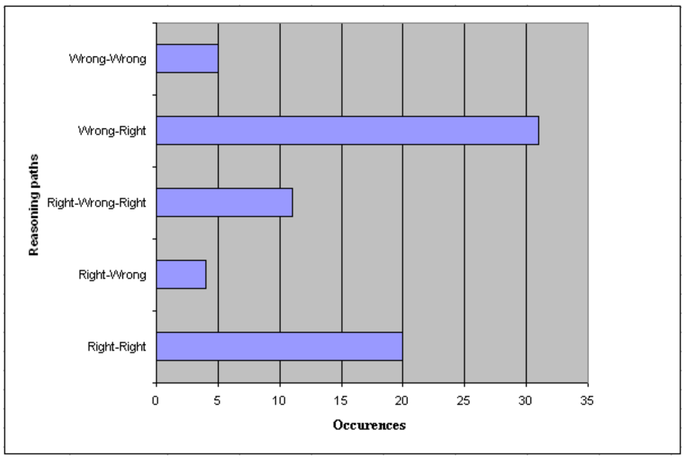


Figure 6.2: The occurrences of different cognitive paths

6.8 Adaptation in AEINS

Evaluation of adaptive systems can provide feedback that can be used to modify the adaptation strategies of the system itself. The adaptation decision-making phase can help in assessing the system's ability at building student models and the supply of a personalized learning process based on these models. This section discusses the importance of the student model and provides evidence for its positive role from the study of the participants' log files. However, we would start with the assumptions upon which we judged the efficacy of the model as follows:

- The student modeling has a positive result if the process is able to determine correctly the participant's misconceptions or missing conceptions underlying unethical action or choice and provides the appropriate feedback.
- The student modeling has a negative result if the process fails or is unable to determine the participant's misconceptions and consequently does not provide the right feedback corresponding to the participant's actions.

The level of success of the student model component depends on how comprehensive the implemented rules are and the complexity of the rules for determining the participant's misconceptions. From the study of the log files, it has been found that the presence of the student model allowed the presentation of the appropriate teaching moments' according to the participant's needs; the rest of the teaching moments were not presented because the participant's learning level did not require them. On the other hand, obviously, with the absence of the student model the teaching moments would be presented in a specific order to all the learners without any considerations to their differences and regardless of their needs.

A well designed student model offers good help for a class instructor to use in order to know the participants in his/her class in a better way. It also gives the instructor a guide to the most suitable dilemma(s) to prepare for the next class; a dilemma that addresses the misconceptions of most of the class participants. AEINS was able to produce final summarized report for every single participant that gave information about the student's level and provided a summary about the whole experience. The report also contained information about the teaching moments experienced by the participant, the participant's actions and the system's evaluation for each action. Moreover, the report reflected on the acquired skills of the participants associated with a confidence factor representing the system's confidence that the participant had acquired certain skill(s). With this evidence about how the student model worked in AEINS, we argue that the student modeling has a positive result of the process.

6.9 Discussion

AEINS provides a narrative-based educational environment that provides a personalized learning process. AEINS interacted with every single participant on a different basis according to the student model built for that particular participant. It offers a compelling virtual world and virtual identity, at some level, where some deep learning is able to occur. It can be noticed that the children were able to build a powerful bridge between their real identity and this virtual identity in the game. They did have emotional responses that transfer their real world responses to the game. This goes quite well with Gee's discussion about learning and identity and his illustration about the importance of the ability of children to build these bridges in order not to make the learning imperilled (Gee 2004c:p. 61).

Children got engaged in the game, they were allowed to bridge their real and virtual identities and they were allowed to try things that the game required them to do in a way where some deep learning or thoughts is able to occur. All participants agree on how interesting it was solving conflict situations especially between their friends and how this can be difficult sometimes. We believe that the interactive dilemmas in AEINS succeeded to induce moral interpretations. What is happening here fits really well with Gee and his theory about "what video games have to teach us" and how learners can be unwilling to put in the effort and practice demanded for mastering a domain if this compelling component is missing (Gee 2004c:p. 63).

To be able to say that there is deep learning in an ill-defined domain like ethics, this requires some kind of transformation in the way the person thinks. Through the children's experiences with AEINS, it has been found, that they were, to a large extent, using their real identities. However, this does not mean that every child has only one identity, it is actually a combination of various real identities mixed up together. Some of these identities appear in certain situations or under certain circumstances. With their ability to build this bridge between their real identities and the virtual one, the real identities are enriched with this new identity that can also appear in some real situations. Gee discusses this kind of unity in his book (Gee 2004c) mentioning that if children are learning deeply, they will learn through their projective identities, new values and new ways of being in the world based on the powerful combination of their real world identities and the virtual identity at stake in the learning.

6.10 Drawbacks Encountered in AEINS

The evaluation done provides a suggestion for the possible refinement of the principles of remediation, for example, the graphical interface needs to be more game-like (3-D) with animated characters that can move and act physically and a bigger world with more places and characters. Most of the participants have not experienced any problems with the text interaction with the game, however we think the addition of natural language component may ease this interaction.

Although the evaluation method developed for the evaluation of AEINS provides a tool for the examination of teaching ethics through computers and providing adaptive learning, alternative methods might be applicable and more advanced evaluation methods in the future may eventually provide better suggestions for the improvement of interactive narrative with intelligent tutoring and their employment in edugames environments.

6.11 Summary

The AEINS edugame prototype has been implemented as a proof-of-concept. It aims to teach in the ethics domain to foster character education. The AEINS platform makes use of four features shown to individually increase effectiveness of edugames environments, yet not integrated together: first, the presence of a student model that handles different information about the student such as the acquired skills, his strength points, his weaknesses and his needs in order to provide personalized learning as mentioned previously. Second, a dynamic generated narrative approach that aims to provide the student with high agency within the environment and generates a story according to the student's preferences. The third feature is the use of scripted narrative that constrains the student agency at certain parts that supply education in order to allow tracking the student's actions and assessment of them. Finally, the presence of a continuous story engages the user and allows the presence of evolving non-player characters. To the extent of our knowledge, no edugame has integrated these features in a single architecture before.

The evaluation of AEINS provides a good indication for the usefulness of the designed model for adaptive educational games and can be considered a first step towards an architecture that integrates interactive narrative with Intelligent Tutoring techniques that: i) employs a student model, ii) integrates more than one narrative generation technique, iii) allows the presence of continuous story and evolving non-player characters. AEINS has been evaluated using various methods: first, the game aspects of AEINS have been validated against Gee's games aspects (Gee 2004a). Second, AEINS has been evaluated intrinsically to check the implicit goals embodied by aspects of the design and to show that AEINS's components are well interrelated, they are able to operate in the right manner. The student model was able to identify misconceptions and help the pedagogical model to choose the next educational step. Finally, empirical evaluation has been performed that provides encouraging results.

The empirical evaluation was conducted to test AEINS for different criteria such as the technical infrastructure, its functioning, its ability to support or enable specific activities, and generate predicted educational outcomes. Post interviews were conducted that focus on five different themes, such as the functions and features inherent in the system and its ability to support or enable a specific activity. With the realism in the teaching moments, the children were able to pro-actively bridge their real identity to the virtual identity and they were projecting their own hopes, desires, values and beliefs onto that their in-game persona. It has also been seen that this success in bridging the real identity to the virtual identity allows the learners to discover certain skills they possess or at least know that they have the capacity to use these skills and they may also learn about their limitations. The final contribution can be seen in addressing the classroom problems mentioned earlier, and providing a safe exploratory environment for children.

The main interesting results achieved from the AEINS evaluation are: firstly, the ability of AEINS to generate a continuous story underpinned by strong educational objectives. The logical and dramatic coherence of the story unfolding was well acheived. Secondly, AEINS manages to offer the required privacy for this domain allowing the children to act and explore freely the environment and test their own selves. They were able not only to bridge their real identity to the virtual identity in the game, but also they were able to evaluate the current situation and re-evaluate it after several steps forward in the story. This can be considered as an important achievement where the ability to analyze situations and self reflection are important features that help learning in the ethics domain. Thirdly, the idea of being involved in real life-like situations seems very successful in engaging the learners and capturing their attention. Lastly, the children were actively participating in the game and were able to socialize with the inhabitant agents. This aspect helped in maximizing the agents pedagogical role where they often succeeded to alter the student's wrong opinions.

CHAPTER 7

Discussion

7.1 Overview

The research done in this thesis is multidisciplinary. It involves educational games and how they can employ intelligent tutoring to teach in ill-defined domains. The contribution of this work can be seen in the integration of individual components that each has shown to positively enhance educational games. This integration allows addressing the story coherence and the user interaction problem; allows high user's agency within the environment and tracks the learning process at the same time. The developed architecture is based on the learning theories, such as Gagné's principles and Keller's ARCS Model and has been applied in the ill-defined ethics domain to foster character education.

Based on the developed architecture, an edugame called AEINS was implemented to provide training on concrete moral activities and aiming to develop the participants' moral reasoning. The AEINS system tightly integrates gaming and learning whereby the boundaries between both are blurred. Various evaluation forms have been performed: intrinsic and empirical evaluation, which provide promising results. This chapter discusses the extent AEINS manages to achieve the goals set at the beginning of this research and how the questions raised during this research course have been answered. The chapter ends with a summary and conclusion of this thesis.

7.2 Thesis questions

The research done in this thesis falls into three areas: ill-defined domains, educational games and intelligent tutoring. The contribution of this thesis lies in the integration of multiple components that each has individually shown to be effective when used in educational games environments but not yet integrated in a single architecture. The work done in this thesis aims to achieve the following goals:

1. The development of a generic architecture based on learning theories. The architecture should exhibit the following:
   - The creation of a continuous generated narrative that allows the presence of evolving characters.
   - The integration of an intelligent tutor that makes use of a student model to attempt to solve the bandwidth problem and allows adaptation.
   - Addressing the student agency versus tracking the learning process problem.
2. The use of the Socratic Method as the teaching pedagogy that helps in developing moral reasoning.
3. Solving classroom problems such as adaptation to individual students and helping shy students to express their beliefs.

The next sections discuss the extent the above goals have been met, the challenges provided and the advantages and the limitations of the applied techniques.

7.2.1 Generic Architecture and Learning Theories

7.2.1.1 Generic Architecture

A generic architecture is an architecture which can be utilized in more than one application domain that exhibit similar features. According to this research, the developed architecture targets those domains within which narrative can act as the suitable learning medium. The architecture consists of six different modules communicating and interacting together using rules: four modules to serve the educational targets instantiated in a domain model, a pedagogical model, a student model and an interface module. The other two modules are concerned with creating the game story and modeling the world. The integration of these modules offers some challenges, advantages and limitations as will be discussed below.

The developed architecture, as a proof-of-concept, has been used to implement an edugame, AEINS, to teach in the ethics domain fostering character education. AEINS offers a problem-solving learning environment since it encourages students to construct knowledge for application in the real world, develop problem-solving skills such as critical thinking and scientific reasoning, develop skills of self-directed learning or lifelong learning, and be more motivated in learning (Graf et al. 2009). Many challenges have been faced during the implementation of AEINS. The first challenge was the representation of the domain model because of the lack of a predefined curriculum for the ethics domain. For this reason, help was required from educational psychologists and ethical philosophers in order to define the dependencies between various concepts of the domain. Although such a process was taxing where we were asked to produce our draft model first in order to be assessed by them, we managed to reach an acceptable defined representation in the end.

The defined dependencies between the model concepts force specific sequences for the concepts presentation during the learning process. Such predefined sequences can obstruct the supply of an adaptive learning process to the user. A solution arises in the use of the frame knowledge representation that offered a partial order hierarchy that provides flexibility in changing the curriculum presentation order. In addition, it required no costly search processes where all the facts and properties connected with a concept are located in one place. The evaluation proves the validity of this representation where adaptation to the learner needs was enabled due to the partial ordering of the model.

Transferability of knowledge to the real world is a general aim of digital learning environments. Situating the learners in familiar contexts should serve this aim where it allows them to better activate their prior knowledge (Anderson et al. 1977). This issue has been considered in designing the tasks (teaching moments) that contextually discuss situations familiar to the student and use a suitable language level for the targeted age. For example, problems that occur in the school environment. In this way, the student was willing to contribute to the story and to get involved in situations as an active participant. The authoring of these teaching moments needed extended effort. Currently, both the domain concepts and the teaching moments can be only manipulated at the code level, which requires programming skills. Since it is an aim to incorporate the full version in the ethics curriculum at schools, the need of an authoring tool that allows data entry and avoids dealing with the code level is raised. This would help teachers with little or no programming knowledge to use the platform in an easy way. However, this is out of the scope of this thesis.

There were no difficulties in designing the pedagogical model. It was built using production rules that allow tracking the user's actions, assessing them and updating the student model accordingly. Another challenge was the design of the student model that does not only include knowledge about the student's level but also is able to infer the student's intentions. This kind of knowledge is referred to as the mental bandwidth, see Section 2.3.2, and is a problem in the literature that has not yet been completely solved. Production rules have been used to infer that kind of knowledge from the student's actions. The designed rules of these models have been revised by a cognitive scientist who agreed on their functionalities. The evaluation supports our intuitions about the current representations and provides good evidence on the validity of the chosen model. However, this does not deny that more rigorous evaluation is still needed to completely confirm the current results.

Certainty factors have been attached to the designed rules as they provide the simple computations by which uncertainty propagates in the system based on fuzzy logic and certainty factor theories. Moreover, the certainty factors are easy to understand and clearly separate belief from disbelief (Roventa & Spircu 2009). The empirical evaluation provides evidence on the validity of the model design. The evaluation also showed that the student models were built in an individualized way leading to a personalized learning process for individual users. Whilst the current developed rules do not offer complete inference about the student's intentions, they will give context and background in addressing the bandwidth problem in the future.

The presence of the student model enforces re-playability. Due to the adaptive nature of AEINS, students can face different teaching moments and different stories every time they interact with the game. The evaluation shows that the participants were willing to re-play the game as they were eager to solve the discrepancies that exist in the teaching moments the best way they could. The participants were engaged in solving the tasks and asked for more tasks to be added to the platform. Based on the student model, AEINS is capable to produce an end evaluation report that includes information about the student's strong and weak points during the learning process. Such reports can be seen as a good tool in providing teachers and researchers with a rich view of the learners progress and facilitates identifying their strengths and weaknesses, however the actual usefulness of these reports needs to be verified empirically in the future.

The fourth module is the story generator that can be considered the main innovation of this work. The story generator employed hybrid narrative techniques: the first one is a STRIPS-like planner that generates a story based on the student's and the virtual characters' actions. The second one is graph structured narratives that represent the teaching moments. The hybrid narrative generation can be considered as a further step in addressing the agency problem discussed in Chapter 5. The problem can be summarized as follows: using dynamic generated narrative allows high agency but overrides the educational side, and the use of graph structured narrative allows tracking the learning process but offers low agency. The blend of both techniques sustains balance between the participant's freedom and keeping track of the educational process. It allows student's high agency and increases his feel of control and at the same time, conserves the educational process by allowing tracking and assessing the student's actions in addition to guiding the student. The STRIPS planner generates the story in favour of the learning objectives where the story acts as the 'glue' which sticks the teaching moments together to form a continuous coherent story. The recognized result obtained from the empirical evaluation is that the used techniques are integrated together in a seamless way that neither affect the student's game experience nor the student's learning experience. Although there are no current problems with the STRIPS planner, scalability issues could be raised when bigger worlds are used.

The fifth component is the story world that models the current world state and hosts the inhabitant agent models. The agents have various characteristics such as their ability to participate in the story generation and to evolve during the course of the game play. For example, they can change their relationship to the user (a friend who becomes an enemy), change beliefs where an agent who exhibits certain moral attitudes such as *do_lie* can exhibit the opposite virtue *do_not_lie* according to the story events. The agents are semi-autonomous in the sense that they are able to react according to a reactive planner in a way that increases their believability and at the same time allows the story generator to dictate what they should do when required, i.e. to satisfy certain learning objective(s). Finally, the agents perform a pedagogical role by helping in supplying the learning situation.

The presence of agents that perform pedagogical roles have been used in multiple systems as seen from the literature. However the evolving agents have been considered in only a few systems such as FearNot! (Figueiredo et al. 2008). The evolving agents have a recognized role in engaging the learner, their evolving personalities during the story course increase the system's believability and motivate the learner. This ability is attributed as a motivator in the learning environment that prompts learners to spend more time using the platform (Rebolledo-Mendez et al. 2009). The presence of autonomous agents rather than semi-autonomous can be investigated in future work. The main challenge appears in the agents' independence that provide no guarantee of allowing the presence of a pedagogical dramatic story.

The AEINS system partially considers sex difference. On one hand, it provides male and female player-controlled characters from whom the user can choose his/her playing character. On the other hand, the generated story does not consider the player sex in the story generation. This is a point that may be considered in future work where the story generation can provide stories that suit the current player sex. Lastly, a presentation module that provides a graphical user interface has been developed. The interface is limited to 2D point and click that can be considered as a limiting feature. However, the interface is able to signal the user's intentions through the normal course of problem solving. For example, it can be seen that the shortest way to move from one teaching point to another is to follow the planner generated plan exactly as it is, it will only take a longer path if the user violates the plan. So, if during certain period of the play time, the user keeps asking the agents to act, the plan actions will be executed consecutively by the agents and the teaching moment will be presented once the preconditions are satisfied. Passing this information to the pedagogical model allows it to infer about the learner's favourite parts or times during the learning course. This information can be also used to categorize learner's stereotypes and to expand the student model. This kind of adaptation to learning styles and sex specific stories can also be considered in future work.

Transferability to other domains is quite straight forward attributed to the generic nature the architecture enjoys. The techniques applied in the developed architecture can be easily transferred to other domains such as history, literacy or cultural studies, whilst the implementation process is left to the programmers choice. However, the application of the AEINS platform in other domains requires knowledge of logic programming and visual environments. This means that all the required changes should be made at the code level by an expert programmer. The presence of an authoring tool could facilitate this transmission and allows knowledge manipulation away from the code level. This is an important part of the future work as it will allow teachers and researchers to easily interact with the AEINS platform.

7.2.1.2 Learning Theories

Learning theories are an essential requirement in the design of educational games. They inform the design how to effectively employ the individual game elements to serve the educational objectives. The learning theories inspired AEINS are: Keller ARCS Motivation Model (Keller 1987b) and Gagné's Events of Instruction (Gagné et al. 1992). Attention is one important factor in the ARCS model and also in other learning theories (Keller

1987b). It is related to gaining and keeping the learner's attention. This factor has been considered in the design of the graphical user interface that captures the student's attention. Moreover it raises the learner's inquiry arousal through involving him in the story generation and through the use of a series of thought provoking questions within the teaching moments.

Another important factor to consider is the confidence attribute that is concerned with the level of the activity where it should not be perceived as either too hard or too easy. This attribute is important both in game play and in an educational context, where providing the student with the appropriate level of difficulty in the attempted tasks guarantees engagement and eventually satisfaction. In AEINS, various teaching moments that address different student knowledge levels have been designed.

Gagné's principles are important in the game design. They mainly draw the attention to provide instruction on a set of component tasks that build toward a final task and sequencing the component tasks to ensure optimal transfer to the final task. These principles have been considered in the design of the teaching moments, where coaching is afforded using the Socratic Method and by providing personalized feedback. Misconception is another technique used in favour of the learning process. This actually goes well with Bergin (1999) who shows that when learners faced with evidence that what they believe to be true is, in fact, false and a misconception, they often become interested in resolving the discrepancy. AEINS also words the question from the perspective of the learner to provide a meaningful context and facilitate the activation of prior knowledge; this technique has shown its usefulness in the learning process as shown in Anderson & Pichert (1978). For example, if we would like learners to investigate the effects of stealing, we could pose the problem of shoplifting and what if they are the owners themselves. The second principle has been considered by the pedagogical model that works on providing the suitable sequence of learning tasks based on the current student skills to ensure the gradual and smooth transfer of the student from one learning stage to another leading to the final educational target(s).

Bloom's taxonomy has also been considered for a long time in the educational field (Bloom & Krathwohl 1956). It helps teachers and researchers in setting a balanced set of questions that allows the student to recall information, make use of information and work on evaluating tasks. In this work, Bloom's taxonomy have been employed in a different manner, in designing the questionnaire, open questions were provided that help the student to express himself in his own words. The resulted data were rich enough to be interpretable. The analyzed data has been found to attempt the high levels of Bloom's taxonomy. The learners were able to reason about moral values and see in what pattern they were framing the situation(s). Through being involved as active participants, they were forced to aggregate parts together, and evaluate the situation in order to provide either judgments or justifications for their actions.

7.2.2 The Teaching Pedagogy

Teaching in ill-defined domains is a challenging task, therefore rigorous research has been done seeking for suitable teaching pedagogies. Simon proposes the idea of dividing the main ill-defined problem into subproblems (Simon 1973), where each can be individually investigated as a well defined problem. This view has inspired our work on designing the moral dilemmas as problem-solving episodes. The used dilemmas have been analyzed and transferred to graph structure representations in order to allow the student to interact at interleaved points. These points require ethical reasoning and an ability to evaluate the current faced discrepancy, thereby helping the participants to experience the complexities of making ethical decisions in realistic situations (Winter & McCalla 1999).

The empirical evaluation done has shown that some participants were able to draw analogies and relate their experience to real world ones. The results also showed some evidence on transferability, such as

P6: "I think this can help me solve school problems."

So it seems that this kind of experience can enrich the analogical-problem solving skills of the students and may allow them to use the solution to a source problem as a plan for solving a target problem in real life. The effect of multiple analogical problem-solving episodes has been seen as a way for individuals to induce abstract schematic representations of problems and their solutions that can be retrieved and applied as solution plans when structurally similar problems are presented (Ormerod 2006).

The Socratic Method has been chosen to act as the main teaching pedagogy for many reasons: it can be easily weaved within the teaching moments stories and for its ability to provide a medium that encourages the student to think critically in order to solve the discrepancies encountered in the moral situations they got involved in. Evaluation of AEINS shows positive and encouraging results from using this method as discussed in Section 6.6.5.3. The students were forced to think about the suitable action(s) they should take to solve the conflict in the situations they face, in addition to considering the consequences of their actions. Raising the stakes strategy in the Socratic Method forces the students to think differently, consider issues that were not considered before and see things from different perspectives.

From studying the participants' log files, it has been found that most of the participants who performed an unethical action were able to discover the negative aspects of this action and reconsidered their situation. For example, one participant who chose to help his friend to take a chocolate bar without paying for it has been involved in a Socratic Dialogue. It can be seen that the participant was able to discover what was wrong and eventually to tell his friend to return the chocolate back. This is considered as one of the interesting findings as it provides evidence on the validity of the used techniques. Further work on this method would be on the dynamic generation of the Socratic questions using natural language interface and free text input.

Adaptation and providing feedback are crucial to any successful educational process. It was found that following a player's misconception, a subsequent adaptive hint improved the player's subsequent approach to the correct solution. Based on the intrinsic evaluation and the study of the log files, the sequence of the presented teaching moments was the right sequence for those participants.

Deciding on the way of providing feedback and how frequent it should be delivered is an open question in adaptive educational applications. In story-based learning environments, it is agreed that providing implicit feedback is much more preferable than providing explicit feedback in the form of interfering 'right answer' and 'wrong answer' messages. The implicit feedback exhibits the following advantages. First, it can be delivered in a non-invasive way since it is part of the story without affecting the player's experience. Secondly, it is more suitable for ill-defined problems that have no complete right or wrong answers, because it leaves the user to freely interpret and self-reason on the whole argument from his own perspective.

Since learners differ in style and ways of learning, AEINS offers two types of feedback: the first type is formative feedback (delivered after a single or a few steps in a single task) and the second type is summative feedback (delivered after completion of the whole task) implicitly within the narrative context. Both kinds of feedback are provided as intrinsic rewards of learning and as part of the story. These rewards are based on a high congruence between the material being taught and the motivational techniques used (Lepper & Cordova 1992).

Other ways of providing feedback have been thought of, for instance adding extrinsic rewards in the form of visualized objects such as scores or tool bars that represent the strength of the student relationship with the agents inhabiting the environment. The idea at the first glance seems advantageous to apply, but further consideration of the type of domain AEINS is dealing with suggests some deep-rooted conflicts. On one hand, they may engage the user and on the other, they can have a detrimental effect on learning (Lepper & Cordova 1992) leading to distraction and/or deviation from the educational goals. For example, having a scoring system in AEINS can affect the application of the student's actual beliefs where the focus will be on increasing the score by any means. On the other side of the spectrum, even if the student chooses to try things and not applying his own beliefs, the educational goals are still persistent as he will be faced by consequences that allows him to test the validity of what he chooses to apply. In this case, it seems also that a scoring system can be disadvantageous in a way that can prevent the student from trying to discover other routes and possibilities of the teaching moments; where some of these routes can lower his score.

7.2.3 Classroom Problems

Classroom problems that may hinder ethics teaching have been discussed previously in this thesis along side a discussion about how the developed system can address these problems. Due to time limitations and schools schedules, we did not get the chance to use the system in real classroom settings. However, the results from the performed evaluation throw some light on the effects of the system, which leads to a conclusion that this platform can act as good assistance in classroom environments. This study is considered as a part of the future work.

7.3 The Impact of the Work Done

The work done in this thesis falls into three areas: educational games, intelligent tutoring and ill-defined domains. On the educational games side, AEINS offers an innovative architecture that can inspire the development of educational games in similar domain areas. AEINS evaluation verified the validity of the developed architecture. We consider this architecture a step forward in the design of educational games that require tracking the learner's progress to provide an adaptive learning process and high user agency at the same time. The game actions in AEINS have direct connection with the student's understanding of the underlying concepts, this facilitates assessing the learner's knowledge from the interaction with the game. Moreover, AEINS provides feedback through the pedagogical agents inhabiting the environment and who are already actors in the generated narrative, therefore it prevents external interferences that may affect the engagement educational games usually trigger.

On the intelligent tutoring side, AEINS provides a personalized learning process using a student model that attempts the bandwidth problem (inferring the learner's intuitions in addition to estimating his knowledge level based on his actions). The interpretation of intentions allows the consideration of other aspects such as the current learner's level and whether it allows him to transfer to the next learning level or still needs more training on the same topic. Building a prediction model that can predict the learner's behaviour can be done through building a learner's cognitive model (an aspect of AI that is linked to a particular learning situation). This is not part of the focus of this thesis.

Finally, AEINS shows significant results in teaching in the ill-defined ethics domain. It provides a suitable environment, which integrates narrative that allows the transfer of tacit knowledge and intelligent tutoring that allows one-to-one instruction and personalized learning. The use of the Socratic Method has shown its power in ill-defined environments where it seems able to develop the moral reasoning of the learners as shown from the evaluation results.

7.4 Better Game

While AEINS has been successful in many aspects such as engaging the student in moral dilemmas, providing an adaptive learning process and generating a continuous story that is able to integrate the student's actions within, there is still room for further development. Specifically, the following aspects of the system could be improved:

Include more details about the learner in the student model, such as how quick the player is in making decisions, whether he plays safe or he is risk aversive, whether he is aggressive or not, or has an exploring nature. This can be another factor that affects how the story unfolds in a way that fits the learner's stereotype. Other factors to be considered are the learners' stereotypes that can emerge from an analysis of the ethical decision making such as the work of Winter & McCalla (1999). Actually this might lead to the implementation of an advanced level of the game that provide special types of dilemmas especially designed for every stereotype.

More work can be done through adding more life-like attributes to the agents especially the ability to convey emotions for its benefit to the learning experience, enhancing the graphical user interface to be more 3D; this kind of interface offers visual appearances that attract human attention, especially children. 3D animated interfaces are more efficient, satisfying, and fun to use, in addition to creating a bigger story world to allow the presence of larger sets of actions the student can take. In turn this would increase the student freedom and agency within the environment, in addition to increasing the complexity of the whole game.

Other aims appear in developing an authoring tool to help teachers with no or weak programming skills to handle the teaching moments authoring in an easy way. The tool should have a great range of options for interactivity in order to build highly effective, engaging and interactive courses, such as the presence of a networked multi-player facility in order to suit the classroom environment. This should allow peer-to-peer interaction which has its educational advantages. In addition to the system's produced feedback reports that can assist the teacher in the teaching process.

Moreover, on the interaction side a full natural language processing (NLP) engine can be used to enhance the learner-system interaction. This would facilitate the human computer interaction and allow free expressions through enabling the use of human-language type commands and queries. Understanding human-language text to provide a summary or to draw conclusions is the function of NLP. One of the easiest tasks for a NLP system is to parse a sentence to determine its syntax. A more difficult task is determining the semantic meaning of a sentence, which in turn could cause more difficulties in analyzing the student's knowledge and intentions.

7.5 Summary and Conclusion

The research done in this thesis is a continuation for the literature in the area of educational games (edugames) and adds more insight into the area of intelligent tutoring in ill-defined domains. It presents the challenges when trying to integrate various components that individually has shown effectiveness in edugames into a single architecture. The work also describes the positive role the integrated architecture has. The idea is centered around the integration of edugame features that has been shown to individually increase the effectiveness of the edugames environments, such as dynamic generated narrative, scripted generated narrative, student modeling and evolving agents. The integration allows the presence of a continuous story that acts as the 'glue' between the learning objects and forms the story dramatic arc from the beginning to the end. The integration also allows addressing the common conflict requirement which exist in interactive narrative environments: coherent narrative and user agency. The combined narrative techniques allow high user agency and coherent narrative, in addition to the possibility of tracking the learning process.

Educational games is an area that gained much attention in the last few decades for its powerful engaging property and the ability of such platforms to deliver learning in various contexts. In the work done in this thesis, a generic architecture for educational games was developed that can be applied in other ill-defined domains such as cultural studies or history. The architecture has been designed based on learning theories that point out important features that should exist to well-establish the learning environment as well as the learning objects. The architecture integrates individual components that each has shown useful to the edugames environments but not integrated altogether before.

The architecture consists of several modules: a domain model that allows the hierarchical representation of the moral virtues, a student model that allows a personalized learning process and attempts the bandwidth problem discussed in the thesis, a pedagogical model that provides adaptation to the learner's knowledge and intentions, a story generator that is capable of generating hybrid narrative that attempts the learner's agency problem mentioned in this thesis and allows the generation of a continuous story with evolving non-player characters. More components are the story world that inhabits all the agents and objects in the game world and a representation of the current world state and finally a presentation module that offers a graphical user interface. We argue that although each individual attribute is not innovative in itself, their integration in one environment yet maintaining a continuous narrative, is.

In ill-defined domains, knowledge to be acquired is more conceptual than perceptual. Accordingly, it is important to provide interaction with just the type of conceptual materials that we want students to learn. Games offer an advantage over traditional schooling, where connection between perception and action that is a highly prototypical form of knowledge, can be represented in the following form of production rules: If this is the current situation, do these. Moreover immersing the student in a (simulated) environment provides a much richer experience than a worksheet or other homework assignment could. Problems encountered in classroom environments while teaching ill-defined domains such as ethics have also been discussed, and how computers can act as a solution. A learning environment, AEINS, has been developed as a proof-of-concept and which can act as an assistant tool in the ethics curriculum, especially with its ability of providing summary reports, based on the student model, for individual students. Such reports help the teachers to identify the students' weak points in a quick and easy way addressing the time constraint issue in the classrooms. The teachers can decide on upcoming educational materials which suit the majority of the class.

AEINS is a narrative-based educational environment that provides a personalized learning process. AEINS has been designed as an endogenous game, where the content material is intimately tied in with the game play. AEINS interacts with every single participant on a different basis according to the student model built for that particular participant. It offers a compelling virtual world and virtual identity, at some level, where deep learning may occur. It can be noticed that the children were able to build a powerful bridge between their real identity and this virtual identity in the game. They did have emotional responses that transfer their real world responses to the game. This goes quite well with Gee's discussion about learning and identity and his illustration about the importance of the ability of children to build these bridges in order not to make the learning imperiled.

The learning objects in AEINS are called teaching moments. They represent various moral situations inspired from Kohlberg's dilemmas and others that have been designed specifically for middle school children. The teaching moments have been represented as graph planned with non-interactive story presentations that are interleaved with student decision points. The motivation of learning roots in the uncertainty and curiosity resulted from the nonlinear structure of paths and different ending alternatives (Lo et al. 2008). In this way, the player expects to play the game many times, trying different strategies each time. The teaching moments were selected and presented in a way that allows the student to draw analogies from one problem to another (if needed). The Socratic Method was used as the teaching pedagogy because of its capability of forcing the learner to face the contradictions present in any course of action that is not based on principles of justice or fairness. So, learning in AEINS occurs through experiencing different situated learning environments regarding moral situations, within which the user can make their experiences more engaging and meaningful and have a better understanding of various moral virtues. When students learn in such an environment, they benefit not only from the educational content but also from the culture that is in the environment (Lo et al. 2008).

A Strips Planner was used as the planning algorithm to generate the main interactive story. However, it has been extended to involve a reactive planner to be used by the non-playing characters to maintain more realism and believability. The Strips Planner generates a story at run time that aims to connect the teaching moments together as parts of the whole continuous story, where the interactive narrative provides a learning medium that helps in transferring tacit knowledge and enrich the edugame world through the presence of a continuous story and evolving non-playing characters. The thesis discussed how the non-playing characters acted as pedagogical semi-autonomous agents and helped in supplying the educational process. With the presence of a student model in AEINS, the intelligent tutor managed to provide adaptation based on the learner's explicit actions and the inferred intentions. In the current version of AEINS, the intelligent tutor uses an overlay student model; no representation of misconceptions of alternative views exists. However, adaptation in AEINS managed to provide a tunable level of learning skills and a personalized learning process. Extending the student model to contain a bug model, knowledge and misconceptions that are assumed not to be part of the expert model, is a step we intend to consider in the future work.

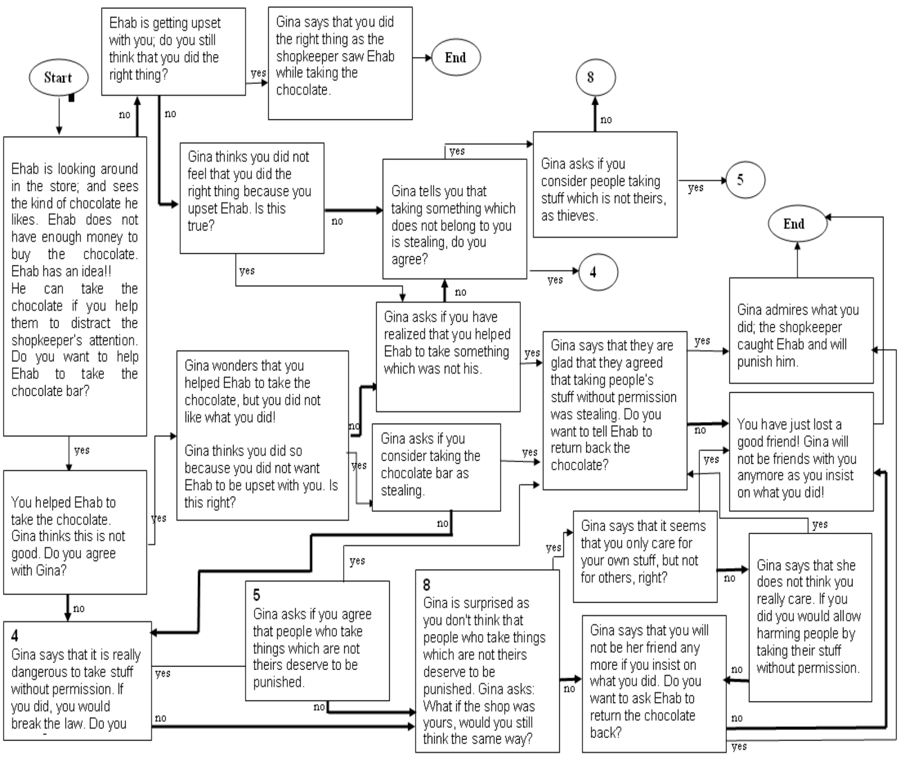
Inference rules have been used to allow easy interaction between the various modules, for example the pedagogical model uses knowledge from the domain and student models in order to decide about the next educational step easily and in an inexpensive way. To show validity of AEINS design and implementation, AEINS has been intrinsically evaluated to ensure the attempt of all the design goals.

AEINS has been evaluated against Gee's games criteria and it has been found that the platform satisfies the majority of these specifications. Qualitative and quantitative measures of motivation and data log files of each participant's interactions with the learning environment were recorded. They confirmed common intuitions about the motivational benefits of educational games. This benefit does not appear to come at the expense of efficiency or quality of learning. We suggest that this motivation to interact with game environments as characterized by high levels of engagement, enjoyment, and perceived challenge may encourage students to continue game-play and ultimately experience high learning gains. Finally, AEINS has been empirically evaluated considering the following themes: Architecture and implementation, Social aspects, and educational achievements. The evaluation of AEINS shows positive results starting from its ability to engage young learners to its ability to transfer ideas and thoughts about basic ethical values. The evaluation resulted in useful feedback that helps in modifying the system to be more user friendly and more enjoyable.

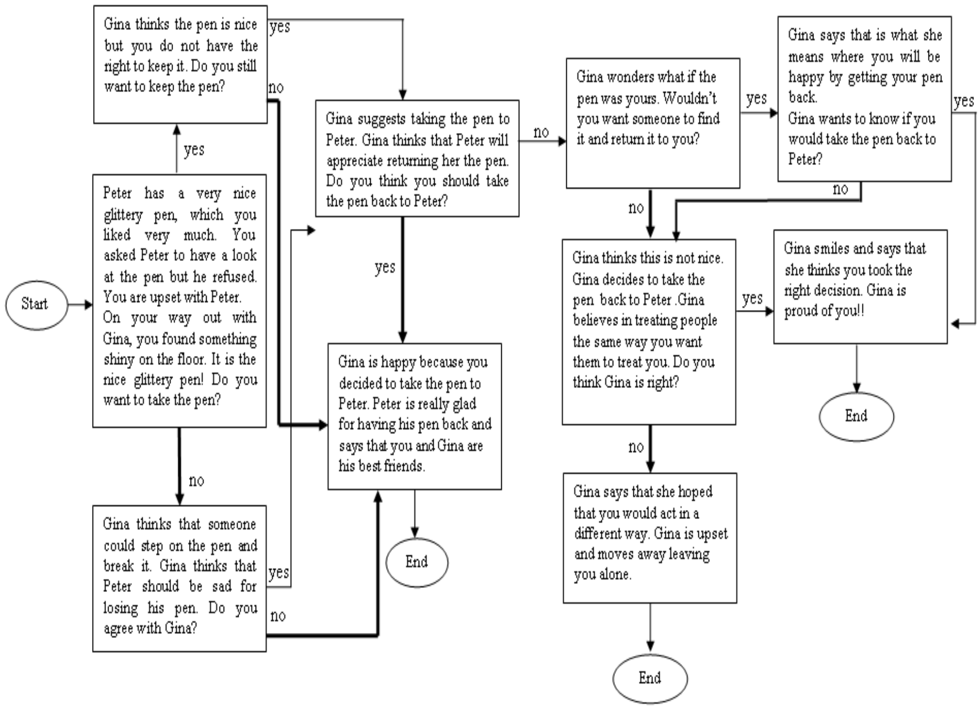
Overall, we believe this research provides students with practical means of exploring abstract issues in concrete settings, allows students to practice making ethical decisions in a realistic context and enables them to see various consequences (positive and negative) in a safe environment. Future work includes improving the prototype focusing on three aspects from Section 7.4, which are: the addition of more life-like attributes to the agents, the development of an authoring tool to help the teachers in classroom environments and the incorporation of a natural language processing (NLP) engine. The next step is the integration of the modified version with the ethics curriculum in schools.

APPENDIX A

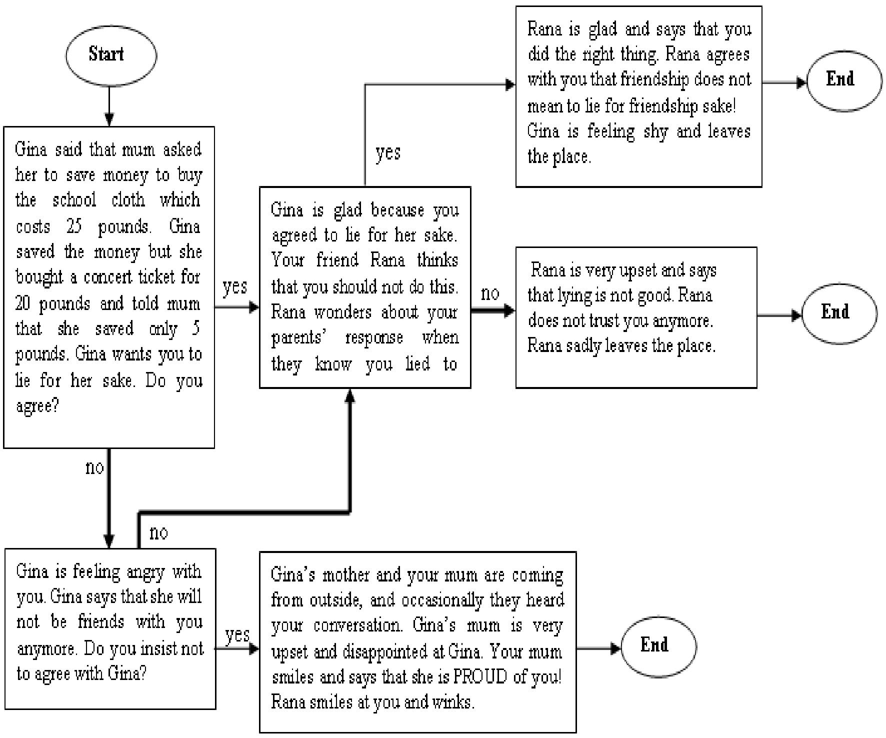
Graph Structured Moral Dilemmas



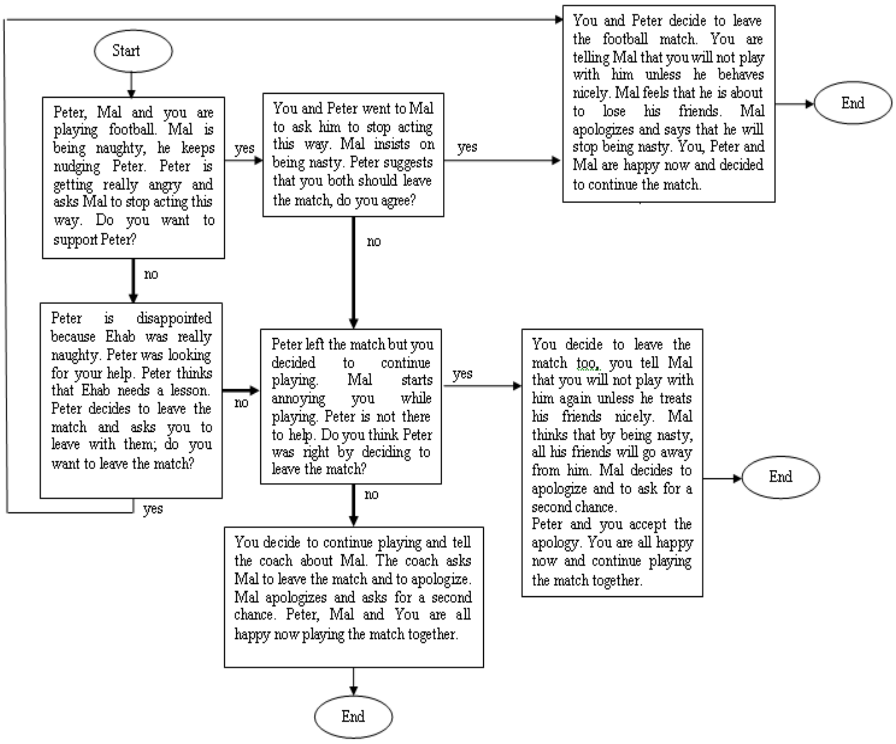
a. The first teaching moment



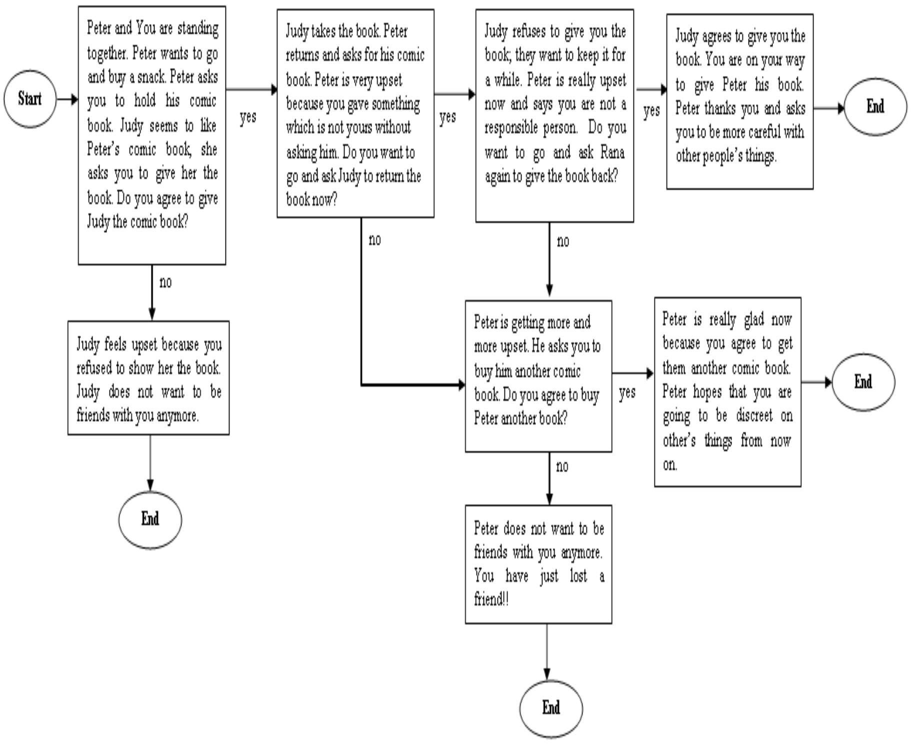
b. The second teaching moment



c. The third teaching moment



d. The fourth teaching moment



e. The fifth teaching moment

Figure A.1: Implemented dilemmas in AEINS

APPENDIX B

Consent Form

This appendix shows the consent form template used in the empirical study. All the forms have been signed by the parent/guardian of the participant child. All the participant children approved on their participation.

Children interacting with an educational game

Consent form

Rania Hodhod,

Dept of Computer Science

University of York

To	Name of the child's parent or guardian:	
Name of child:		
Age of Child:		

You are making a decision whether or not to have your child participate in this study. Your signature indicates that you have read (or been read) the information provided below and decided to allow your child to participate in this study.

This research study aims to assess the ability of the educational game to transfer tacit knowledge that teaches children basic ethical values. Your child will play a computer based game that presents a story containing situations in which your child will need to make ethical choices. Whilst some of these choices might be difficult for your child, there is no overall right or wrong choice. Also the game does not reinforce any bad or unacceptable attitudes in any way.

Your child will be interviewed for about 15 to 20 minutes after playing to allow us to fill out our questionnaire. This interview will be audio recorded. This is a private recording that is not shared with any other party other than my PhD supervisor, Dr Paul Cairns. In any presentation of my PhD work, written or spoken, we will ensure that your child is not identifiable in any way.

You are more than welcome to accompany your child during the research session. Please, if you decided to attend we would ask you to allow the child to play their way and answer our questions in their own words. We are not testing your child only testing our game.

Your child taking part in this study is your choice. You are free to withdraw your child from this research study at any time, whenever you or he/she wants, and without having to give a reason.

If you have any further questions please ask me or feel free to contact my supervisor: pcairns@cs.york.ac.uk

Parent's or guardian's signature:		Date:	
Name (in block capitals):			

Assent of Child

________________________(name of child/minor) has agreed to participate in research titled AEINS: Adaptive Educational Interactive Narrative System.

____

Signature Of Child
Date

APPENDIX C

Post Interview Questions and The Corresponding Coding

This appendix presents the post-interview questions and their mappings to the research questions of interest.

Table C.1: Post interview analytical questions

Interview question	Coding
Question type 1: Technology. These questions are related to the technical infrastructure, its functioning, or the degree to which the students were appropriately trained to use it.	
- What did you find difficult or unclear while playing the game? - What part do you find really easy to use in the interface? Did you feel you could do all the things you wanted to do?	- To what degree was the interface usable?

Table C.2: Post interview analytical questions (continue)

Interview question	Coding
Question type 2: Interaction of Technology and Activity. These questions are related to the functions and features inherent in the system and its ability to support or enable a specific activity. (Did X technology enable you to do Y?)	
- Do you think there are enough actions for you to do?	- What about the user agency?
- Did you feel in control of your player in the game?	
- What are the actions you wanted to do but could not? Were they not available or could you just not find them?	
- What did you most enjoy in the game?	
- What did you really not like?	
- What do you think of the whole story?	- To what extent was the generated story coherent?
- What parts in the story did you not like? What parts did you particularly like?	
- Did your friends in the game behave like your real friends? In what ways?	
- Were there any strange reactions from your friends in the game? If so, what were they?	

Table C.3: Post interview analytical questions (continue)

Interview question	Coding
Question type 3: Activity. These questions are related to the student tasks.	
- Do you always do what you think is right? Would your Mum or Dad agree with you? - Have you chosen to do something wrong on purpose? Why? How did that make you feel? - Was there sometimes where you do not know if you did the right thing or not? What have you discovered since then? Do you think that your time with the game can help you with this? If so how?	- During the interaction with the teaching moments, do they provide what they aim for?
Question type 4: Interaction of activity and Learning outcomes. These questions are related to the capability for specific technology-based activities to generate predicted outcomes. (Did activity Z help the student to accomplish S?)	
- What do you gained from this experience? - Do you think this session can help you in your real life? - What do you think of the stories you took part in?	- Do the activities (teaching moments) result in what they aim for?

Table C.4: Post interview analytical questions (continue)

Interview question	Coding
Question type 5: Re-usability of the system. These questions are related to self reflection and replayability.	
- Did you use the save button at the end of the session? Why or why not? - What have you done with your saved file?	- What about self reflection?
- Do you want to have another turn with AEINS? - How often do you think you would like to play AEINS?	- What about the system re-playability?
Question type 6: Adaptation to individual users. These questions are related to the student model and its design	
- By checking the students' log files - Have the student model rules infer correctly the students' skills and the confidence factors?	- Is the teaching moments presented in the correct order?

Glossary

AEINS	Adaptive Educational Interactive Narrative System
Character education	Moral development of young people
Dynamic generated narrative	Narrative generated at runtime
Educational games	Games that have been specifically designed to teach people about a certain subject, expand concepts, reinforce development, understand an historical event or culture, or assist them in learning a skill as they play
Endogenous game	A game where there exist an intimate tie of the content material and the game framework
Evolving agents	Non-playing characters with evolving personalities
Exogenous game	A game where there is a loose coupling of the content material and the game framework
Ill-defined domains	Domains with no clear conceptual models

Intelligent tutoring system	It is any computer system that provides direct customized instruction or feedback to students whilst performing a task
Learning theories	Theories that can be applied in educational contexts, such as the design and implementation of teaching and learning activities
Moral dilemmas	Moral conflict situations
Moral reasoning	It is the individual or collective practical reasoning about what, morally, one ought to do
Moral virtues	Ethical values, such as wisdom, courage, chastity and justice
Personalized learning	It is the tailoring of pedagogy, curriculum and learning support to meet the needs and aspirations of individual learners
Scripted generated narrative	Graph structured narrative usually designed offline
Serious games	Games designed for a primary purpose other than pure entertainment. They are not a game genre but a category of games with different purposes. Educational games is included under this category
Situated learning	Learning that takes place in the same context in which it is applied
Socratic method	Named after the Classical Greek philosopher Socrates. It is a form of inquiry and debate between individuals with opposing viewpoints based on asking and answering questions to stimulate critical thinking and to illuminate ideas

Teaching moments	Moral dilemmas
Virtual identity	The player's fictional identity in the game world

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