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Modelling the Requirements of an Animated Pedagogical Agent for a Web-Based Learning Environment through Input-Process-Output Relationships

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Abstract:

This paper describes and discusses the importance of having a representation which models the key factors associated to the requirements of an animated pedagogical agent for an interactive learning environment, in particular, for school students. The IPO (Input-Process-Output) relationships are proposed to address this issue. The formulation of IPO relationship are described in detail and the application of IPO relationship is shown through the case study of specifying the requirements of an animated pedagogical agent for a web-based learning environment for primary school students to learn science.

1 Introduction

Pedagogical agents are lifelike 3D animated characters that have knowledge of the subject domain and the pedagogy in facilitating and interacting with students during the learning process in an interactive learning environment [5,8,9]. They interact with a student through a humanlike combination of verbal and non-verbal communications. They adapt to student's performance state to provide appropriate feedback and assistance. Hence, pedagogical agents carry a persona effect in the interactive learning environment to bring positive learning experiences to students [5,3,9].

Although pedagogical agents and learning systems have been the subject of many research and development, but little is known about the requirements of an animated pedagogical agent for a web-based learning environment, in particular, for school students. Questions such as follows are commonly being raised for pedagogical agent design: What are the suitable roles to be performed by the agent – the role of a tutor, coach, presenter or facilitator? What are the required features to be exhibited by the agent to make them more lifelike and engaging when interacting and facilitating with the student? It is also argued that in specifying the requirements of animated pedagogical agents, an analysis of the problems that students encountered when using a typical interactive learning environment as well as an analysis of the benefits to be gained with the incorporation of an animated pedagogical agent in the learning environment are essential.

This paper addresses these issues by formulating a model of the key factors associated with both, the pedagogical agents and the students' problems and needs. The formulation of the model, named IPO Relationships is described in section 2, while section 3 discusses the survey study of specifying key design considerations of an animated pedagogical agent for a

web-based learning environment for primary school students to learn science. IPO relationships are used as a framework of the study. The paper is concluded in section 4 which summarizes the findings from sections 2 and 3.

2 IPO Relationships

2.1 An Overview

The factors of IPO Relationships are derived from a detailed analysis of literature review on pedagogical agents [1,4,6,7,9,11,12,14] and the analysis of students problems encountered with the traditional learning environment [2,8,10,15,13]. The factors are aggregated into three broad sets of relationships, namely, Input, Process and Output (IPO relationships). The underlying concept of IPO is that output factors are dependent on the process factors which, in turn, are determined by the input factors.

Input factors are related to students' problems and needs, and inevitably influence the roles to be performed by the pedagogical agents in an interactive learning environment. This leads to the process factors which emphasize on the key design considerations of the roles. Output factors refer to those positive effects (i.e. benefits) that a student will experience as a result of the selected roles. The model is used as a frame of reference which describes and categorizes the key factors associated to the requirements of pedagogical agents for an interactive learning environment. The model can also be used to show the dynamic relationships between the key factors – different combination of factors can yield different opportunities/results. Table 1 summarizes the IPO factors and their associated components.

2.2 Input Relationship

Problems and roles are the two main factors of Input relationship. $P_1 - P_n$ indicate a list of problems that students encountered when using a computer-based learning environment. The six common problems identified in this study are: lack of attention to help students study; lack of motivation for students to learn independently; lack of support while students are doing exercises; students feel lonely when they are learning by themselves; nobody to ask for advice or guidance (no guider); students do not get helpful feedback when they are making mistakes or get stuck with the exercises. P_n denotes that the list can be expanded as more studies and analysis of the students problems are investigated.

Roles represent the agent functionality to be perceived by the learner as a tutor, a facilitator, or as a motivator depending on the roles that the agent is carrying in the learning environment. The five main roles identified in this study are: facilitator, tutor, presenter, advisor/mentor and motivator (indicated as R_1 to R_n). The role of a tutor is expected to teach and guide students through a series of practice exercises. The role of a motivator on the other hand, is expected to encourage and stimulate students in their thinking and learning. Key characteristics of the roles are shown in table 1.

Table 1: IPO Factors and Components

IPO	Factors	Components
Input	Problems	P₁ Lack of attention P₂ Lack of motivation P₃ Lack of support P₄ Feel lonely P₅ No guider P₆ No feedback P_n
	Roles	R₁ Facilitator (explains, helps, responds and offers suggestions) R₂ Tutor (teaches and guides students) R₃ Presenter – (informs, provides information and directs students to source additional information) R₄ Advisor/mentor (provides guidance and develops social relationship to motivate students to achieve the desired skill levels) R₅ Motivator (encourages and stimulates students in their thinking and learning) R_n
Process	Personas	S₁ Knowledge on subject domain S₂ Verbal communication S₃ Understand students' emotional states (distress, surprise, happy) S₄ Nonverbal communication S_{4.1} Facial expressions (smiles, nods) S_{4.2} Gestures and body movements S_{4.3} Visual orientation (eye contact) S_{4.4} Appearance (cartoonish, gender, clothes) S_n
	Behaviours	V₁ Helpful (explaining, suggesting, reciting, guiding, informative etc.) V₂ Motivating (encouraging, congratulating, suggesting etc) V₃ Responsive (prompting, monitoring, suggesting etc.) V₄ Entertaining (clapping, waving, cheering etc.) V₅ Friendly (listening, comforting etc.) V₆ Expressive (providing clear feedback, confident. demonstrating etc) S_n
Output	Benefits	B₁ Motivation and supports B₂ Advice and explanation B₃ Attention B₄ Assistance B₅ Performance B₆ Encouragement B₇ Interest B_n

2.3 Process Relationship

Personas and behaviours are the two key factors of Process relationship. Personas are aspects in an agent that portrays the roles carried by the agent. The four personas components identified in this study are: knowledge on the subject domain that the student is learning; verbal communication to interact with the students; understanding students' emotional states to share and facilitate the learners emotional experiences such as being empathic to students performance; non-verbal communication which is sub-divided into facial expression, gestures and body movement, visual orientation, and appearance (indicated as S_1 to S_n). These are central in meeting the expectations of an agent that can guide students with its intelligence, interact with students through a humanlike combination of verbal and non-verbal communication, and adapt to students' emotional state. Behaviours are aspects in an agent that are important to instill the believability of the learners towards its played roles. The six behaviours identified in this study are: helpful, motivating, responsive, entertaining, friendly and expressive (indicated as V_1 to V_n). These are essential in meeting the expectations of an agent that has a natural behaviour and presentation. Table 1 also highlights some characteristics of how these behaviours can be achieved. If these expectations are not met, then the degree of human/teacher-like of the agent is diminished and the students lose their trust in the agent, ruining the interaction altogether. Consequently, roles must be supported with appropriate personas and behaviours features.

2.4 Output Relationship

Benefits gained by using a learning environment with an animated pedagogical agent are the main factors of the Output relationship. The seven benefits identified in this study are: motivation and supports that an animated agent can give, students are able to get quick advice and explanation, increase students attention with the learning environment, agents direct students to source additional assistance (e.g. hints, link), agents care about performance of students under its supervision, encourage students to answer their exercise/test questions, and students feel excited having a companion during study.

3 Application of IPO Relationships

3.1 The Questionnaire

The application of IPO relationships is shown through the case study of specifying the requirements of an animated pedagogical agent for a web-based learning environment for primary school students to learn science. Questionnaires were distributed among 100 science teachers in the selected primary schools to give their opinions and views on the expected requirements of an animated pedagogical agent, out of which 98 of them responded completely to the questionnaire questions. The questionnaire is divided into 3 sections:

- Section A gathers details of the teachers' background;
- Section B is crucial in discovering the problems that students always encountered when using a computer-based learning environment, the preferred roles on assisting students' learning, personas and behaviours of the animated pedagogical agent, and the benefits of the implementation of animated pedagogical agent in learning environment. In essence,

section B draws together from the teachers information on the IPO factors and components.

- section C allows teachers to express their opinions and views on any other related aspects of animated pedagogical agents.

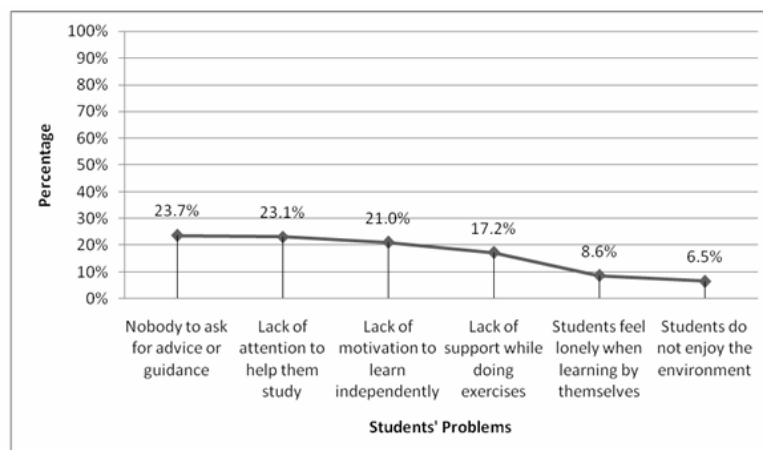
The focus of this paper is on section B in which the results are described in section 3.2

3.2 The Results

3.2.1 The Students' Problems

Figure 1 shows that the four most common problems are: nobody to ask for advice or guidance, lack of attention to help them study, lack of motivation to learn independently, and lack of support while doing exercises. Although the other two problems where students feel lonely when learning by themselves and do not enjoy the environment are not considered as serious as the above 4 problems, both are also common problems that can be faced when students are studying in the computer-based environment.

Figure 1: Students' problems when using a web-based learning environment



3.2.2 The Roles

As shown in table 2, the three most preferred roles to be implemented in an animated pedagogical agent are: facilitator, tutor and presenter. This is followed by the roles of an advisor/mentor, motivator and guider.

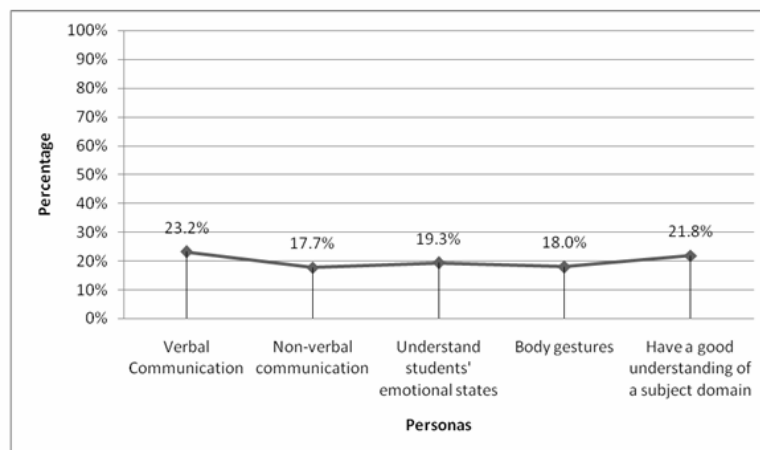
Table 2: The respondents' preferred roles of the animated pedagogical agent

Roles	Percentages%
Facilitator	29.7%
Tutor	23.8%
Guider	7.9%
Presenter	19.8%
Advisor/mentor	8.9%
Motivator	9.9%

3.2.3 The Personas

Figure 2 shows percentages on personas that an animated pedagogical agent should possess. Verbal communication, has understanding of a subject domain, and understands students' emotional states are categorized as the three most crucial personas an agent should have as these personas will aid in creating an agent that is more teacher-like. Although facial expression and body gestures percentages (non-verbal communication) are a little lower than the previous three, but these personas are equally important to support the agent to appear more naturally like human.

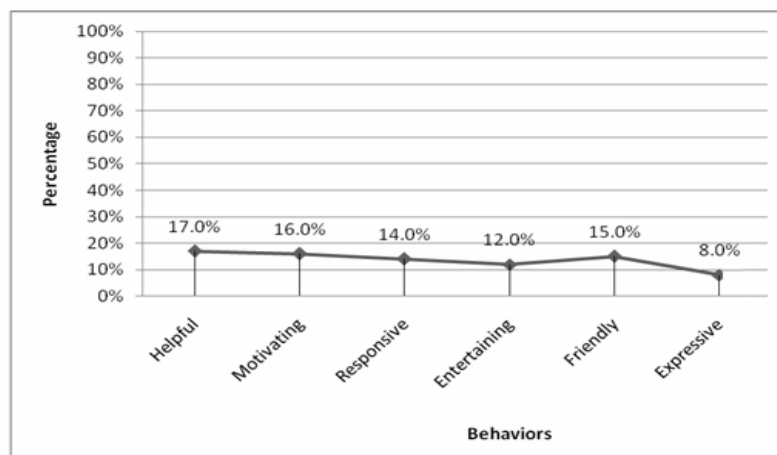
Figure 2: The respondents' preferred personas of the animated pedagogical agent.



3.2.4 The Behaviours

As shown in figure 3, generally, the behaviours like helpful, motivating, responsive, entertaining, friendly, and expressive are essential in meeting the expectation of an animated pedagogical agent that has a more human kind behaviour and not a repetitive or mechanic one. Behaviours like helpful, motivating, and responsive is incorporated to meet the target of achieving emotional believability. Whilst behaviours like entertaining and expressive are complementary behaviours that will enhance the agent presentation.

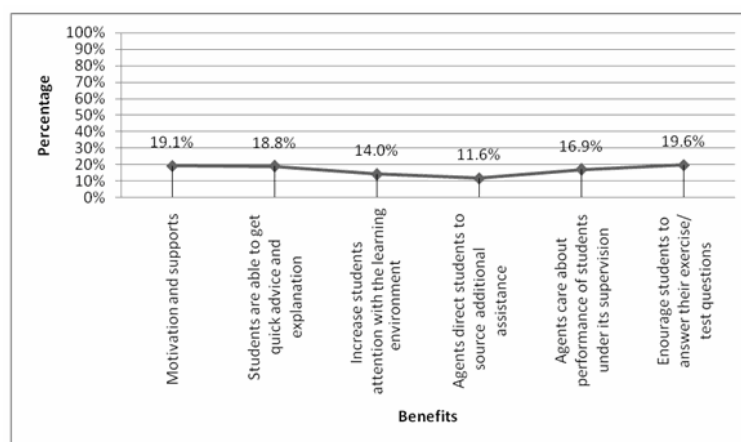
Figure 3: The respondents' preferred behaviours of the animated pedagogical agent.



3.2.5 The Benefits

Figure 4 shows the benefits that are expected to be experienced by using a learning environment with an animated pedagogical agent. While all benefits can be considered as valuable to students, the focus is more on the motivation and support that an animated pedagogical agent can give, ability of students to get quick advice and explanation, and the increase of students attention with the learning environment. Other benefits such as encouragement that students will receive when answering their exercise or test questions, direction to source additional assistance, and concerns on performance of students by the agent will add additional points on supporting the implementation of animated pedagogical agent.

Figure 4: Benefits of the implementation of animated pedagogical agent.



4 Conclusion

The underlying concept of IPO is that output factors are dependent on the process factors which, in turn, are determined by the input factors. Thus, discovering the most idyllic personas and behaviours are dependent on the selected roles, which are influenced by the problems faced by the students. Table 3 shows one instance of the key design requirements of an animated pedagogical agent for primary school students to learn science that are captured through IPO relationships. The requirements are divided into two clusters - essential and complementary design concerns.

Table 3: Essential and complementary requirements of an animated agent

	Problems	Roles	Personas	Behaviours	Benefits
Essential	<ul style="list-style-type: none"> Nobody to ask for advice or guidance Lack of attention to help them study Lack of motivation to learn independently Lack of support while doing exercises 	<ul style="list-style-type: none"> Facilitator Tutor Presenter 	<ul style="list-style-type: none"> Verbal communication Understand students' emotional states Have a good understanding of a subject domain 	<ul style="list-style-type: none"> Helpful Friendly Motivating Responsive 	<ul style="list-style-type: none"> Motivation and support that an animated agent can give Students are able to get quick advice and explanation Increase students' attention with the learning environment
Complementary	<ul style="list-style-type: none"> Students fell lonely when learning by themselves Students do not enjoy the environment 	<ul style="list-style-type: none"> Advisor/Mentor Motivator Guider 	<ul style="list-style-type: none"> Non-verbal communication 	<ul style="list-style-type: none"> Entertaining Expressive 	<ul style="list-style-type: none"> Encourage students to answer their exercise/ test questions Agents direct students to source additional assistance Agents care about performance of students under its supervision

The IPO model is used as a frame of reference of the key factors associated to the requirements of pedagogical agents, as well as to show the dynamic relationships between the key factors. The survey results can be manipulated to show how roles, behaviours, personas, and problems are interrelated to each other and how it maps back to the benefits of the implementation on an animated pedagogical agent. IPO factors and components as listed in Table 1 are still at the experimental stage. A more generic and detailed IPO model can be produced as more studies and analysis are carried out on the IPO relationships.

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