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Edited by Monique Grandbastien

Foreword

From AIED 1999 in Le Mans we established a tradition of running a Young Researcher Track during our conferences, the Track continued in AIED 2001 and AIED 2003. The AIED 2005 YRT call for papers reminded that "Usually, PhD students cannot write and submit a paper at the early stage of their research; however, they can present the main ideas they are currently developing and implementing and they can benefit from advice and exchanges from senior researchers from outside their lab. The submitted papers are reviewed by senior researchers. The accepted papers are presented during sessions that are scheduled during the main conference, and feedback will be provided during these presentations. Students can also benefit from participating in the AIED conference, which is a major event for the research community, they can establish links at the international level with other students working in the same area and they can prepare themselves to become the AIED researchers of tomorrow. Several authors selected for previous YRT sessions wrote that they would never have attended the conference without being accepted for this category of presentation and they would really have missed something important for them."

This call was very successful, we received 42 papers and accepted 29. Each paper was reviewed by at least two members of the YRT committee or additional reviewers, the review criteria are specific to this track. Due to the high number of submissions to the main conference and to the Young Researcher Track, we were not able to affect a mentor to each selected paper in order to help the author to prepare his final version. However, we sent the reviewers' names (with reviewers' permission) to the authors, so that they can contact their reviewers if they need further comments about the recommendations made in the review.

Each accepted contribution got a "one page summary" in the main conference proceedings and a "six pages paper" in the present volume. All together, these contributions give a nice overview of the research topics on which AIED PhD students are currently working. We can for instance notice a strong interest for modelling affects and affective behaviour, as well as a continuing interest in supporting collaboration and in designing pedagogical agents.

We would like to thank all the reviewers who provided useful comments despite the tight schedule of the reviewing process, the special involvement of the YRT committee members has to be gratefully acknowledged, as well as the contribution of additional reviewers who were requested for their field of expertise. Our thanks also goes to the other chairs of the conference for their tireless efforts for scheduling the Young Researchers presentations despite all the constraints we had to face. Last but not least, we would also like to congratulate all the authors who made the success of this track and we are looking forward stimulating presentations and challenging discussions in Amsterdam.

May 2005

Monique Grandbastien

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Computer-Supported Collaborative Argumentation-Based Learning: How students solve controversy and relate argumentative knowledge

Marije VAN AMELSVOORT & Lisette MUNNEKE
Utrecht University, Heidelberglaan 2, 3584CS Utrecht, The Netherlands
Tel: +31 30 2534867
e-mail: m.a.a.vanamelsvoort@fss.uu.nl; e.l.munneke-devries@fss.uu.nl

Abstract. This paper focuses on argumentative diagrams for computer-supported collaborative argumentation-based learning. Thirty pairs of students discussed two cases on the topic of Genetically Modified Organisms (GMOs) via the computer. They communicated via chat. Pairs of students were either asked to collaboratively construct a diagram using argumentative labels to describe the boxes in the diagram, to construct a diagram using argumentative labels to describe the arrows between the boxes, or to collaboratively write a text without using labels. The collaborative process of discussing the topic and constructing the representation (diagram or text) was analysed on how broad and deep students explore the topic of GMOs. Special attention was given to the way students resolve controversy and relate different aspects of the topic under discussion. Preliminary results show that students do not discuss the labels very often and overall are not more aware of controversies and relations in their arguments. They are mostly focused on finishing the diagram or text. Further results will be discussed in Amsterdam.

Keywords: computer-supported collaborative learning, argumentative interaction, diagrams

Introduction

Who could have imagined the enormous impact of the invention of computers on our daily lives? For us researchers the use of computers to analyze data, write articles, and communicate with fellow researchers cannot be underestimated. Also, for several decades, computers have been object of study in educational sciences.

The learning theory behind the use of computers has changed over the years [1]. The first investigations in educational technology started from a behaviorist theory in which instruction was programmed to have students acquire formal knowledge, researching whether the computer had efficiently led the students to the set learning goals. In recent years, focus is put on socially oriented theories of learning, researching how students *do* computer-supported learning.

This focus on socially oriented theories of learning emphasizes specific points in computer-supported learning, such as learning in process and in collaboration. Researchers are interested in how learners make meaning together. The interaction or collaboration itself is researched to find out what interactions are helpful and what conditions can trigger these beneficial interactions [2]. In this paper, we research both of these questions.

First, we investigate the interactions between pairs of students in a computer-environment. We believe that argumentation is especially useful in learning together, since learners have to negotiate different meanings [3]. The argumentative interactions are closely investigated to see in what ways students collaboratively broaden and deepen their discussion. We return to this topic in section 1. Second, we investigate how students' collaborative argumentation-based learning can be supported with representational tools. We hypothesize that the collaborative construction of a representational tool will support students' discussion on controversy existing in the domain under discussion or between the collaborative partners. We believe that a focus on relations between arguments, for example in specifically labeling these relations, will be especially helpful for relating knowledge, thus broadening and deepening the discussion. We return to this topic in section 2.

1. Argumentative interactions

We start from the premise that processes such as collaboration and argumentation are crucial factors in a learning process [4], since they force learners to make their thoughts explicit, and listen and react to the other person's ideas. Since most people only have knowledge about part of a certain domain, argumentative interaction can help them to collaboratively acquire, refine, and restructure knowledge in order to get a broader and deeper understanding of the domain [5, 3].

Research [6,7] showed that students indeed elaborate, argue and change their conceptions when negotiating during collaboration on a task, but this kind of research has mostly been done in problem-solving environments with a scientific or physical topic. Generalising results of this research to more open domains can be problematic [8], because the aim of negotiation in these domains is not to find the right answer but to come to a better understanding. Learning about open-ended issues is important, because many of the problems we are facing in society are open-ended (e.g. war and peace, life and death, environment and economics).

Our research focuses on argumentative interactions in the domain of Genetically Modified Organisms (GMOs). GMOs are highly controversial. The debate is very complex, including a variety of points of view and social actors in the debate. All views, arguments, decisions, facts, emotions, and consequences together make up the "space of debate" of the issue. To form an idea on the domain and form an opinion, people have to explore this space of debate.

Argumentation, especially argumentative interaction, is not easy. Kuhn [10] found that when adults are arguing alone it is fairly easy for them to enumerate different arguments and counterarguments for an opinion and to give supportive (pseudo)evidence for their arguments. However, it is more difficult for them to come up with rebuttals and counterarguments for their supportive arguments and evidence. In short, people can think about different subtopics, but it is difficult for them to handle controversy in these subtopics. We call the different subtopics in a domain the breadth of the domain, and the exploration of these (sub)topics the depth of the domain.

Kuhn´s later research focused on argumentative skills of young adolescents in dialogue [11]. It appeared that despite of having an argumentative partner it is still difficult for students aged 16/17 to deepen their arguments. Counter argumentation is very difficult for them. Students also lack the skill to explore the ideas of their argumentative (counter)partners. When they deepen an argument it is only their own argument. So, students can handle the breadth of the space of debate, but the deepening of arguments, handling controversy and relating different subtopics is difficult for them.

2. Computer support of argumentative interactions

A computer-supported environment might solve the problems such as the ones described above, for example by making controversy explicit, or by focusing on relations between arguments. This can be done by providing students with possibilities to construct an external representation, such as an argumentative diagram. With a diagram students can construct, research, and manipulate their own representation of the space of debate. An argumentative diagram might help them in relating argumentative knowledge, because it specifically displays relations (arrows) between knowledge parts (in boxes), and can give an instant overview of the space of debate. Also, because the diagram has to be made in collaboration, it makes differences between students clearly visible, and could help them to address controversy. Students are invited to counter and rebut arguments together, because they are shown on screen.

However, earlier studies [12] found that students do not benefit much from the construction of an argumentative diagram to learn about the space of debate. They find out how to use the diagram fairly quickly, but do not make use of it for addressing controversy or relating knowledge. Displayed contradictions are not discussed, and relations put between boxes are often arbitrary. Diagrams are used to display bits and pieces of information, without considering their structure. Overall, students did not really discuss each other´s arguments, but simply took them for granted. Short fragments of argumentation were followed by rapid reconciliation. We think that students might need more guidance in focusing on relations and controversy. In the first versions of Belvédère, boxes had many labels, which changed students' focus of discussing content to discussing categories [13]. For diagrams supporting deepening discussions and relations between knowledge-parts, we feel that discussing meta-levels of content might exactly be what is needed.

In our study, we explore how different argumentative representations influence the way students broaden and deepen the space of debate. We hypothesize that students who have to explicitly label arguments (with labels such as ´argument in favour´, ´counterargument´, ´rebuttal´) in a diagram will have a deeper discussion than students who do not use labels, because it helps them to focus on the deepening activities of counter-argumentation and rebuttal. The labels help them to realize what kind of argumentation they haven´t used yet. We also think that labeling relations between arguments (with labels such as ´because´, ´but´, ´such as´) will lead to a deeper discussion while also taking relations between subtopics into account. Students who have to label relations will address controversy more than students who have to label arguments or students who do not use labels, because the labelling is a visual display of the controversy and maybe in this way students are 'forced' to solve these kinds of contradictions in collaboration. We also expect that controversy displayed in this way in diagrams will give more communication in chat about the content of boxes and arrows.

3. Method

3.1 Participants

Participants were 60 students aged 15 to 17 from two upper secondary schools (pre-university) in the Netherlands. Three classes participated, two during biology lessons, the other one during Dutch language and literature. The sample included 27 boys and 33 girls. Pairs of students were randomly formed within classes, with each student working at his or her own computer. Pairs were divided into three groups according to three different conditions.

3.2 Design and procedure

The study roughly consisted of three phases: a preparation phase, a discussion phase and a closing phase. The task sequence is described in more detail in Table 1.
Pairs of students were put in one of three conditions. In one condition, they were asked to collaboratively construct a diagram, using the following labels for the viewpoint and arguments (boxes): viewpoint, argument in favour, argument against, support, rebuttal, and example. In the second condition, students were asked to collaboratively construct a diagram using the following labels for relations (arrows) between arguments (boxes): because, but, and, thus, such as. In the third condition, students were asked to discuss the topic without a diagram and collaboratively write notes or text in a textboard.

Table 1. Task sequence

Phase	Task	Duration (min)
Preparation	We started the lesson with a description of the task at hand, followed by a short interaction with students on argumentation and discussion in general. A five-minute video was used to introduce students to the topic of GMOs. Then students received information sources on the topic, and were asked to individually make a list with as many arguments for and against genetic modification as they could think of. The information sources were different for each student in a pair.	90
Discussion	Pairs of students discussed the lists with arguments they made via the computer environment DREW. They were asked to collaboratively construct a diagram or write in a textboard reflecting the integration of their arguments. Next they were asked to debate about two cases, one at a time. Both times, students were asked to discuss and put ideas either in text or diagram. At the end of discussing the first case, students were asked to fill a questionnaire on the possible occurrence and solution of controversies between them.	130
Consolidation	Students individually made a post test in which their argumentative knowledge of the topic was tested. In the final lesson, a classroom debate in groups of about 8 to 10 persons was held. Students were assigned to a for or against position. They debated about GMOs in general or on a subtopic.	60

3.3 Tool

The computer environment we used in this study is called DREW[1], developed within the SCALE[2] project The screen is divided in two windows: a chat window, and a diagram window or a text window, depending on the condition students are in. In the diagram, students can make boxes and draw arrows between boxes. Every box and arrow can be filled with text and additional pop-up comments. In the two diagram conditions students were asked to start every box with an argumentative label or to define an arrow with a relational label as described above. In the non-diagram condition students get a text window instead of a diagram in which they can type everything they want.

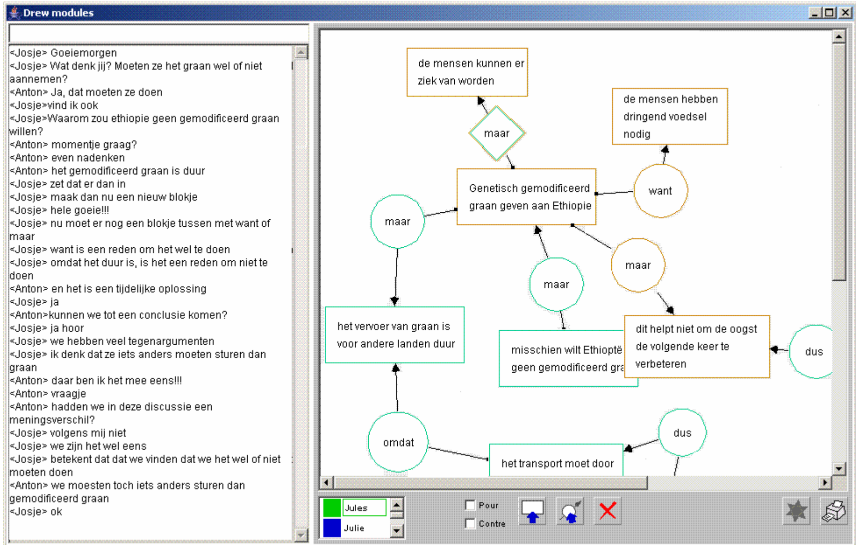

Figure 1. Screendump of DREW with diagram window (labeling arrow-condition).

3.4 Data and analyses

Main data in this research were the dialogues, diagrams and notes in the textboard which were logged in such a way that every action of students is recorded. This enables coding of all interactions. To get a first impression of data, we firstly performed a functional analysis on all students´ interactions. This functional analysis is called the Rainbow-framework[3] and distinguishes the argumentative interactions from more task-specific or socially oriented interactions. On the argumentative interactions we performed an analysis which codes exploration of the space of debate in breadth and depth. The breadth of the space of debate is determined using a topic list that distinguishes 14 possible GMO-topics students argue about. The depth of the space of debate follows Kuhn's argumentative elements [10]; claim, supportive theory, alternative theory, evidence, counter, and rebuttal. A claim that is followed by a supportive theory is deeper than a claim alone, and so on. Supplementary data are delivered by questionnaires and the face-to-face debate. These data show whether students are aware of controversy and which arguments have become part of their own knowledge-base.

4. Results

At this moment, eight pairs have been analyzed on exploration of the space of debate and labeling their diagrams. These preliminary results show that students hardly ever discuss controversy and relations in chat, nor talk about the labeling of the diagram. They are mainly focused on finishing the diagram or text, without explicitly exploring the space of debate together. Even the removal of boxes and arrows is seldom discussed. Again, like in our earlier research [12], students seem to avoid controversy, probably because they value their social relation, and because they want to finish the task quickly and easily.

Students mainly explore the space of debate in the diagrams. The diagrams in the label-arrow condition are bigger than the diagrams in the label-box condition. There was no difference in conditions in amount of counterarguing or rebutting arguments in the diagram. Most students indicated there was no controversy in their discussion with their partner. However, when looking at the diagrams, many controversies can be found that are not related or discussed. We wonder whether students do not see controversy or whether they don't feel the need to solve it.

Summarized, diagrams seem to be supportive for argumentative processes in the individual student, but not for argumentative *interactions*. Students are mainly working on their own parts, not aware of controversy and not discussing contrasts in their ideas. Further results will be discussed at our presentation.

Notes

[1] DREW: Dialogical Reasoning Educational Web tool. DREW is developed within the RIM research team at the Ecole des Mines de St. Etienne (France).
[2] SCALE project (Internet-based intelligent tool to Support Collaborative Argumentation-based LEarning in secondary schools, March 2001–February 2004) funded by the European Community under the *Information Societies Technology* (IST) Programme. Information on the project can be found at: http://www.euroscale.net/
[3] The Rainbow framework is collaboratively developed by researchers from four different countries involved in the European SCALE project: Michael Baker, Jerry Andriessen, Matthieu Quignard, Marije van Amelsvoort, Kristine Lund, Timo Salminen, Lia Litosseliti, and Lisette Munneke. An article on this framework is in preparation.

References

[1] Koschman, T. (1996). Paradigm shifts and instructional technology: an introduction. In: T. Koschman (Ed). *CSCL: Theory and Practice of an Emerging Paradigm. Lawrence Erlbaum associates*. Mahwah, New Jersey.
[2] Van der Linden, J., Erkens, G., Schmidt, H., & Renshaw, P. (2000). Collaborative Learning. In: R.J. Simons, J.L. van der Linden and T. Duffy (Eds.), New Learning. Dordrecht: Kluwer.
[3] Andriessen, J., Baker, M., Suthers, D. (2003). Argumentation, Computer Support, and the Educational Context of confronting cognitions. In J. Andriessen, M. Baker, and D. Suthers (Eds.). *Arguing to Learn: Confronting Cognitions in Computer-Supported Collaborative Learning environments* (pp. 1-25). Dordrecht: Kluwer Academic Publisher.
[4] Petraglia, J. (1998). *Reality by design: the rhetoric and technology of authenticity in education.* Mahway, New Jersey: Erlbaum.
[5] Voss & Wiley (1997). Developing understanding while writing essays in history. *International Journal of Educational Research,* 27, pp. 255-265.
[6] Roschelle, J. (1992). Learning by collaborating: convergent conceptual change. *The journal of the learning sciences,* 2(3), pp. 235-276.
[7] Baker, M. (2003). Computer-mediated argumentative interactions for the co-elaboration of scientific notions. In: J.Andriessen, M.Baker, and D. Suthers (Eds*.) Arguing to Learn: Confronting cognitions in Computer-Supported Collaborative Learning environments, (pp. 47-78). Dordrecht:* Kluwer Academic Publisher.
[8] De Westelinck, K.D., Valcke, M., De Craene, B., & Kirschner, P. (2005). Multimedia learning in social sciences: limitations of external graphical representations. *Computers in Human Behavior, 21*(4), pp. 555-573.
[9] Van Eemeren, F.H. & Grootendorst, R. (1999). Developments in Argumentation Theory. In J. Andriessen en P. Courier (eds.) *Foundations of Argumentative Text Processing.* Amsterdam: Amsterdam University Press.
[10] Kuhn, D. (1991). *The skills of argument.* University Press: Cambridge.
[11] Kuhn,D. & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), pp. 1245-1260.
[12] Munneke, L., Van Amelsvoort, M., & Andriessen, J. (2003). The role of diagrams in collaborative argumentation-based learning. *International Journal of Educational Research, 39*, pp. 113-131.
[13] Suthers, D.D. (2001). Towards a systematic study of representational guidance for collaborative learning discourse. *Journal of Universal Computer Science, 7*(3), 254-277.

Generating Reports of Graphical Modelling Processes for Authoring and Presentation

Lars BOLLEN
University of Duisburg-Essen
Faculty of Engineering
Institute for Computer Science and Interactive Systems
47048 Duisburg, Germany

Abstract. Today's computer supported modelling environments could provide much more information about the users' actions and problem solving processes than they usually store for later usage. Thus, relevant information about learning processes which could be used for reflection and analysis is lost.
This paper describes an approach to tackle this issue by generating "reports", in the sense of augmented summaries of states and action traces from modelling processes. This approach includes a) gathering information about actions and states from specific modelling environments, b) analysing these information using domain knowledge (if available) and c) represent the results in a way suited for various use cases like authoring, presentations or monitoring of learning processes.

1. Introduction and problem description

In many areas of teaching and learning (especially in natural sciences and computer science), the task of modelling is crucial for students to get deeper insights into the problem domain, to be able to create hypotheses and predictions of complex phenomena and to improve communication and coordination between peers and with the teacher [1]. Especially when learners create models themselves that are executable and actively explorable, there is definitely value added compared to static representations (e.g. in books or on a chalkboard). While modelling, the learner interacts with computational objects, manipulates them and thereby makes his thoughts explicit. In this context, the phrase "objects to think/work with" has been introduced in [2], meaning that the exploration, manipulation and creation of artefacts support in establishing understanding.

Having these ideas in mind, the modelling environment Cool Modes (Collaborative Open Learning and Modelling System) [3] has been developed. Cool Modes is a framework for collaborative modelling with graph based visual languages like Petri Nets, System Dynamics, UML class diagrams and many more.

Nevertheless, when a learner finishes a modelling task with a modelling environment like Cool Modes, usually only a result is stored. The process of creating and exploring a model is compressed to a single artefact. In more detail:

- *The process* of his work gets lost, since only the result is stored. The single actions that lead to this result, are usually lost.
- *Information about different phases* (e.g. phases of argumentation and coordination with peer, design, verification, revision, annotation etc.) the user went through in his problem solving process gets lost.
- *The design rationale* is lost, unless the user made it explicit in his solution or in additional documents.

- Elaboration of *alternative solutions* usually cannot be reproduced, since older creations are simply overwritten by newer ones.
- Information about *collaboration* gets lost having only a single artefact as the output of a modelling process.

Knowledge about these issues is helpful for various target groups and for various purposes:

- The learner himself could use this information for self reflection, self / peer assessment, peer authoring / vicarious learning [4] and for presenting own results.
- Teachers could be supported in assessment, authoring (by demonstrating solutions and presenting prepared material) and for finding typical problems in students' solutions.
- Researchers in the field of AIED / CSCL could use the additional information for interpreting and understanding learners' actions and results and for applying different analysis mechanisms on the stored states and action traces.

So, having the various information mentioned above might be helpful for different target groups and different use cases. The challenge is to obtain the required information, to interpret the information, to organise and present it in a general but still useful way.

2. Related work

2.1 Record and Replay

Some approaches like Ottmann's "Authoring on the fly" [5] and Rojas' "E-Chalk" [6] store process-related data in additional to the result, too, but they use a "record and replay" approach. The purpose is to record whole lectures in universities in order to stream them via internet or to replay them later. The target group of this approach is mainly students. Only a linear structure of material is supported; alternative solutions cannot be represented easily without recording a completely new session. During the record, there is no analysis or interpretation of actions taking place. Thus, you have to cut or skip irrelevant phases manually.

2.2 Series of snapshots: COPRET

A different approach called COPRET ("COllaboration Progress REproduction Tool") can be found in [7]. Here, a collaborative discussion support tool is observed by an analysis component that generates snapshots (images) of the learning environment at well defined points in time (e.g. after a change of control between the users or after insertion, modification or deletion actions). As a result, this tool produces a Word file that contains the teacher's and the students' actions and messages as well as screenshots in a chronological order. This approach combines some basic aspects of analysing user actions and storing process-related data, but focuses on supporting teachers assessing and interpreting students' results and cannot be used for authoring or presentations.

2.3 Behavior Recorder / CTAT

Another approach that focuses on analysing and tutoring problem solving processes is described by Koedinger et. al [8]. For well-defined problems (including a well-defined user interface) like the addition of two fractions, the so-called Behavior Recorder is able to record various paths of actions, which are specified by a teacher, that lead to correct or incorrect solutions. Enriching these paths manually with tutor messages builds a pseudo cognitive tutor that is able to feed back messages into the learning environment when the same (correct or incorrect) actions are done again by a learner. Recently, this approach has been extended to analyse collaborative, open modelling tasks [9]. Alternative solutions can be recorded and displayed, but they cannot be fed back into the modelling environment. Thus, the focus in this approach is on analysing and tutoring users' actions.

3. Approach and prototypical implementation

The problem that has been described in the chapters above can be addressed and solved by generating *reports*. Reports, in the sense of this approach, are summaries of states and action traces from modelling processes. The problem description raises some requirements that a report generation tool has to comply with.

Generally speaking, a modelling environment can provide information about the actual *state* of a model as well as information about the *actions* that the learners execute while modelling. Thus, a report generation tool has to be able to gather and organise both types of information. Collecting information about *states* and about *actions* of a modelling environment enables for a rich examinations of the modelling process, since action-based analysis methods as well as state-based analysis methods can be applied [10].

Having these different kinds of information calls for an appropriate way of visualising them. A graph-based visualisation of a report generation tools seems to be adequate for two reasons. First, most modelling environments use graph-based visualisations themselves, so it reduces cognitive load when teachers, students or researchers are using a modelling environment and a report generation tool. Second, when talking about traces of actions that lead to different states, it seems to be quite similar to paths on a map that lead to different places. Thus, a graph-based representation seems to be quite naturally (see figure 1).

The problem description came up with the possibility of using reports for presenting results to peers or to students. This requirement can be fulfilled by having means for interactive browsing and for feeding states from the reporting tool back into the modelling environment, thus providing *flexibility in presentation*.

When using a report generation for authoring learning material, re-arranging, modifying and establishing new connections between states in the captured material has to be possible, providing *creativity in authoring*.

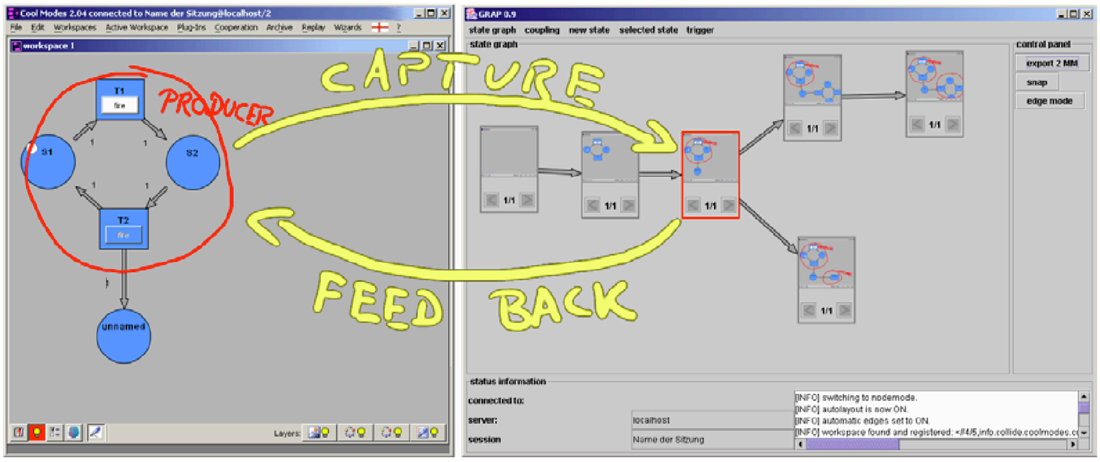

Figure 1. Using GRAP with Cool Modes when modelling a Petri Net. On the left, the modelling environment Cool Modes is shown; on the right, the report generation tool GRAP. The basic modes of operation, capturing and feeding back, are sketched in the figure.

On the way fulfilling and implementing these requirements, a prototypical report generation tool called "GRAP" ("Generating Reports for Authoring and Presentations") has been created. GRAP's basic modes of operation are capturing states of a modelling environment at specific times during the learning / modelling process as well as storing the actions that occur between these states, display this information in a graph-based structure and feeding these states back into the learning support environment. Typically, the nodes of this graph represent the states of a model while the edges hold the information about the users' actions (see figure 1).

The decision about suitable moments for capturing is critical for having a useful summaries of modelling processes. According to specific usage scenarios, this can be decided by the user of GRAP herself (e.g. for authoring, see chapter 5) or automatically by the system (e.g. for automated documentation). In the latter case, the report generator has to interpret the actions to be able to detect phases or milestones in the modelling process to find detect suitable moments for capturing. This interpretation of user actions is usually dependent on the domain that these actions are related to, as it has been described in [1].

Cool Modes provides all requested features like supplying information about the actual state of the model, about the users' actions and it is capable of playing back states and actions. Technically speaking, Cool Modes is able to be synchronised with other application by using a communication server called MatchMaker [11], replicating the state of the modelling environment on each client and propagating user actions. GRAP is attached to this distributed system as just another client, able to listen to user actions, to capture the complete state of the modelling environment and to feed information (e.g. states or actions) back into the system.

These features made Cool Modes an appropriate candidate as a modelling environment to build a prototypical implementation of a report generation tool. At the current moment, GRAP is able to capture the states and user actions of the modelling environment Cool Modes at any time. This information is organized in a graph-based structure (see figure 1, right hand side); the nodes represent different states, the edges represent the actions that lead from one state to another (these actions are not shown in figure 1). The states can be fed back into the modelling environment at any time.

4. Scenarios

To clarify this approach and to point out the usefullness of the solution described above, three scenarios will be presented in the following.

4.1 Authoring

A teacher of a biology course in school chooses the to model predator-prey interactions (e.g. foxes and rabbits) as a topic for the next lesson. He decides to use a modelling software like Cool Modes (using the System Dynamics plug-in [12]) to model, visualise and simulate the equations that represent the predator-prey interactions. Creating the model from scratch would be too time consuming for a lesson in school; presenting a pre-constructed model is probably too difficult for the students. He starts creating the model the day before at home, using GRAP to snap important steps during the modelling process. He creates several, different, non-linear *presentation paths* to be able to explain intermediate results and alternatives, to show typical mistakes and dead ends and to have answers to possible questions at hand. During the lesson, the teacher uses GRAP to feed back different stages of the model into the modelling software, still being able to use the modelling tool as such, rather than doing a predefined slide show. GRAP may propose *presentation paths* from given start and end states to visualise (and to understand) the evolution of a desired solution.

Thus, GRAP would be used in a way similar to an authoring tool. Prepared material can be arranged in a complex, non-linear structure to have flexible means for presenting prepared material, still being able to shift into modelling activities and simulations at any time.

4.2 Documentation on-the-fly

During discussion in class at school or during meetings in a research group, it is quite common to create concept maps of the problem domain, to create QOC [13] networks to document design decisions or to point out (or even solve) problems. For people that could not attend the meeting, for students trying to remember the course of a lesson, or simply for late-comers, it is often difficult to reconstruct the meaning and creation process of a model or the evolution of a concept map. GRAP will be able to analyse modelling actions while they take place, decide about important stages and take snapshots from these important steps. These snapshots are arranged in a graph, showing which state lead to another. In a linear process this graph will be a simple linked list. However, if the users go back to a previous state and continue from there to create an alternative solution, the graph becomes more complex. This graph can be used to catch up on the content of the discussion, meeting or lesson.

In this way, GRAP can be used for documenting and retrieving various modelling processes. Viewers do not have to watch whole replays, but can fall back on a compressed, yet relevant summary of a modelling process.

4.3 Monitoring and analysing

A researcher in the field of computer-supported learning and artificial intelligence in education is interested in particular features of collaboration such as joint exploration of a given model. He uses GRAP to capture the state of a modelling environment at specific times while groups of students are trying to solve modelling tasks. Various filters and analysis methods could be applied to the states and action traces that are gathered by GRAP. Even more, results and process related data from different groups of students are displayed and compared at the same time, still being able to feed back intermediate results to get a detailed insight into the learning process that is being analysed.

Here, GRAP is used to support analysis of learning processes by capturing states and action traces from modelling environments and applying state based analysis methods as well as action based analysis methods.

5. Challenges and future work

On the way to finish this prototypical implementation, several challenges have to be mastered:

One of these challenges is an appropriate analysis, interpretation and assessment of user actions, potentially taking into account the domain and the context of these actions. This interpretation of user actions helps identifying phases and milestones in modelling processes, thus being a way to find suitable moments for capturing the state of a model.

Another challenge is the elaboration of the meaning of edges between states in the report graph. Here, an appropriate approach for teacher's authoring could be the classification into didactical relations (e.g. "X introduces to Y"; "X is exemplified by Y") as described in [14].

Another interpretation of the meaning of edges might be the "degree of relevance" of user actions. Considering the domain and context of an action (as described above), the system will be able to decide the relevance of particular actions for the modelling actions.

A challenge on a broader scale is to find a way to integrate a report generation tool like GRAP into several other modelling tools like CoLab [15] or ModellingSpace [16]. Therefore, a common data format to describe actions and states on modelling environments has to be found or defined. A standardised message and state description opens the way for integration, which would be obviously beneficial.

6. Conclusion

It has been described, that the potential information about learning and modelling processes from modelling environments is not used to a full extent at the moment. Details about intermediate states of models and about users' actions get lost in most cases.

This information can be valuable for target groups like students, teachers and researchers for use cases like authoring, documenting and analysing modelling processes.

An approach and a prototypical implementation called GRAP has been described. This approach uses state based and action based analysis to capture the states of a modelling environment at specific time as well as storing the users' action that occurred. The captured states and actions are summarised in a report, that is visualised in a graph-based structure. These states can be fed back into the modelling environment.

Still, there are several challenges like using domain knowledge to interpret the actions, calculating suitable moments for automated capturing of states and finding a common, standardised description for states and action of modelling processes.

7. References

[1] Harrer, A., and Bollen, L. (2004). *Klassifizierung und Analyse von Aktionen in Modellierungswerkzeugen zur Lernerunterstützung.* In Workshop-Proc. of Modellierung 2004, Marburg.

[2] Harel, I. and Papert, S. (eds.) (1991): *Constructionism.* Ablex Publishing. Norwood, NJ.

[3] Pinkwart, N. (2003). *A Plug-In Architecture for Graph Based Collaborative Modelling Systems.* In Proc. of the 11th Conference on Artificial Intelligence in Education (AIED 2003), Amsterdam, IOS Press.

[4] Rummel, N., and Spada, H. (2002). *Combining worked-out examples and vicarious learning to promote the coordination of computer-mediated interdisciplinary collaboration.* In Proc. of AERA 2002, New Orleans.

[5] Müller, R., Ottmann, T. (2000). *The "Authoring on the Fly" System for Automated Recording and Replay of (Tele)presentations.* Special Issue of Multimedia Systems Journal, Vol. 8, No. 3, ACM/Springer.

[6] Rojas, R., Knipping, L., Raffel, W.U., and Friedland, G. (2001). *Elektronische Kreide: Eine Java-Multimedia-Tafel für den Präsenz- und Fernunterricht.* In Beck, Sommer (eds.): Tagungsband der Learntec, Vol 2, pp. 533-539, Karlsruhe.

[7] University of Aegean / LTEE (2004). *State of the Art on Interaction Analysis: Interaction Analysis Indicators.* Deliverable D.26.1 of Kaleidoscope "Network of Excellence" research project on "Interaction and Collaboration Analysis supporting Teachers' and Students' Self-regulation".

[8] Koedinger, K. R., Aleven, V., Heffernan, N., McLaren, B. M., and Hockenberry, M. (2004). *Opening the Door to Non-Programmers: Authoring Intelligent Tutor Behavior by Demonstration.* In Proceedings of 7th International Conference on Intelligent Tutoring Systems, ITS 2004, Maceio, Brazil.

[9] McLaren, B., Bollen, L., Walker, E., Harrer, A., and Sewall, J. (2005). *Cognitive Tutoring of Collaboration: Development and Empirical Steps Towards Realization.* Accepted for the Conference on Computer Supported Collaborative Learning, CSCL 2005, to take place in Taipei, Taiwan in May/June 2005.

[10] Gaßner, K., Jansen, M., Harrer, A., Herrmann, K., and Hoppe, H.U. (2003). *Analysis methods for collaborative models and activities.* In Proceedings of the International Conference on Computer Supported Collaborative Learning (CSCL 2003), Bergen.

[11] Jansen, M. (2003*). Matchmaker - a framework to support collaborative java applications.* In the Proceedings of Artificial Intelligence in Education (AIED 2003), IOS Press, Amsterdam.

[12] Bollen, L., Hoppe, H.U., Milrad, M., and Pinkwart, N. (2002). Collaborative Modelling in Group Learning Environments. In Proc. of the Int. Conf. of the System Dynamics Society, Palermo (Italy), July 2002, pp. 53.

[13] MacLean, A., Young, R., Belloti, V., and Moran, T. (1991). Questions, options, and criteria: Elements of design space analysis. Human-Comput. Interaction, 6(3–4), 201–250.

[14] Baloian, N. (1997). Strukturierte Erstellung und Kooperative Nutzung von Instruktionsmaterial in einem Computerintegrierten Klassenraum. PhD Thesis. University Duisburg, Germany, September 1997.

[15] CoLab – Collaborative Laboratories for Europe, website http://www.co-lab.nl

[16] ModellingSpace - website http://www.modellingspace.net

Towards An Intelligent Tool To Foster Collaboration In Distributed Pair Programming

Edgar **ACOSTA CHAPARRO**
IDEAS Lab, Dept. Informatics,
University of Sussex BN1 9QH, UK
E.A.Chaparro@sussex.ac.uk

ABSTRACT

This paper outlines a research proposal that intends to explore the pair programming task for remote collaboration. It proposes to investigate the suitability of the Task Sharing Framework (TSF)[1] in the design of an intelligent tool that aim to monitor and foster the collaboration between distributed pair programmers facilitating their efforts at learning programming.

1. Introduction

Teaching programming is not an easy task. For this reason, it has been the subject of study for many researchers. Brusilovsky et all. [2], for example, in a review of approaches and tools for teaching procedural programming, noted that programming causes cognitive overload and for this reason should be taught in small subsets. With Object Oriented Programming, an approach that is increasingly finding agreement in academic environments this is not different. The large number of concepts, whose familiarity is required for handling object oriented programming constitutes a major difficulty for novices [3]. Thus, new tools and methods that could facilitate the learning of programming must be explored.

Pair programming is a novel well-accredited approach to teach programming. Students who practice pair programming have shown better results on graded assignments and more satisfaction/less frustration on doing course projects [4]. In pair programming (as in any other collaborative learning situations) there is a need for tools that support peer collaboration. It is also necessary to consider the strong movement towards distributed learning technologies and how this movement could influence the design of such tools[5]. Indeed, there have been some attempts to implement tools to support distributed pair programming [6, 7]. However, none of them have had any influence of pedagogical theories. Moreover, little attention has been paid into the different affordances that distributed pair programming provides compared with collocated pair programming.

Therefore, this doctoral research intends to explore and understand the discussed collaborative situation (distributed pair programming). The Task Sharing Framework (TSF) developed by Pearce et al. [1] will be used to design a prototype of an intelligent tool that will monitor and foster the collaboration between distributed pair programmers facilitating their efforts at learning programming

2. Collaborative Programming and Shared Learning: A look into Pair Programming

Pair programming is the situation in which two programmers work side by side, designing and coding, while working on the same algorithm. A relevant aspect of pair programming is that it transforms what used to be an individual activity into a collaborative effort [8, 9]. Typically there are two roles in pair programming: the driver who controls both the computer keyboard and the mouse, and the navigator who examines the driver's work, offering advice, suggestions and corrections to both design and code [9]. Those two roles are often not fixed but exchangeable.

According to Cockburn and Williams [8] who observed the method in academic environments, Pair Programming improves the quality of the software design, reduces the deficiencies of the code, enhances technical skills, improves team communication and is considered to be more enjoyable for the participants. Moreover, other studies [10, 11, 12, 13] that compared the performance of pair programming students and solo students showed that the former were more likely to hand in solutions for their assignments that were of higher quality.

Considering all outcomes from these studies is not difficult to see why pair programming has been extensively used as a method for teaching programming to computer science students in recent years. However, some studies [14, 15] have suggested that it is not obvious that pair programming is more efficient than solo programming. Tessem [15], for example, showed that some students found the experience irritating, extremely inefficient and very exhausting. Another study [16] that explored students' perceptions of pair programming highlighted three issues that must be addressed to guarantee a good collaboration: schedule conflicts (availability to work), pair incompatibility (skill level, cognitive styles), and unequal participation by the individuals in a pair.

Despite all criticism, there is enough evidence to suggest that pair programming in some situations appears to be more engaging and enjoyable [17]. Therefore, in pair programming (as in other collaborative learning situations) there is a need for tools that support peer collaboration and also take action to overcome difficulties during the interaction.

2.1 Distributed Pair Programming

In the area of computer supported cooperative work, it is well know that distance matters [18]. Consequently, as argued in [7] it follows that collocated pair programming will most likely outperform distributed pair programmers in terms of productivity. On the other hand, it is difficult to ignore the enthusiasm for distributed learning. Indeed, there are many factors motivating distributed work. Organizations have offices in multiple locations with teams interacting cross-geographical sites in different time zones. Universities are launching distance learning courses to reach wider populations [10].

It is reasonable to argue that a tool that successfully supports distributed pair programming will bring many benefits. For example, it will remove conflicts with collocation requirements [10] and it could support synchronous and asynchronous cooperation among student who will be geographically distributed [6]. Baheti, Gehringer et all [6] have shown that distributed programmers foster teamwork and communication. They also argued that software development involving distributed pair programming seems to be comparable to collocated pair programming in terms of productivity and quality. Hank [10] also showed some evidence of the efficiency of distributed pair programming. However both works of distributed pair programming were more interested in performance and suggested environments and tools that tried to recreate a collocated situation using video. Little attention has been paid for the different affordances those two different situations (Collocated and Distributed) can provide.

Different from collocated, distributed pair programming will provide one set of keyboard, mouse and monitor for each peer. This situation per se changes the nature of the task a lot. If we consider for example the roles suggested in [9], each member could be a driver at the same time, because they can take control of their own keyboards. So, should the tool only allow one person editing per time? Should each peer have his/her own copy of the task? Another aspect that should be considered is the collaboration among the pair, in the design of tools for supporting pair programming less importance has been given to pair incompatibility and unequal contribution of participants. However, these two problems have been the subject of study in Collaborative Learning for a long time. As argued in [19], just putting people together does not mean that they will collaborate. Although there were some attempts to build tools to support pair programming [6, 7], none of them, as far as this author is aware of, have had any influence of pedagogical theories or have taking into account the different affordances provided. Therefore, to support the development of a tool, the author looked into the field of Collaborative Learning for some grounding theory and to the framework proposed in [1] .

3. Collaborative Learning: Constructing Knowledge in a Social Context

Learning in a collaborative environment is a process that could be subject to two different perspectives [19, 20]: individual effort and social sharing of knowledge. The first derives from as Cognitive Constructivism [21]; the second instead derives from Social Constructivism [22].

Social Constructivism focuses on learning as an action that occurs within a social context during the interaction between the learner and its interlocutor(s). It has tended to stress cooperation rather than conflict. This approach stresses learning as a process triggered by social interaction in a context of dialogue (ie. tutor-learner). Because of the engagement in collaborative activities, individuals can master something that they could not do before the collaboration [23, 20, 24]. From a Social Constructivist perspective, learning would occur in social environments with rich interaction between a learner and his/her peers.

Dillenbourg [19] defined collaborative learning as follow:

> "... the words "collaborative learning" describe a situation in which particulars forms of interaction among people are expected to occur, which would trigger learning mechanisms, but there is no guarantee that the expected interactions will actually occur. Hence, a general concern is to develop ways to increase the probability that some types of interaction occur"

According to Dillenbourg, in order to maximize the likelihood of such specific forms of interaction, there are four conditions to accurately set a collaborative context: (1) set up the initial environment, (2) over-specify the collaboration contract with a scenario based on roles, (3) scaffold productive interactions by encompassing interaction in the medium, and (4) monitor and regulate the interactions. These four conditions could be easily applied to Pair Programming, which is considered in this work as a specific type of collaborative interaction.

Therefore, a tool to support distributed pair programming, should foster the collaboration among peers and also have intelligent mechanisms to establish rules in the medium and monitor interactions. The Task Sharing Framework [1] will be used for the design of such tool. This framework operationalizes the sharing of collaborative tasks between multiple users. More important the framework will provide information about the task activity of each and every user. This will allow the use of intelligent features from the system that could for example detect undesirable patterns of interaction such as plagiarism.

4. An Intelligent Tool for Fostering Collaboration

The aim of this doctoral research is to investigate the suitability of the TSF [1] in the design and implementation of a prototype of an intelligent tool that monitors and enhances the collaboration between distributed pair programmers facilitating their efforts at learning programming. Supported by the TSF, the goal of the intelligent tool is to foster their collaboration, by monitoring and occasionally prompting with feedback or suggestions. In particular, the tool will search for signs of collaboration difficulties and breakdowns of pair programmers solving a pre-determined exercise of object-oriented programming.

The Task Sharing Framework supports the sharing of collaborative tasks between multiple users. The proposed framework supports different options for designing a tool, for example we can have one version where all users will have their own identical yet independent copy of the task that by default, only they themselves can manipulate. The visual representation of agreement and disagreement has the potential to constructively mediate the resolution of collaborative disputes [1]. Because this framework is going to be applied on a distributed task, the focus of this work will be on creating the visual representation of agreement.

We must bear in mind that the Task Sharing Framework was developed for children collaboration with simple representations. Therefore, some issues should be considered. Programming is a heavy cognitive task and with the Task Sharing Framework each student will have two representations to look at: his/her own and the one he/she agrees with his/her peer. This might impact students' cognitive efforts. Another aspect to be considered has to be with the roles played in pair programming: navigator and driver [9]. Does this framework support these roles or does it change the nature of pair programming? Finally, for the design of the tool decisions should be taken. For example, what type of agreement is expected for the pair, syntactical, semantical or both? Will the system only compare reserved words and parameters used (syntactical) or will it compare solutions using different syntaxes but with the same meaning (semantical)?

Supported by the framework, there will be many places where intelligence mechanisms could be applied. It could be used on recognizing how different one peer version of the task is different from the other peer. It also could be applied on recognizing a moment to intervene, such as when the computer notes that one peer is just copying the version of the other one, prompting some messages. However, many ideas are still speculative. The decisions about the intelligent features of the tool would be based on a study about pair programming the author is currently conducting.

This doctoral proposal is also strongly influenced by the work produced in IHELP [25]. On the basis of a student model, the intelligent tool would match good pairs, considering cognitive styles, learning goals, interests, among other characteristics of students. However, different from the work in IHelp, the proposed prototype will not work as a help seeker but as a tool that will aim to facilitate the collaboration among peers. The intelligent tool will be grounded on social constructivism [22].

5. Conclusion

This doctoral research proposes the design and implementation of an intelligent tool prototype supported by the TSF to coordinate and stimulate the collaboration between peers in distributed pair programming. Students learning via Computer Supported Collaborative

Learning need guidance and support on-line, just as students learning in the classroom need support from their instructor [26]. The advantage of using an intelligent tool is that it plays a non-authoritative role in a social learning environment [27]. The author is interested in exploring the learning gains and the peer collaboration with different design versions of the intelligent tool using the TSF. Each participant will do a pre-test to evaluate her level of expertise in object-oriented programming. The learning gain and the collaboration will be measured comparing the results from pre and post-tests, plus analysing verbalizations and performance on the task.

If the cognitive tool proves that it can be effectively used by students who are pair programming remotely, it will extend the benefits of pair programming to a large population. Moreover, it will strength the case for the Task Sharing Framework [1] as a language with which it is possible to reason about and design collaborative tasks. Progress in this area would also be of major significance in the area of intelligent learning systems used for teaching programming and collaborative learning.

References

[1] D. Pearce, L. Kerawalla, R. Luckin, N. Yuill and A. Harris, "The task sharing framework for collaboration and meta-collaboration," *to appear proceeding of 12th International Conference on Artificial Intelligence in Education*, Amsterdam - Netherlands, 2005.

[2] P. Brusilovsky, A. Kouchnirenko, P. Miller and I. Tomek, *Teaching programming to novices: A review of approaches and tools*, World Conference on Educational Multimedia and Hypermedia, 1994, p.^pp.

[3] F. Detienne, *Assessing the cognitive consequences of the object-oriented approach: A survey of empirical research on object-oriented design by individuals and teams*, Interacting with Computers **9** (1997), no. 1, 47-72.

[4] L. Williams, E. Wiebe, K. Yang, M. Ferzli and C. Miller, *In support of pair programming in the introductory computer science courses*, (2003).

[5] A. Fjuk, "Computer support for distributed collaborative learning. Exploring a complex problem area.," *Department Informatics - Faculty of Mathematics and Natural Sciences*, vol. Dr. Scient., University of Oslo, Olso, 1998, p. 256.

[6] P. Baheti, E. F. Gehringer and P. D. Stotts, *Exploring the efficacy of distributed pair programming*, Second XP Universe and First Agile Universe Conference on Extreme Programming and Agile Methods - XP/Agile Universe 2002, 2002, p.^pp. 208-220.

[7] P. D. Stotts and L. Williams, "A video-enhanced environment for distributed extreme programming," Department of Computer Science. University of North Carolina, 2002.

[8] A. CockBurn and L. Williams, "The cost and benefits of pair programming," *Extreme programming examined*, I. G. S. a. M. Maresi (Editor), Addison-Wesley, 2001, pp. 223-247.

[9] L. Williams and R. Kessler, *Pair programming illuminated*, Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2002.

[10] B. Hanks, *Empirical studies of pair programming*, Position paper for EEAP '03 - 2nd International Workshop on Empirical Evaluation of Agile Processes, 2003, p.^pp.

[11] B. Hanks, C. McDowell, D. Draper and M. Krnjajic, *Program quality with pair programming in cs1*, ITiCSE '04: Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education, ACM Press, 2004, p.^pp. 176-180.

[12] C. McDowell, L. Werner, H. Bullock and J. Fernald, *The impact of pair-programming on student performance, perception and persistence*, ICSE '03: In Proceedings of the 25th International Conference of Software Engineering, IEEE Computer Society, 2003, p.^pp. 602-607.

[13] L. Williams, R. Kessler, W. Cunningham and R. Jeffries, *Strengthening the case for pair-programming*, IEEE Software **17** (2000), no. 4, 19-25.

[14] R. Gittins and S. Hope, *A study of human solutions in extreme programming*, 13th Workshop of the Psychology of Programming Interest Group, 2001, p.^pp. 41-51.

[15] B. Tessem, *Experiences in learning xp practices: A qualitative study*, Extreme Programming and Agile Processes in Software Engineering, 4th International Conference, Springer, 2003, p.^pp. 131-137.

[16] G. Melnik and F. Maurer, *Perceptions of agile practices: A student survey*, Proceedings Agile Universe/ XP Universe, Springer, 2002, p.^pp. 10.

[17] S. Bryant, *Xp: Taking the psychology of programming to the extreme*, 16th Workshop of Psychology of Programming Interest Group, 2004, p.^pp.

[18] G. M. Olson and J. S. Olson, *Distance matters*, Human-Computer Interaction **15** (2002), no. (2/3), 139-178.

[19] P. Dillenbourg (Editor), *What do you mean by collaborative learning?* Pergamon, Oxford, 1999.

[20] L. Lipponen, *Exploring foundations for computer-supported collaborative learning*, Proceedings of the Computer-supported Collaborative Learning 2002 Conference, Mahwah: Erlbaum, 2002, p.^pp. 72-81.

[21] J. Piaget, *The judgement and reasoning in children*, Routledge and Kegan, London, 1928.

[22] L. S. Vygotsky, *Mind in society: The development of higher psychological processes*, MIT Press, Cambridge, 1978.

[23] J. Bruner, "Vygotsky: A historical and conceptual perspective," *Culture, communication and cognition: Vygotskian perspectives*, J. Wertsch (Editor), Cambridge University Press, Cambridge, 1985.

[24] N. Mercer, *The guided construction of knowledge: Talk among teachers and learners*, Multilingual Matters, Clevedon, 2003.

[25] J. Greer, G. McCalla, J. Cooke, J. Collins, V. Kumar, A. Bishop and J. Vassileva, *The intelligent helpdesk: Supporting peer-help in a university course*, Fourth International Conference on Intelligent Tutoring Systems, 1998, p.^pp. 494-503.

[26] A. Soller, *Supporting social interaction in an intelligent collaborative learning system.*, International Journal of Artificial Intelligence in Education **12** (2001), no. 1, 40-62.

[27] C.-Y. Chou, T.-W. Chan and C.-J. Lin, *An approach of implementing general learning companions for problem solving*, IEEE Transactions on Knowledge and Data Engineering **14** (2002), no. 6, 1376-1386.

Online Discussion Processes: How Do Earlier Messages Affect Evaluations, Knowledge Contents, Social Cues and Responsiveness of Current Message?

Gaowei Chen
*Department of Educational Psychology,
The Chinese University of Hong Kong, Shatin, N.T., Hong Kong*

Introduction

This study examined how earlier messages affected the property of current message, i.e., evaluations, knowledge contents, social cues and responsiveness. If earlier messages help to explain these features in current one, we can further know the interrelationship of online messages, and thereby taking measures to improve online discussion processes.

As past studies on online discussion and face-to-face discussion suggested (Henri, 1992; Chiu, 2000; Chiu, 2003; Norris & Ennis, 1989; Davidson-Shivers et al., 2001), the property of online discussion message can be classified into five dimensions, namely, person status, evaluations, knowledge contents, social cues and responsiveness.

Person status measures the characteristics of message poster. In face-to-face discussion, the status indicators can be ability (Chiu & Khoo, 2003), gender (Lockheed et al., 1983) and race (Cohen, 1982), etc. In online discussion, posters may not know gender, age and background of each other. Instead, nickname, IP address, personal statement and visit number on the Website can work as indicators of person status.

Evaluations characterize how the current speaker assesses the previous action and the current problem-solving trajectory (Goodwin & Goodwin, 1987; Pomerantz, 1984). Chiu (2000) classified the evaluations dimension into three categories: supportive, critical, and unresponsive. Supportive actions tend to reinforce the direction of the current problem-solving approach (Sacks, 1987). Criticisms tend to alter the problem-solving trajectory by identifying flaws and developing alternatives (Chiu, 2000). Unlike criticisms, unresponsive actions do not acknowledge the previous speaker, which in some contexts suggest that his or her proposal was unworthy of comment (Chiu, 2000).

Knowledge contents characterize the knowledge displayed in the messages. Chiu & Khoo (2003) classified knowledge contents dimension into null content, repetition, contribution and justification. Their research showed that justification in previous speaker turn may threaten the agreement in current turn.

Social Cues of a message is a part of statement not related to formal content of subject matter (Henri, 1992). Social cues might include a self-introduction, expression of feeling (e.g., “I’m feeling great…”), greeting (e.g., “Hi, everyone”), closure (e.g., “That’s it for now”), jokes, the use of symbolic icons (e.g., “^_^”), and compliments to others (Hara et al., 2000). The frequency of the social cues might be an indicator of the level of learner focus on the task (Henri, 1992).

Responsiveness measures whether the current message is cited and thereby responded to by any later messages. A message with response contributes to the continuation of discussion. Responsiveness is also an important indicator to test whether the message is read or not. In online discussion, usually many messages cannot receive later responses (Hara et al., 2000; Thomas, 2002; Chen, in press).

Method

7 hot topics were selected from the math board, an academic discussion forum of the Bulletin Board System (BBS) Website of Peking University (URL: bbs.pku.edu.cn). The independent forum is free for entrance or leaving, with little requirement or limitation for participants' activities. There were totally 131 messages, 47 participants responding to the 7 topics. Messages responded to the 7 topics ranged from 11 to 33. The discussion durations of the 7 topics ranged from 14 hours to 106 hours.

Variables

Person status. The indicators of person status can be personal statement and visit number.

Evaluations. Evaluation can be agreement (e.g., "I agree with you." or "Good answer. Can you speak it in detail?") or disagreement ("I don't think so." or "Something you said can be right, but, …").

Knowledge contents. Knowledge content can be null content (e.g., "I got it."), on-topic ("I don't understand your question, can you say more about it?"), contribution ("In my opinion,…") and justification ("I think…, the reason is…").

Social cues. Social cues measure the personal feeling (PF) shown in the message. Social cue can be PF if the message include special words ("four times seven equal to twenty four?! are you kidding?") or symbolic icons ("☺").

Responsiveness. Responsiveness measures whether the current message is cited and thereby responded to by any future message.

Analyses

Variables in lag 1, lag2 and lag 3 messages were used to predict the variables in current message. (In this paper, I use the convention that message (-1) refers to lag 1 message, message (-2) refers to lag 2 message; and so on.). The sequential set binary Logit regressions were performed with the statistical software, SPSS version 10.0 (SPSS, 1999). Structural equation model (SEM) tested direct and indirect effects on responsiveness on the LISREL (Joreskog & Sorbom, 2001) program. An alpha level of .05 was used for all statistical tests.

Results and discussion

As lag variables required data from preceding turns, some messages could not be used, leaving 109 messages available for lag 1 turn variables and 84 for lag 2 turns ones. At the message level, I discussed below how these predictors affect current message.

Disagreement (-1) and contribution (-1) affecting disagreement

Disagreement positively predicted disagreement. That is, disagreement in previous message elicited disagreement in current message, which helps to make the online discussion be controversial. In this way, it might differ from face-to-face collaborations in which a spiral of disagreements can threaten group collaboration in the discussion (Chiu & Khoo, 2003). Contribution also had a significant positively effect on current disagreement, showing that proposing a new idea is more likely to receive a critical rather than supportive response. This supports the claim that the online discussion forum can promote critical thinking (Greening, 1998; Thomas, 2002).

Visit number (-1) and personal feeling (-2) affecting contribution

Visit number of the previous poster on the website significantly affected the contribution in the response. Contribution tended to occur when the current message is responding to the message which poster has visited a lot on the website. Personal feeling (-2) had a significant negative effect on contribution of current message. That is, personal feeling in lag 2 message is likely to reduce the contribution in current message. This support Walther's (1996) argument that, the more socioemotional communication exists, the less effective online discussion is.

Disagreement (-1) and contribution (-1) affecting personal feeling

Both previous disagreement and contribution positively predicted personal feeling in current message. This result suggests that, when a poster is confronting a disagreement or a new idea, he or she is more likely to add personal feeling to the response. Disagreement or contribution led to personal feeling in the response. But unfortunately, the evoked personal feeling threatened the proposing of contribution in future responses, as discussed in the previous section. This dilemma implies that online discussion should better meet the desire of posters showing personal feeling, and meanwhile, not to make the social cues in message weaken contribution in future responses.

Disagreement and on-topic (-1) affecting responsiveness (+1)

Responsiveness characterizes whether the current message can get future response or not. I use the contention responsiveness (+1) to represent it in the analyses. No one responded to 45% of the messages of the 7 topics, a little more than half, 55% messages got responses. The final SEM model is shown in figure 1. The SEM showed a good fit (IFI = 0.97, CFI = 0.97, NNFI = 0.95, RMSEA = 0.07, SRMR = 0.04).

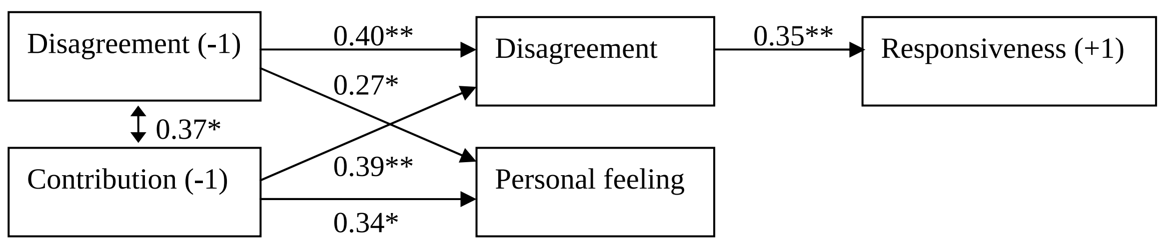

Figure 1. Structural equation model for predictors of responsiveness with significant standardized parameter estimates ($\chi 2$ [df =5, N = 109] = 8.19, p = .146)

Disagreement in current message positively affected its responsiveness. Also, previous disagreement and contribution had indirect effects on responsiveness. These suggest that disagreement messages are more competitive to attract later posters and get their responses. Furthermore, it shows that messages with critical thinking are more popular in the discussion, which is consistent with the claim that online discussion forum can promote critic thinking (Greening, 1998; Thomas, 2002). Previous on-topic message had a positive effect on responsiveness of current message. It shows that previous on-topic message can help the current message to get later response.

Implications

Attach more earlier messages to current message. The branch structure of online discussion made it difficult for current poster to track earlier messages. As shown in the results and discussion, only lag 1 and lag 2 messages, which were displayed together, can affect current message. To help posters understand the discussion thread more easily, designers can attach more earlier messages to current post, e.g., adding lag 3 and lag 4 messages. Such design may also make the discussion more coherent (Thomas, 2002) for the current message is based on more early messages. In fact, some BBS websites have adopted this kind of discussion style, e.g., the “unknown space” BBS (URL: www.mitbbs.com).

Carry on controversial discussion in online forum. As shown in this study, participants were likely to perform and continue controversial interactions in online discussion. It implies that instructors can move some controversial topics, e.g., new theories or problems without certain answers, to online forum for discussion. Under such topics, participants can come into different sides to controvert and argue by posting personal ideas.

Reference

Aitchison, J., & Silvey, S. D. (1957). The generalization of probit analysis to the case of multiple responses. *Biometrika, 44,* 131-140.

Bales, R. F. (1951). *Interaction Process Analysis*. Cambridge, MA: Addison-Wesley.

Chen, G. W. (2004). Online discussion in an independent academic BBS forum: Comparative case studies. *Educational Research Journal, 19(2), 281–305*.

Chiu, M. M. (2000). Group problem solving processes: Social interactions and individual actions. *Journal for the Theory of Social Behavior, 30*(1), 27–50.

Chiu, M. M. (in press). Adapting teacher interventions to student needs during cooperative learning: How to improve student problem solving and time-on-task. *American Educational Research Journal*.

Chiu, M. M., & Khoo, L. (2003). Rudeness and status effects during group problem solving: Do they bias evaluations and reduce the likelihood of correct solutions? *Journal of Educational Psychology, 95*, 506–523.

Cohen, E. G. (1982) Expectation states and interracial interaction in school settings. *Annual Review of Sociology, 8*, 109-235.

Cox, D. R. & Snell, E. J. (1989). *The Analysis of Binary Data*. London: Chapman and Hill.

Damon, W., & Killen, M. (1982). Peer interaction and the process of change in children's moral reasoning. *Merrill Palmer Quarterly, 28*, 347-367.

Davidson-Shivers, G. V., Muilenburg, L. Y., & Tanner, E. J. (2001). How do students participate in synchronous and asynchronous online discussion? *Educational Computing Research*, *25*(4), 351–366.

Dehler, C., & Parras-Hernandez, L. H. (1998). Using computer-mediated communication (CMC) to promote experiential learning in graduate studies. *Educational Technology*, *38*(3), 52–55.

Finney, D. J. (1971). *Probit Analysis*. 3rd edition. New York: Cambridge.

Gersick, C. J. G. (1988). Time and transition in work teams: Toward a new model of group development. *Academy of Management Journal, 31*, 9-41.

Goodwin, C., & Goodwin, M. H. (1987). Concurrent operations on talk: Notes on the interactive organization of assessments. *IPRA Papers in Pragmatics*, *1*(1), 1–54.

Greening, T. (1998). Building the constructivist toolbox: An exploration of cognitive technologies. *Educational Technology*, *37*(2), 23–35.

Hara, N., Bonk, C. J., & Angeli, C. (2000). Content analysis of online discussion in an applied educational psychology course. *Instructional Science*, *28*, 115–152.

Henri, F. (1992). Computer conferencing and content analysis. In A. R. Kaye (Ed.), *Collaborative learning through computer conferencing: The Najaden papers* (pp. 115–136). New York: Springer.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6 (1)*, 1-55.

Joreskog, K. & Sorbom, D. (2001). *LISREL*. New York: Scientific Software International.

Kaiser, S. & Wehrle, T. (2001). The Role of Facial Expression in Intra-individual and Inter-individual Emotion Regulation. In D. Cañamero (Ed.), *Emotional and Intelligent II: The Tangled Knot of Cognition* (pp. 61-66). Menlo Park, CA: AAAI Press.

Lockheed, M. E., Harris, A. M. & Nemceff, W. P. (1983). Sex and social influence: Does sex function as a status characteristic in mixed-sex groups of children? *Journal of Educational Psychology, 75*, 877-886.

Mazzolini, M., & Maddison, S. (2003). Sage, guide or ghost? The effect of instructor intervention on student participation in online discussion forums. *Computers & Education, 40*, 237–253.

Miller, S., & Brownell, C. (1975). Peers, persuasion and Piaget: Dyadic interaction between conservers and non-conservers. *Child Development, 46*, 992-997.

Nagelkerke, N. J. D. (1991). A note on a general definition of the coefficient of determination. *Biometrika, 78 (3)*, 691-692.

Norris, S. P., & Ennis, R. H. (1989). *Evaluating critical thinking*. Pacific Grove, CA: Critical Thinking Press & Software.

Patwardhan, P. (2004). Exposure, Involvement and Satisfaction with Online Activities: A Cross-National Comparison of American and Indian Internet Users. *Gazette: International Journal for Communication Studies, 66 (5)*, 411-436.

Pomerantz, A. (1984). Agreeing and disagreeing with assessments: Some features of preferred/dispreferred turn shapes. In J. M. Atkinson & J. Heritage (Eds.), *Structures of social action: Studies in conversation analysis* (pp. 57–101). Cambridge:

Cambridge.

Romiszowski, A., & Mason, R. (1996). Computer-mediated communication. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 438–456). New York: Macmillan.

Ruberg, L. F., Moore, D. M., & Taylor, C. D. (1996). Student participation, interaction, and regulation in a computer-mediated communication environment: A qualitative study. *Journal of Educational Computer Research, 14*(3), 243–268.

Sacks, H. (1987). On the preferences for agreement and contiguity in sequences in conversation. In G. Button & J. R. E. Lee (Eds.), *Talk and social organization* (pp. 54–69). Philadelphia: Multilingual Matters.

Shank, G. & Cunningham, D. (1996) Mediated Phosphor Dots. Toward a Post-Cartesian Model of Computer-Mediated Communication Via the Semiotic Superhighway. In C. Ess (Ed.), *Philosophical Perspectives on Computer-Mediated Communication* (pp. 27-41). State University of New York Press, Albany, NY.

SPSS Inc. (1999). *SPSS Base 10.0 for Windows User's Guide*. SPSS Inc., Chicago IL.

Thomas, M. J. W. (2002). Learning within incoherent structures: the space of online discussion forums. *Journal of Computer Assisted Learning, 18*, 351–366.

Walther, J. (1996). Computer-mediated communication: Impersonal, interpersonal, and hyperpersonal interaction. *Communication Research, 23*(1), 3–43.

Warschauer, M. (1997). Computer-mediated collaborative learning: Theory and practice. *Modern Language Journal, 81*(4), 470–481.

Willis, J. (1991). Computer mediated communication systems and intellectual teamwork: Social psychological issues in design and implementation. *Educational Technology, 31*(4), 10–20.

PECA: Pedagogical Embodied Conversational Agents in Mixed Reality Learning Environments

Jayfus T. Doswell
George Mason University

Abstract. The Pedagogical Embodied Conversational Agent (PECA) is an "artificially intelligent", computer 3D graphic, animated character that teaches from computer simulated environments and naturally interacts with human end-users. What distinguishes a PECA from the traditional virtual instructor or pedagogical agent is the PECA's ability to intelligently use its 3D graphical form and multimodal perceptual ability. While so doing, the PECA has capabilities to communicate with human end users and demonstrate a wide variety of concepts from within interactive mixed reality environments. More importantly, the PECA uses this intuitive form of communication to deliver personalized instruction for enhancing human learning performance by applying its underlying knowledge of empirically evaluated pedagogical techniques and learning theories. A PECA combines this "art and science" of instruction with knowledge of domain based facts, culture, and an individual's learning strengths in order to facilitate a more personal human learning experience and to improve its own instructional capabilities. The challenge, however, is engineering a realistically behaving 3D character for human interaction in computer simulated environments and with capabilities to provide tailored instruction based on well defined pedagogical rules and knowledge of human learning capabilities across cultures. This paper presents a novel approach to building PECAs for use in mix reality environments and addresses key challenges researchers face in integrating pedagogy and learning theory knowledge in PECA systems.

1. Introduction

The Pedagogical Embodied Conversational Agent (PECA) is a virtual instructor that provides a personalized human learning experience by applying empirically evaluated and tested instructional techniques. Combining state of the art technologies and techniques, the ultimate goal for PECAs is to improve and accelerate human learning performance anytime, anywhere, and at any pace. However, in order for the PECA, virtual instructor, or pedagogical agent to improve and accelerate human learning performance, it must combine instructional strengths of "master" instructors. The resulting PECA then possess expertise in specific academic/knowledge domains to effectively guide learners through complex concepts/task and become intimately involved understanding the learner's. These depict some of the computational challenges for all virtual instructor developers and that require interdisciplinary expertise in areas such as cognitive science, anthropology, sociology, computer software engineering, computational humanities, educational technology, artificial intelligence, 3D computer graphics, linguistics, and display technologies. A solid engineering approach for best designing PECA systems is the focus of this paper.

2. Background

2.1 Virtual Instructor

The building blocks of 3D computer animated PECAs have their basis in virtual human systems. Virtual humans have started to penetrate our daily operations, starting by inhabiting our auditory world [8]. For example, if people call British Airways, they can have a satisfactory conversation with their virtual reservation agent. Through a combination of state of the art vocabulary, over the phone speech recognition, and natural language processing, one can talk with a pleasantly mannered virtual human about anything within the domain of a British Airway reservation. On the web, virtual taking heads are starting to emerge with definitive personalities incorporating face animation, and avatars representing virtual reality participants. The international noted author and "futurist", Ray Kurzweil stated that by year 2010, virtual humans will have the ability to pass the Turning Test [8] where we will not mistake virtual humans for real ones, but will interact naturally with them as information assistants, virtual coaches, virtual sales clerks, entertainers, and even for love replacement therapy [8]. Perhaps, one of the most important applications of virtual human technology will be in the teaching domain where the virtual instructor may efficiently operate with no pay, provide quality instruction separately from school system politics, and maintain an unwavering goal to improve the knowledge of human learners.

2.2 Mixed Reality Environment

The simulated environments PECAs inhabit and from which they provide instruction also merits discussion. Typically, virtual instructors, pedagogical agents, and virtual humans have occupied virtual reality environments [1,5,6,7]. However, to support PECA's operation in existing digital environments and ones unforeseen, a PECA should be engineered as a 'decoupled' subsystem that may operate in any digital environment. Some of these existing digital environments may include, but are not limited to, augmented reality (AR), volumetric displays, hand-held displays, and holographic environments. The term *mixed reality environments* are used to organize a categorization for various types of virtual reality (VR) type systems. Hence, researchers have defined a continuum of real-to-virtual environments, in which VR and AR are parts of the general area now considered, "mixed reality". Figure 1 illustrates this mixed reality continuum. In *Augmented Reality* digital objects are added to the real-environment. In *Augmented Virtuality,* real objects are added to virtual ones. In *virtual environments* (or VR), the surrounding environment is virtual.

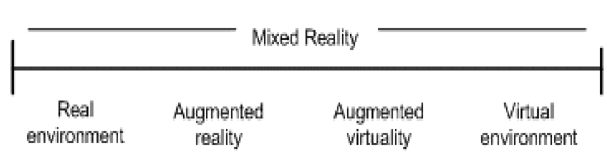

Figure 1: Milgram's reality-virtuality continuum.

The advantage of designing PECAs to operate in mixed reality environments is that they may be programmed to intelligently adapt and use the best simulated environment for igniting learner motivation, reinforcing concepts, guiding learners through new and complex task, clarifying ambiguity, and thus, providing a more enhanced and intuitive *e-learning* environment. For example, if a learner wanted to learn about a historical building, during an outdoor student tour, the PECA may be loaded in an augmented reality environment and supplement the tour guide by tailoring the experience to the learner's personal interest and correspondingly, their learning strengths.

2.3 Computational Pedagogy

Neither the PECA's advanced human computer interface capabilities or ability to interact within mixed reality environments is useful without it's knowledge of best instructional methods for improving human learning. This instructional method is formally called **pedagogy** and is defined as the *art and science of teaching* [2]. PECA pedagogy may include *scaffolding* techniques to guide learners when necessary; *multi-sensory* techniques so students use more than one sense while learning; multi-cultural awareness where awareness of the individual's social norms potentially influences learning outcomes [4], among other instructional techniques. The PECA should also tailor a particular instructional method to, at minimum, weighted learning strengths, including: *visual learning* seeing what you learn; *auditory learning* hearing spoken messages or sounds to facilitate learning; *kinesthetic learning* to sense the position and movement of what is being learned; and *tactile* learning where learning involves tough. These foci may be structured and decomposed, without losing their inherent value, into a 'codifed' set of pedagogical rules expressed, naturally, by the PECA. These rules may even evolve in ever-increasing detail to deal with individual facets of instruction, including research and practices relating to cognitive neuroscience, developmental psychology, deep learning, meta-cognition, sociology, cross-cultural studies, learning outcomes, educational governance and management, learning communities, and curriculum content.

3. PECA Product Line Architecture

To build PECAs that operate in mixed reality environments and effectively provide instruction to human learners requires an extensible, interoperable, modular, and scalable software architecture. Comprehensive research has been conducted to design such an architecture model, the PECA Product Line (PPL) architecture. The PPL is designed to generate families of PECAs that may provide instruction from mixed reality environments such as virtual reality, augmented reality, volumetric displays, holographic environments, and adapt to evolving virtual environment technologies. The PPL architecture was developed to address limitations in dynamic 3D animation, knowledge domain dependence, autonomous operation within mixed reality environments, realistic interaction with human end-users, and pedagogy intelligence. The PPL supports the "plug-in-play" integration of various system/software components [2] ranging from speech recognition and speech synthesis components to 3D animation algorithms and pedagogical techniques.

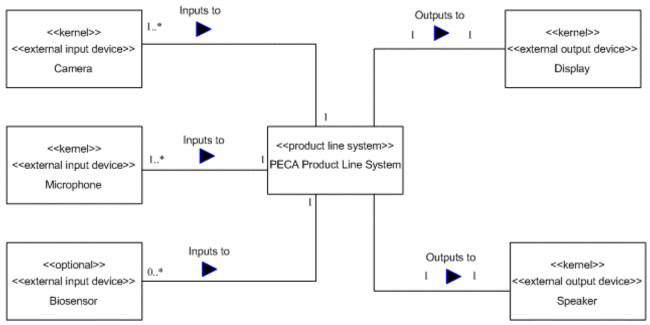

Figure 2: PECA Context Diagram

The PPL supports multimodal external inputs into a target PPL system as illustrated in Figure 2. Multimodal inputs supported in all (i.e., kernel) PECA systems include human body gestures (i.e., face and body); human environment objects (e.g., toys) captured by digital camera devices; and human verbal input and human environment noise captured by microphone devices. Optionally, a PECA system created from the product line may support the capture and interpretation of human physiological data captured from biosensors to help measure and evaluate the learning progress of the human learner.

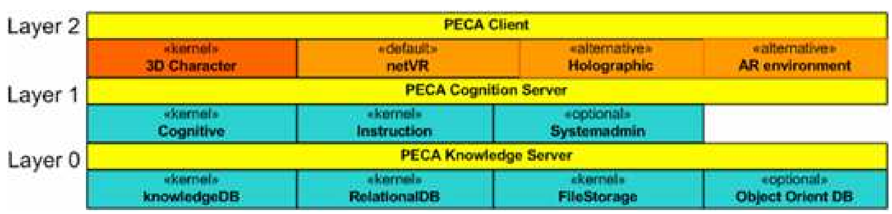

Figure 3: PECA Layered Architecture View

Figure 3 illustrates the multi-tier view of the PPL architecture. This view is based on the *Layers of Abstraction* pattern (also known as the Hierarchical Layers or Levels of Abstraction pattern) [2]. In this view, the PECA Knowledge Server, PECA Cognition Server, and PECA Client tiers are depicted as Layer 0, Layer 1, Layer 2, respectively. Each layer contains subsystems and their corresponding components. In the PECA Client layer (i.e, Layer 2), the 3D Character (i.e., PECA) is the kernel graphical component with which the end user (i.e., learner) interacts. The netVR, Holographic, and AR environment are alternative mixed reality environments in which a PECA may be integrated. Because these environments are denoted as alternate, one and only one mixed reality environment must be selected in which PECA will inhabit. The *default* environment is netVR. In the PECA Cognition Server layer (i.e., Layer 1), several subsystems exist including, *Cognitive, Instruction, and Systemadmin*. All are kernel subsystem except for the Systemadmin subsystem. The PECA Cognition Server is the most dynamic aspect of the three layers with regards to system configuration and component/subsystem updates. Consequently, the Cognitive and Instruction Subsystems are subjected to expansion faster than the other layers The PECA Knowledge Server has several data repositories with which the PECA Cognition Server interfaces. Data repositories including knowledge databases/expert systems, relational database systems, and file storage systems are kernel data repositories supported by the PECA Product Line Optional data repositories may be object oriented databases among other data repositories or data management systems.

4. PECA System in Virtual Reality

The PECA Product Line was used to develop and prototype 3D animated PECAs and all of their corresponding software components for use as tutoring system in mathematics, particularly basic numeric concepts. Two of the 3D characters were designed as "cute" and non-authoritative figure in order to sustain a comfortable learning medium for children. The other character was designed as Benjamin Bannekar, a renowned African American inventor, to teach science and math instruction. The resulting PECAs demonstrate the ability to assess a learner's strength and learning style in a particular academic domain and instruct using a pedagogical technique, scaffolding. The prototype demonstrates PECA's ability to naturally communicate with human end-users utilizing speech recognition,

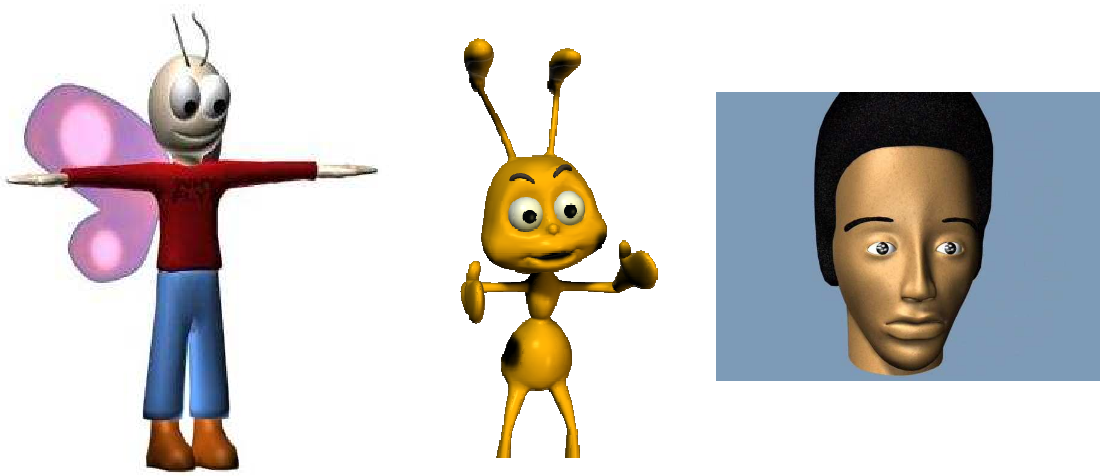

Figure 4: PECA Prototypes

speech synthesis, and natural language recognition components. Additionally, the prototype demonstrates the ability for the PECA to recognize human gestures. The PECA prototype was deigned with the knowledge to provide basic numeric concepts and basic Newtonian physics instruction to children ages 8-10. To prepare the PECA model for operation within a netVE, a 3D animated character was developed in 3D Studio Max with a controllable skeleton and bone structure. Subsystems within the PECA Product Line read the 3D file to analyze and store the PECA's body and face structure in order to prepare it for dynamic animation within a virtual reality environment.   For human input interpretation, the PECA Product Line, and thus, the resulting prototype used a combination of Java, C++, share-ware, and Commercial-Off-The Shelf (COTS) software. Rules for storing conversational and instructional knowledge was done using the Artificial Intelligence Markup Language (AIML), and XML type of rule based repository of knowledge. Microsoft SQL Server was used to store dynamic learning tracking data and a learning profile for each learner. In order for the PECA to see learners and other objects in their environment, Intel's OpenCV image algorithms were integrated for specifically recognizing human face gestures, body gestures (e.g., hand gestures), and the presence or the learner. For recognizing and responding to human speech, the Java Speech Application Programming Interface (JSAPI) was used to develop speech synthesis and speech recognition components on the PECA Cognition tier. Custom software components were developed in Java to enable the PECA to apply pedagogy techniques during its instruction. Pedagogical rules were stored in both in AIML and the relational database. To provide a more pervasive interface when verbally communicating, a wireless Bluetooth enabled headset was configured to enable the learner to roam about while communicating with the PECA and listening to its instructional responses.

5. Conclusion and Future Direction

The PPL architecture and resulting prototype demonstrate the complexity of building PECAs that provide instruction from virtual environments, and thus mixed reality environments. The implication of autonomous interactive 3D-character instructors that provide instruction based on proven pedagogical models and knowledge of individual learning needs is paramount to increasing human learning performance. This type of interactive learning medium demonstrates a fun and effective learning environment especially for K-12 learning needs. Continued research is planned to extend the PPL architecture with capabilities to provide instruction from augmented reality, holographic environments, and volumetric displays.

References

[1] CASSELL, J. ET. AL. 2000. Human Conversation as a System Framework: Designing Embodied Conversational Agents. *Embodied Conversational Agents*, MIT Press, 29-61.

[2] DIXON, H. ET. AL 2001. *Theory in Practice for Educators*. Palmerston North: Dunmore Press.

[3] GOMAA, H. 2005. *Designing Software Product Lines with UML: From Use Case to Pattern Based Software Architectures*. Addison-Wesley.

[4] LEE, K. T. 2002. Designing Enhanced Learning Environments on the Web – The Challenge. *IEEE Proc. of the International Conference on Computers in Education*. Hong Kong Institution of Education.

[5] LESTER, J. ET. AL. 2000. Deictic and Emotive Communication and Animated Pedagogical Agents. *Embodied Conversational Agents*, MIT Press, 123-154.

[6] NORMA, T. 2000. Design of a Virtual Human Presenter. *IEEE Computer Graphics and Applications*, 79-83.

[7] RICKEL ET. AL. 2000. Task-Oriented Collaboration With Embodied Agents in Virtual Worlds. *Embodied Conversational Agents*, MIT Press, 96-122..

[8] PLANTEC, P. 2005. *Virtual Humans: A Build-It-Yourself Kit*.

Social Learning from Social Model Agents: Examining the Inherent Processes

Suzanne J. EBBERS
Centre for Research in Interactive Technologies for Learning (RITL)
Learning Systems Institute, Florida State University, Tallahassee, FL 32306

Abstract. The proposed learner-pedagogical agent study examines in a 2x2 design the impact of type of social model (Mastery self-efficacy or Coping self-efficacy) and type of social interaction (direct or vicarious) in an social learning experience on learner motivations, learning, performance evaluations, frustration, competence similarity perceptions, attitude, and feelings about experience. Expected results include positive outcomes with the Coping agent, negative outcomes with the Mastery agent, and a stronger reaction in both cases in a direct social interaction than in a vicarious (overheard) social interaction.

Introduction

In the last decade the use of computers as social information conveyors has drawn widespread attention from the research and business worlds. Research in this area became significantly more credible with the publication of Reeves and Nass' [1] seminal work. The business community banks on this concept of computerized conveyance of social information to sell their products, including video games, consumer service interactions, computer voices and decision trees.

More recently, the use of "pedagogical agents" (e.g., computerized anthropomorphic characters that facilitate learning) has come to the forefront of research in the educational community. Pedagogical agent researchers have studied a number of agent features, characteristics and behaviors and what they impact, including 1) Voice, Image and Animation [2-12]; 2) Gender [13, 14]; 3) Ethnicity [13, 14]; 4) Competence [4]; Realism [14-16]; and 5) "Persona" [17-21].

Much, however, has yet to be addressed. Already pedagogical agents are termed "social interfaces". Yet in order for them to be fully useful, it is important to delineate how similarly to humans they socially function and to determine if and how they differ functionally from human social presence and behavior. Concurrently, it is important to determine the extent to which humans interact with pedagogical agents as they would with other human beings.

Most recently, researchers have begun researching pedagogical agents as social models [18, 22-24]. When we look at the pedagogical agent literature, researchers have learned that multiple pedagogical agents can be utilized as social models to achieve outcomes and that agents can be persuasive social models used to change human attitudes. To expand on this literature, it would be useful to look at studies involving human-human social modeling and seek to replicate those studies in human-agent interaction.

One such group of studies was performed by Schunk and colleagues [25-27]. These studies looked at two social model instantiations in an social learning situation with child peers to examine such outcomes as self-efficacy, skill, and persistence. The social models included a Mastery model and a Coping model that were, essentially, two different representations of a self-efficacy response to a difficult learning situation. The Mastery model had high self-efficacy and rapid learning throughout the learning activities, while the Coping model had initially low self-efficacy and slow learning but developed high self-efficacy and rapid learning through the use of coping strategies. Key to these studies is that learners socially compared themselves with the social model for similarity. These studies have not been replicated in a learner-agent social learning situation.

While this research was done with elementary aged children, the mentorship [28-31] and social comparison [32-34] literatures suggest that the same findings would be true for adults. Likewise, in the Schunk and colleagues' studies [25-27], observers were essentially being influenced to increase their self-efficacy to cognize certain mathematical formulations. What *is* important is that the Mastery and Coping social models are clearly conveying defined types of self-efficacy expression. Mastery and Coping social model instantiations have not been researched with agents fulfilling these roles.

Social interaction is another element that can be found within social learning in the form of conveying information and/or feedback. It is another social activity whose social impact does not appear to have been examined with pedagogical agents to any great extent [35, 36]. Social interaction with a model is more intensely experienced than is a vicariously-experienced social interaction [35, 36]. As the result, the impact of each human social model (either Mastery or Coping) on learner outcomes is expected to be stronger in social learning situations in which direct social interaction occurs. No study has been performed to evaluate the impact of direct or vicariously-experienced social interaction using Mastery and Coping social model agents as interactees with learners.

Threat creates anxiety, and anxiety is a strong motivator to socially compare oneself to others [34, 37, 38], especially when one experiences cognitive dissonance [39] as their view of the world is threatened [40]. Schachter [37] states that we affiliate in order to reduce anxiety. Therefore, it is reasonable to expect that under threat one would more strongly seek to affiliate with someone similar to them [32, 33], someone who could corroborate his/her view of the world [40] and reduce cognitive dissonance [39]. In the proposed study learners would perceive themselves to be under threat when they are initially told that the instructional activity will be easy but is in fact quite difficult, and that their actual class grade for that day depended upon their performance. Threat is used here to force an affiliation reaction. Everyone wants to "belong" [41], and seeking to affiliate in such a situation would be a natural human behavior when one does not feel s/he belongs and is threatened. It is expected that if the only "individual" available for affiliation is a pedagogical agent, learners would socially compare themselves to that agent and seek to affiliate or disaffiliate depending on how similarly or dissimilarly learners view their agent.

If the Mastery model then demonstrates a non-threatened learning experience through a cheerful self-efficacy performance while the Coping agent demonstrates a threatened learning experience by initially demonstrating self-doubt and apprehension, and if learners have socially compared themselves to their respective social model agents, then it is reasonable to expect that the Mastery model agent would negate learners' experience of threat while the Coping model agent would corroborate learners' experience of threat. Therefore, with a dissimilarity social comparison to the Mastery model, learners would be expected to seek to disaffiliate with that model [34, 38] – and direct social interaction would only intensify that desire. Anxiety in the form of frustration would be heightened in learners with a Mastery model, and would lead them to have lower self-regulation [42] and greater cognitive dissonance [39]. There would be lower resulting outcomes.

Likewise, with a similarity social comparison regarding the Coping model, learners would be expected to seek an affiliation with that model [34, 38] – with social interaction intensifying that inclination. Learners with a Coping model will therefore find their anxiety, in the form of frustration, diminished as their view of the world is corroborated and as they experience a "true partner" influence (e.g., one that corroborates their experience in the fact of a majority disconfirmation) [43]. This should lead to better self-regulation and lower cognitive dissonance. There would therefore be more positive outcomes, with direct social interaction intensifying the results.

The activities of social comparison and subsequent affiliation or disaffiliation have been studied in great depth in human-human interactions [25, 32-34, 38, 42-48]. These processes have not been examined in a learner-agent interaction. This study proposes to examine these dynamics using pedagogical agents.

The primary motivation for this study is to examine the social processes extant within the process of social learning in a learner-agent context. As stated, no study has been performed to examine any of the following with pedagogical agents: 1) Social comparison processes; 2) Affiliation tendencies; 3) Direct social interaction impact as compared to vicariously experienced social interaction. Further, research on the use of pedagogical agents as social models is in its infancy**.** No learner-agent students have been performed using agents as Mastery and/or Coping social models.

1. Methods

The primary purpose of the proposed research is to examine the impact of type of social model agent (Mastery, Coping) and type of social interaction (Vicarious or Direct) on participant motivation (self-efficacy, satisfaction), learning, performance evaluations, frustration, competence similarity perceptions, attitude, and feelings about experience. The secondary purpose of the proposed research is to describe how two essential social sub-processes (e.g., social comparison and social interaction) manifest within agent-participant social learning situations in terms of affiliation activities**.**

1.1 Research Questions and Hypotheses

The study investigates the following questions:

1. What is the impact of type of social model agent (Mastery vs. Coping) on participant outcomes?
2. How do type of social model agent (Mastery, Coping) and type of social interaction (Vicarious Interaction, Direct Interaction) interact to impact participant outcomes?
3. What is the effect of type of social model agent (Mastery vs. Coping) on participant social comparison and affiliation activities?

The specific research hypotheses for this study include:

1. Participants working with the Coping agent will demonstrate significantly greater motivation and learning, significantly similar competence perceptions, and significantly more positive attitudes towards social model agent, performance self-evaluations, and feelings about experience. They will also demonstrate significantly lower frustration and more positive performance evaluations of their social model agent (RQ1 and RQ3).
2. There will be an interaction between type of social model agent and type of social interaction. This interaction will demonstrate that when participants work with the Coping social model agent, it is preferable to have a "Direct Interaction" social learning experience in terms of motivation, learning, performance evaluations, frustration, competence similarity perceptions, attitude, and feelings about experience. In contrast, when working with the Mastery social model agent, it is preferable for participants to have a "Vicarious Interaction" social learning experience in terms of participant motivation, learning, performance evaluations,

frustration, competence similarity perceptions, attitude, and feelings about experience. (RQ2)

1.2 Materials

1.2.1 Instructional Module

The computer-based instructional module teaches participants how to create an E-Learning-based instruction plan on the subject of Time Management. The scenario of the instructional module presents a plausible situation for most undergraduate students at this southeastern university. Participants are told that due to financial cutbacks at “Seminole University”, the university’s mandatory face-to-face “Freshman Year Experience” (FYE) mini “survival” courses must be transitioned into E-Learning classes. Participants are asked to create the E-Learning instructional plan for the “Time Management” portion of the FYE.

1.2.2 Social Model and Other Agents

In each of the module’s three instruction segments, a “teacher” agent provides relevant information on the segment topic. The social model agent behaves as if he is listening to the “teacher” and taking notes, except when he is self-expressing to either a “classmate” agent (vicarious interacation) or to the learner (direct interaction). The agent in the direct interaction waits for a typed response from the learner before turning back to the “teacher” agent. The “classmate”, considered a classroom visitor, just attends to the teacher but does not take notes. Twice during each of the module segments, the “teacher” pauses, allowing the social model agent to speak and the learner to respond where appropriate.

1.2.3 Participants

Participants will include approximately 100 pre-service teachers (20 per condition) enrolled in an introductory educational technology class at a southeastern university.

1.3 Procedure

The experiment will be conducted during a 1.5-hour session of a university-based undergraduate educational technology course for pre-service teachers. The participants will be randomly assigned to one of the five conditions.

2.0 Data Analysis

References

References

[1] B. Reeves and C. Nass, *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Stanford, California: CSLI Publications, 1996.

[2] S. D. Craig, B. Gholson, M. Ventura, A. C. Graesser, and T. R. Group, "Overhearing Dialogues and Monologues in Virtual Tutoring Sessions: Effects on Questioning and Vicarious Leanring," *International Journal of Artificial Intelligence in Education*, vol. 11, pp. 242-253, 2000.

[3] A. L. Baylor and J. Ryu, "The Effects of Pedagogical Agent Voice and Animation on Learning, Motivation and Perceived Persona," presented at ED-MEDIA, Honolulu, Hawaii, 2003.

[4] Y. Kim, "Things That Make Pedagogical Agent as Learning Companion Effective," presented at E-Learn, the Annual Conference of Association for the Advancement of Computing in Education, Phoenix, Arizona, 2003.
[5] Y. Kim, A. Baylor, and G. Reed, "The Impact of Image and Voice of Pedagogical Agents," presented at E-Learn, Phoenix, AZ, 2003.
[6] R. K. Atkinson, "Optimizing Learning From Examples Using Animated Pedagogical Agents," *Journal of Educational Psychology*, vol. 94, pp. 416-427, 2002.
[7] R. Moreno, R. E. Mayer, H. A. Spires, and J. C. Lester, "The Case for Social Agency in Computer-Based Teaching: Do Students Learn More Deeply When They Interact With Animated Pedagogical Agents?," *Cognition and Instruction*, vol. 19, pp. 177-213, 2001.
[8] E. Mercier, B. Barron, and K. O'Connor, "Who is a Computer-Type Person? Sixth Graders' Views of Themselves and Others," presented at AERA, 2004.
[9] J. Cassell, M. Steedman, N. Badler, C. Pelachaud, M. Stone, B. Couville, S. Prevost, and B. Achorn, "Modeling the Interaction Between Speech and Gesture, 1994.," presented at Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society, Atlanta, GA, 1994.
[10] J. Cassell and B. A. Stone, "Living Hand to Mouth: Psychological Theories about Speech and Gesture in Interactive Dialogue Systems," presented at AAAI 1999 Fall Symposium on Psychological Models of Communication in Collaborative Systems, North Falmouth, MA, 1999.
[11] A. L. Baylor and J. Ryu, "Does the Presence of Image and Animation Enhance Pedagogical Agent Persona?," *Journal of Educational Computing Research*, vol. 28, pp. 373-395, 2003.
[12] A. L. Baylor and J. Ryu, "Does the Presence of Agent Image and Animation Enhance Pedagogical Agent Persona?," *Journal of Educational Computing Research*, vol. 28, pp. 373-395, 2003.
[13] A. L. Baylor and Y. Kim, "The Role of Gender and Ethnicity in Pedagogical Agent Perception," presented at E-Learn, Phoenix, AZ, 2003.
[14] A. L. Baylor, E. Shen, and X. Huang, "Which Pedagogical Agent Do Learners Choose? The Effects of Gender and Ethnicity," 2003.
[15] T. Koda and P. Maes, "Agents with Faces: The Effect of Personification," London, England ed. Proceedings of HCI'96, 1996.
[16] C. Okonkwo and J. Vassileva, "Affective Pedagogical Agents and User Persuasion," presented at 9th International Conference on Human- Computer Interaction, New Orleans, Louisiana, 2001.
[17] J. C. Lester, S. A. Converse, S. E. Kahler, S. T. Barlow, B. A. Stone, and R. S. Bhoga, "The Persona Effect: Affective Impact of Animated Pedagogical Agents." Paper presented at CHI'97 Human Factors in Computing Systems, 1997.
[18] A. L. Baylor and S. J. Ebbers, "The Pedagogical Agent Split-Persona Effect: When Two Agents are Better than One," Honolulu, Hawaii ed. ED-MEDIA, 2003.
[19] A. L. Baylor and Y. Kim, "Validating Pedagogical Agent Roles: Expert, Motivator and Mentor," presented at ED-MEDIA, Honolulu, Hawaii, 2003.
[20] S. D. Craig, Z. Hu, B. Gholson, W. Marks, A. C. Graesser, and T. T. R. Group, "AutoTutor: A Human Tutoring Simulation With an Animated Pedagogical Agent Interface," presented at Integrated Command Environments, San Diego, 2000.
[21] N. K. Person, A. C. Graesser, R. J. Kreuz, V. Pomeroy, and T. R. Group, "Simulating Human Tutor Dialog Moves in AutoTutor," *International Journal of Artificial Intelligence in Education*, vol. 12, pp. 23-39, 2001.
[22] A. L. Baylor, "Expanding Preservice Teachers' Metacognitive Awareness of Instructional Planning Through Pedagogical Agents," *Educational Technology Research and Development*, vol. 50, pp. 5-22, 2002.
[23] B. Y. White, T. A. Shimoda, and J. R. Frederiksen, "Facilitating Students' Inquiry Learning and Metacognitive Development Through Modifiable Software Advisers.," in *Computers as Cognitive Tools: No More Walls, Vol. II.*, vol. 2, S. P. Lajoie, Ed., 2nd ed. Mahwah, NJ: Lawrence Erlbaum Associates, Inc., 2000, pp. 97-132.
[24] A. L. Baylor and S. J. Ebbers, "Evidence That Multiple Agents Facilitate Learning," presented at International Artificial Intelligence in Education (AI-ED), Sydney, Australia, 2003.
[25] D. H. Schunk and A. R. Hanson, "Peer-Models: Influence on Children's Self-Efficacy and Achievement," *Journal of Educational Psychology*, vol. 77, pp. 313-322, 1985.
[26] D. H. Schunk and A. R. Hanson, "Influence of Peer-Model Attributes on Children's Beliefs and Learning," *Journal of Educational Psychology*, vol. 81, pp. 431-434, 1989.
[27] D. H. Schunk, A. R. Hanson, and P. D. Cox, "Peer-Model Attributes and Children's Achievement Behaviors," *Journal of Educational Psychology*, vol. 79, pp. 54-61, 1987.
[28] G. T. Chao, "Mentoring Phases and Outcomes," *Journal of Vocational Behavior*, vol. 51, pp. 15-28, 1997.
[29] K. E. Kram and L. A. Isabella, "Mentoring Alternatives: The Role of Peer Relationships in Career Development," *Academy of Management Journal*, vol. 28, pp. 110-132, 1985.
[30] K. E. Kram, *Mentoring at Work*. Glenview, IL: Academy of Management Journal, 1985.
[31] A. M. Young and P. L. Perrewe, "The Exchange Relationship Between Mentors and Proteges: The Development of a Framework," *Human Resource Management Review*, vol. 10, pp. 177-209, 2000.
[32] T. Mussweiler, "Comparison Processes in Social Judgment: Mechanisms and Consequences," *Psychological Review*, vol. 110, pp. 472-489, 2003.
[33] J. V. Wood, "Theory and Research Concerning Social Comparisons of Personal Attributes," *Psychological Bulletin*, vol. 106, pp. 231-248, 1989.
[34] J. A. Kulik and H. I. M. Mahler, "Social Comparison, Affiliation, and Emotional Contagion Under Threat," in *Handbook of Social Comparison: Theory and Research*, J. S. L. Wheeler, Ed. New York, New York: Kluwer Academic, 2000, pp. 295-320.

[35] M. S. Poole, J. P. Folger, and D. E. Hewes, "Analyzing Interpersonal Interaction," in *Interpersonal Processes: New Directions in Communication Research*, vol. 14, *Sage Annual Reviews of Communication Research*, M. E. Roloff and G. R. Miller, Eds. Newbury Park: Sage Publications, 1987, pp. 220-256.

[36] R. E. Mayer, K. Sobko, and P. D. Mautone, "Social Cues in Multimedia Learning: Role of Speaker's Voice," *Journal of Educational Psychology*, vol. 95, pp. 419-425, 2003.

[37] S. Schachter, *The Psychology of Affiliation: Experimental Studies of the Sources of Gregariousness*. Stanford, California: Stanford University Press, 1959.

[38] S. E. Taylor and M. Lobel, "Social Comparison Activity Under Threat: Downward Evaluation and Upward Contacts," *Psychological Review*, vol. 96, pp. 569-575, 1989.

[39] L. Festinger, *A Theory of Cognitive Dissonance*. Stanford, CA: Stanford University Press, 1957.

[40] J. H. Turner, *A Theory of Social Interaction*. Stanford, California: Stanford University Press, 1988.

[41] R. F. Baumeister and M. R. Leary, "The Need to Belong: Desire for Interpersonal Attachments as a Fundamental Human Motivation," *Psychology Bulletin*, vol. 117, pp. 497-529, 1995.

[42] A. Bandura, *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, N.J.: Prentice-Hall, 1986.

[43] K. S. Bordens and I. A. Horowitz, "Chapter 7: Conformity, Compliance and Obedience," in *Social Psychology*, K. S. Bordens and I. A. Horowitz, Eds., 2 ed. Mahwah: Lawrence Erlbaum Associates, 2002, pp. 235-286.

[44] A. Bandura, "Social Cognitive Theory of Self-Regulation," *Organizational Behavior and Human Decision Processes*, vol. 50, pp. 248-287, 1991.

[45] A. Bandura and F. J. Jourden, "Self-Regulatory Mechanisms Governing the Impact of Social Comparison on Complex Decision Making," *Journal of Personality and Social Psychology*, vol. 60, pp. 941-951, 1991.

[46] M. A. H. Braaksma, G. Rijlaarsdam, and H. van den Bergh, "Observational Learning and the Effects of Model-Observer Similarity," *Journal of Educational Psychology*, vol. 94, pp. 405-415, 2002.

[47] B. P. Buunk and T. Mussweiler, "New Directions in Social Comparision Research," *European Journal of Social Psychology*, vol. 31, pp. 367-475, 2001.

[48] A. Tesser, M. Millar, and J. Moore, "Some Affective Consequences of Social Comparison and Reflection Processes: The Pain and Pleasure of Being Close," *Journal of Personality and Social Psychology*, vol. 54, pp. 49-61, 1988.

An Exploration of a Visual Representation for Interactive Narrative in an Adventure Authoring Tool

Seth GOOLNIK
The University of Edinburgh

Abstract: This paper presents a formal system for representing interactive narrative and then explores the extent to which it can be comprehended by children. Through development of computational medium for conveying this system the project shows that the children can understand and generate it. In achieving this the project suggests that future research into interactive narrative has real educational potential, particularly in addressing the important issue of children's writing skills.

Introduction

Language is always present in our lives: from the books we read, to the conversations we have, to the media we watch, to the thoughts in our heads. By writing an imaginative story we must harness language to create narrative, we must reason about the language we have encountered to form our own ideas, and through this process we thus achieve greater comprehension of the world around us. This educational benefit of story writing is well documented (Ellis and Friel, 1998; Smith and Elley; 1998; Engel, 1999) with it being a valued part of the UK National Curriculum, however evidence shows that the standard of British children's writing is a cause for concern (AAP, 2000; DfES, 2003). This poor standard may be attributable to the way writing is taught; research shows "important weakness" in writing instruction at a large number of Scottish schools (Scottish Executive, 1999) and studies highlight problems in the way teachers give feedback on writing (Dunsbee and Ford, 1980; Coupe, 1986).

The Ghostwriter project (Robertson and Good, 2003) attempted to address this issue through the development of a multimedia learning environment targeted to improve children's writing skills. Ghostwriter is a 3D interactive audio-visual adventure game. Pairs of children played roles in the game's fantasy narrative with their actions in the adventure then determining its ultimate outcome. Results showed that children found this experience to be highly motivating and stories written after use of the software displayed significantly better characterisation than those written in typical classroom conditions.

Crucially in relation to this study, the child users of Ghostwriter can be viewed as *consumers* of games technology. Though allowing non-deterministic narratives within its virtual environment, the environment itself was pre-defined by expert designers and thus the child users' creativity was fundamentally bounded. Kafai's studies of children as programmers demonstrates that there are benefits to enabling children to become *producers* of games. Following the principles of constructionism that argue that improved learning can be obtained by allowing children to create learning environments themselves, Kafai (1996) allowed children to produce their own simple games by using programming skills. Her studies showed that this process did indeed appear to lead to 'deeper learning' with her participants acquiring such transferable skills as planning and problem solving (Kafai, in Kafai and Resnick, 1996).

Given the success of Kafai's constructionist approach it is thus reasonable to suggest that the educational benefits of Ghostwriter could be strengthened by enabling children to create their own stories in virtual environments - this is what the Adventure Author project (Robertson and Good, 2004) aims to explore. By developing an authoring tool to allow children to create interactive narrative adventures stylistically similar to that of Ghostwriter, Adventure Author examines whether it would be possible to capitalise on the benefits of that previous project.

This undergraduate student project was a part of Adventure Author, aiming to directly explore the concepts at its heart. It attempted to formalize a system for visually representing interactive narrative that could constitute the core of the Adventure Author project as the next logical step in the development of AdventureAuthor, a 3D virtual environment authoring tool. It then investigated whether children of the 10-12 target age range for AdventureAuthor could understand and generate interactive narratives using this representation, in order to provide a solid foundation for the ultimate development of the authoring tool. Furthermore it explored whether a computational adventure authoring tool might provide support in using the system of interactive narrative by applying the results of an evaluation of a paper-based medium for conveying the representational system in developing a computer-based medium.

A Formal System for Interactive Narrative

Previous work on the Adventure Author project showed firstly that children of a suitable age enjoyed the type of adventures AdventureAuthor should be capable of creating (Good and Robertson, 2003) and secondly that children were capable of devising interactive adventures using a commercial authoring adventure tool (Robertson and Good, 2004). Given this, it was essential that this subsequent project tie down and examine the concepts of interactive narrative that underlie both results; in order to ultimately develop a tool that could feasibly assist the creation of interactive narrative it was next necessary to formalize a clear conception of interactive narrative and directly explore the extent to which it could be understood and generated by children.

To formalize a system of interactive narrative examples of it were clearly required, these were provided by adventure game books. An adventure game book is a piece of interactive fiction: a reader is presented with a series of choices following each of its narrative sections and the reader's choice then determines how the narrative proceeds.

In studying this form of interactive narrative, along with the findings of the previous work, a system was determined that was compatible with the formal structure of an Augmented Transition Network (ATN), a derivative of a State Transition Network (STN) (Gazdar and Mellish, 1989). Essentially, an interactive narrative is visualised as a network of connected 'scenes': there is a single start scene with multiple interim and end scenes and multiple transitions between these scenes; where each scene must have a description of the narrative and a series of choices each motivating a transition. Taking each scene as a state in an ATN the representational system for interactive narrative was thus formalized (see Figure 1 and Figure 2 for the full formal system).

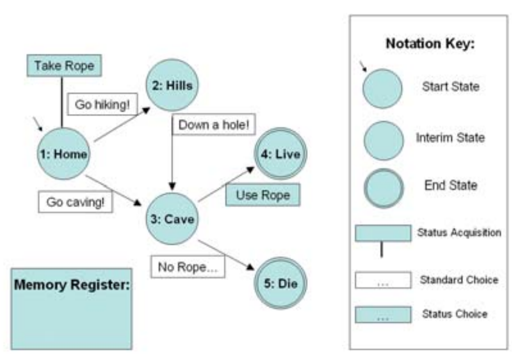

Figure 1 (Left): A formalised representation of a system state (or 'scene'), annotated with content areas
Figure 2 (Right): A representation of interactive narrative as an augmented transition network

Evaluation of a Paper-Based Medium

The extent to which children could understand and generate the formal system was first evaluated through a paper-based medium. A paper-based medium and not a computational one was used at this stage to allow it to inform the design of a computational medium in controlling risk and also determining areas in which support to users of the system might be provided.

The evaluation took place with six children of AdventureAuthor's target age range, with these children also selected as fair representatives for this age range. The children first participated as a group in an interactive narrative by being told it orally and at each scene voting for which choice they preferred. The interactive narrative was developed by the researchers using the formal system to allow that after participating in the interactive narrative the children were shown the formal representation of it via a large paper chart (see Figure 3) and were questioned concerning their understanding of it.

Figure 3: A section of the paper chart used to represent the interactive narrative

Finally they were tasked as a group to generate their own equivalent interactive narrative using the formal system. In order to instigate the generation the children were provided with the stimulus of 'Goldilocks and Three Bears', beyond this the researchers only assisted them in terms of facilitation, ensuring that each of the group members opinions could be heard but providing no advice on how a valid representation could be realised.

The evaluation found that the children were, as a group, able to understand and generate the system of interactive narrative using the paper-based medium, with the participants also appearing motivationally engaged throughout the process. The participants were able to correctly identify attributes of the formal system when presented with the paper chart representation of the sample story and questioned concerning it. Further the 'Goldilocks' narrative generated by the participants featured not only the full system of interactivity but was of a higher complexity than that of the sample they had experienced - suggesting clear understanding of the formal system in addition to generational ability. Despite their ultimate comprehension success, areas of difficulty were observed during generation in terms of managing the data of the narrative's multiple scenes, validating the ultimate representational system structure, and avoiding distraction from the core generation task.

Implementation of a Computer-Based Medium

In developing a computer based-medium that could be used to convey the formal system there were two criteria: that it retain the successful fundamentals encountered with the paper-based medium while ameliorating the difficulties, and that it provide a reasonable foundation for the ultimate AdventureAuthor tool. The initial prototype (AA2D), which was to be used to test the interactive story representation, was simplified to enable users to produce text based interactive stories with 2D illustrations - it was this prototype that was utilised in meeting the first criterion. Based on the success of AA2D, a further prototype (AA3D) has been developed which uses the same visual representation for interactive stories but which enables users to create 3D computer games rather than text based adventure games thus meeting the second criterion in providing a foundation for the further development of AdventureAuthor. AA3D is described briefly in Robertson (2004).

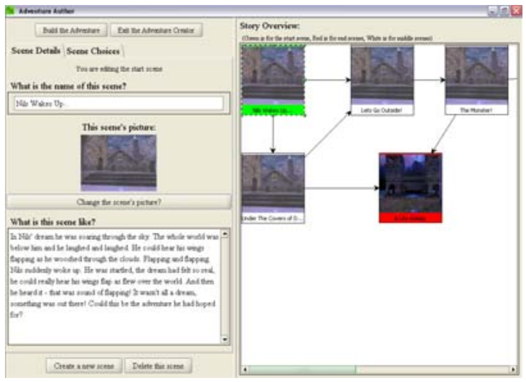

Figure 4: The Scene Editor mode of AA2D showing (right) the overview displaying the structure of the interactive narrative and (left) the editable details of an individual narrative scene

The interface of AA2D fully allows both the generation and subsequent participation in interactive narrative: interactive adventures compatible with the formal system can be visually generated using AA2D's Scene Editor (see Figure 4) and then played using AA2D's Game Engine (see Figure 5). The SceneEditor enables the user to view and edit the attributes of scenes in a story, including the scene title, a textual description, an illustration and choices leading to other scenes. The Scene Editor's Overview Panel is based on the representation used in the paper chart, as scenes are generated and interlinked using choices this is consistently represented in the overview panel as it dynamically updates with a graphical representation of the current system structure.

Figure 5: A standard screen in AA2D's Game Engine showing the details and choices of a scene to a player in the interactive narrative

During the generation process AA2D's Scene Editor interface also directly provides support in those areas identified in the paper-based evaluation: management of scenes and scene data is ensured as each scene is visually represented and uniquely identifiable; an automatic story checker is provided to ensure developed narratives' structures are formally valid, with intelligent feedback given to users concerning any structural problems uncovered; and the user stays focused on the core task of generating the formal system due to the interface preventing users from becoming distracted into illustrating their own scene images and the like as they are given no such opportunities. AA2D also provides logging and monitoring facilities to allow detailed analysis of individual behaviour.

Evaluation of a Computer-Based Medium

AA2D was evaluated using the same six children that previously participated in the paper-based evaluation both because of them being known to be representative for their age range and due to their familiarity with the paper-based medium that could then allow them to express preference. The children individually played through a sample interactive narrative generated with AA2D using AA2D's Game Engine and were then individually questioned on it using a worksheet. After this they examined the structure of the narrative they had just played using AA2D's Scene Editor with their understanding of the Scene Editor assessed through a further worksheet. Next, after receiving a tutorial on its usage, they were tasked to individually generate their own interactive adventure using AA2D with each of their interactive narratives then being analysed to gauge comprehension. Finally the children were interviewed, gaining their opinions on both AA2D and the paper-based medium.

In answering the first worksheet administered after playing the narrative each of the participants showed understanding of its nature: all correctly understood the interactive element that differentiated it from traditional fiction. This worksheet also suggested the participation had been engaging with all recalling in detail the paths they had taken through the narrative. This was further enforced as no participants expressed negativity to the question of whether they had enjoyed the narrative.

The second worksheet addressing the Scene Editor also demonstrated the participants' understanding. Five of the six participants correctly identified that the Scene Editor displayed a representation of the narrative they had just played. The five questions subsequent to this objectively examined other attributes of the representation. All participants responded successfully: three participants got the maximum score of 5, two got 4, and one got 3 – all being predominantly correct.

During the generation phase participants were able to request assistance with AA2D from the researchers. Every time a participant did this their query was noted; all participants asked for assistance at least once however the average total queries was six which factored as only one every 7.5 minutes. Significantly, all participants had generated interactive narratives at the end of the generation phase, with all narratives featuring multiple endings. The narratives generated varied in size from 5 scenes to 9 scenes, with an average size of 6 scenes 3 of these being endings – that there were three narrative outcomes on average shows clear ability to use the system for interactive narrative.

In interview all children explicitly commented that they had enjoyed using AA2D and would be happy to use it again. They also suggested a number of improvements to AA2D such as the ability to record audible dialogue and an automated tutorial. On whether they preferred AA2D to the paper-based medium they were not certain, with equal numbers preferring each medium and their justifications unclear.

Conclusions

The project provides a solid foundation from which the potentially valuable Adventure Author project can continue. By developing a clear formalisation of interactive narrative and then clearly showing that children of the target age group can both understand and generate it, the ultimate AdventureAuthor virtual environment authoring tool can now be seen to be viable. In providing the validated representational structure used in the further AA3D prototype this valuable support is directly evident. Furthermore, given that all experimental participants were admittedly engaged by their experiences and that the initially surveyed literature suggests the educational benefits of their production, this project has shown that such further exploration into interactive narrative through virtual environments has real educational potential.

Beyond suggesting that the Adventure Author project is worthy of continuation, this project also provides a number of immediate avenues for interesting further research: an exploration into whether, with its efforts to provide support, AA2D is a preferable learning environment to the paper-based medium in conveying the system of interactive narrative; a detailed examination of the structural complexities of interactive narratives as developed by different candidates; and perhaps most interesting, an examination of whether long term usage of the paper-based medium or AA2D does bring educational benefits to writing skills. Such studies should be conducted with larger samples of children to provide a significant corpus of data.

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References

AAP (2000). Assessment of Achievement Programme: The Fifth English Language Survey. Scottish Executive.

Coupe, N. (1986). Evaluating Teacher's Responses to Children's Writing. In Harris, J. and Wilkinson, J. eds., Reading Children's Writing A Linguistic View. Allen and Unwen, London.

DfES (2003). Pupil Performance Data: Autumn Package 2003. Department for Education and Skills.

Dunsbee, T. and Ford, T. (1980). Mark My Words: A study of teachers as correctors of children's writing. NATE, London.

Ellis, S. and Friel, G. (1998). 5-14 Teacher Support: Learning to Write, Writing to Learn: Imaginative Writing. Scottish Consultative Council on the Curriculum

Engel, S. (1999). The Stories Children Tell: Making Sense of The Narratives of Childhood. W.H. Freeman and Company.

Gazdar, G. and Mellish, C. (1989). Natural Language Processing in PROLOG: An Introduction to Computational Linguistics. Addison Wesley.

Good, J. and Robertson., J. (2003). Children's Contributions to New Technology: The Design of AdventureAuthor. Interaction Design and Children 2003 Conference Proceedings. New York, NY: ACM Press.

Kafai, Y.B. (1996). Gender Differences in Children's Constructions of Video Games. In P.M Greenfield and R.R Cocking, eds., Interacting with Video. Norwood, NJ: Ablex Publishing.

Kafai, Y.B., and Resnick, M. (1996). Constructionism in Practice: Designing, Thinking and Learning in a Digital World. Mahwah, NJ: Lawrence Erlbuam.

Robertson, J. (2004) An analysis of the narrative features of computer games authored by children. In the Proceedings of Narrative and Interactive Learning Environments 2004, pp33-41. Edinburgh, Scotland.

Robertson, J., and Good, J. (2003). Using a Collaborative Virtual Role-Play Environment to Foster Characterisation in Stories. Journal of Interactive Learning Research 14(1), 5-29.

Robertson, J. and Good, J. (2004). Children's narrative development through computer game authoring. Proceedings of the Interaction Design and Children Conference, Maryland, USA, 2004.

Scottish Executive (1999). Improving Writing 5-14. Scottish Executive.

Smith, J. and Elley, W. (1998). How Children Learn to Write. Paul Chapman, Publishing Limited, London.

Affective Behavior in Intelligent Tutoring Systems for Virtual Laboratories

Yasmín HERNÁNDEZ[1], Julieta NOGUEZ[2]
[1] *Gerencia de Sistemas Informáticos, Instituto de Investigaciones Eléctricas*
myhp@iie.org.mx
[2] *Tecnológico de Monterrey, Campus Ciudad de México*
jnoguez@itesm.mx
México

Abstract. One of the most important highlights of personal tutoring is that of recognizing the student's affective state and reacting accordingly by expressing the pedagogical movements in an affectively suitable way. In this paper, we propose a model for an affective tutor. The intelligent tutor integrates an affective student model based on the OCC cognitive model of emotion, with a cognitive student model, within a virtual laboratory for teaching robotics. The main contribution of this work is in the affective behavior model, which integrates the information from the student cognitive and affective state, and the tutorial situation, to decide the best pedagogical action. We use Bayesian networks and we propose the use of a decision network with a utility measure on learning. By using the decision network, the tutor will select the best pedagogical and affective response given the current state of the student. We present some initial examples of possible affective and pedagogical responses under different situations.

Introduction

We have developed a virtual laboratory for mobile robotics [1]. Since the main goal of the virtual lab is to serve as learning tool for students, we have incorporated an *Intelligent Tutoring System* (ITS) into its architecture. In most developments of ITS, the tutor-student interaction has been unnatural, i.e. students interact with system by means of buttons and menus. However, in the last few years, research on human-computer interaction has tried to mimic human interaction. Most recently, researchers in computer science have turned towards an aspect which was originally believed to be unrelated to computer systems performance: *emotions* [2]. Scientific studies have demonstrated the influence of emotions in human communication [3]; and, a hypothesis is that it can also happen in the human-machine interaction [2]. In an ITS, this hypothesis becomes stronger, since emotions have been identified as important players in motivation, and motivation is very important for learning [4]. When a tutor recognizes the affective state of the student and responds accordingly, it may be able to motivate students and improve the learning process. There are several authors who propose to use the affective state of the student to give him a more suitable response that fits with his affective and cognitive state [5, 6, 7, 8]. However, the affective state has not yet been used to decide the pedagogical response. This is because there are still many questions about emotions without response, such as which affective states are relevant for learning.

In this paper, we propose an *affective behavior model* for a tutor, which combines the affective and cognitive state of the student and the tutorial situation to establish the affective and pedagogical actions. The affective behavior model integrates an *affective* *student model* based on the OCC cognitive model of emotion, represented as a Bayesian network [9]. We are using Bayesian networks because they provide us with an effective way to manage the uncertainty involved in student modeling. The main contribution of this work is the affective behavior model; to implement it, we propose the use of a decision network. By means of the decision network, the tutor will select the best pedagogical response given the current state of the student. We present some initial examples of affective and pedagogical responses under different situations.

Section 1 describes the architecture of an affective intelligent tutoring system. Section 2 describes the affective student model. In section 3, we describe the affective behavior model. The summary of our proposal and future directions are presented in section 4.

1. Affective Intelligent Tutoring System

An intelligent tutoring system (ITS) is a computer-based educational system that provides individualized instruction similar to that of a human tutor [10]. An ITS is based on knowledge about the student (student model), on knowledge about teaching (tutor module) and on knowledge about specific domains (expert module). The basic architecture of ITS also has the interface module, which decides how should the material be presented to the student in the most effective way. An ITS decides how and what to teach, based on the student characteristics in a similar way as a human tutor. However, it has been demonstrated that an experienced human tutor manages the emotional state of the student in order to motivate him and to improve his learning process; therefore, the representation of the emotional state of the student is also needed in the ITS architecture with the purpose of provide students with more suitable instruction. A tutor who has information about the student's affective state might provide better feedback.

In order for the tutor to obtain the capacity to recognize the student's affective state and respond to it, the student model structure needs to be augmented to include knowledge about the affective state. Also, an affective module needs to be incorporated with the ability of reasoning about the affective state in order to provide an adequate response from a pedagogical and affective point of view. The affective module has various functions: 1) it generates and updates the *affective student model*, 2) it provides elements to determine the next pedagogical action to the pedagogical model, and 3) it provides the interface module elements for a physical realization of the response. In this sense, a model of affective behavior for the tutor is required. This model has to establish parameters that enable a mapping from the affective and cognitive student state to pedagogical responses. We propose an *affective behavior model* which is being integrated to an ITS coupled to a virtual laboratory for mobile robotics. In figure 1, we present the architecture of this affective ITS; for a more detailed description of this architecture see [1].

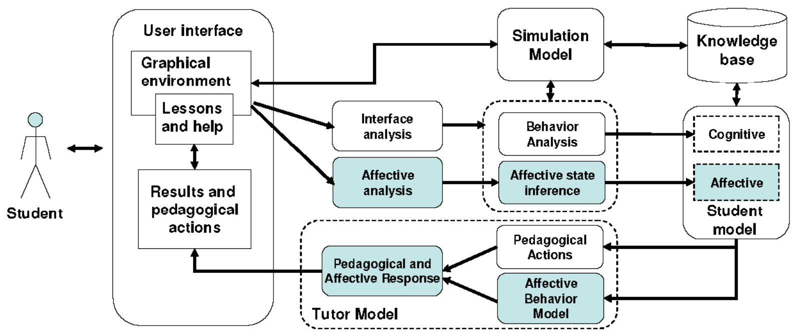

Figure 1. Architecture of the ITS with the affective components (shaded).

In order to integrate affective behavior into the ITS, we added several modules, shown shaded in figure 1. In the affective analysis module, we obtain the indicators used to infer the affective state and to update the affective student model. With this last structure, the affective behavior model will determine the affective action to be delivered by the tutor.

2. Affective Student Model

The student model must contain knowledge about the affective state of the student, in addition to knowledge about its cognitive state, with the aim of to give him an affectively adequate response at the pedagogically appropriate time. Several ways to evaluate the emotional state have been proposed: some are based on the detection of physical and biological signs [11]; others are based on the use of personality and emotion models [5]; and others are based in student interaction [6]. In this work, we use the OCC cognitive model of emotion [12] which establishes the affective state as a cognitive appraisal between goals and situation. The OCC model is one of the most known emotional models; several authors use it to establish the emotional state or to synthesize emotions [5, 13, 14]. In addition, we are using the five-factor model [15] for personality traits; the personality is very important because it determines the goals a person has, and also it determines if a person is inclined to have certain emotions instead of others emotions. Currently, the five-factor model is the most popular approach among psychologists for studying personality traits [16].

To determine the student affective state we use the following factors: 1) student personality traits, 2) student knowledge state, 3) mood, 4) goals and 5) tutorial situation. We represent the affective student model by a Causal Probabilistic Network (CPN) as shown in figure 2. The dependency relations have been established based on the literature and intuition. This way to determine the affective state is similar to the one proposed in [5].

The OCC model establishes emotional state as a cognitive appraisal between goals and situation. We represent this with the nodes *goals* and *tutorial situation*, propagating evidence to the node *affective state*. We think that mood influences the emotional state too; therefore we have the node *mood* also influencing the node *affective state*. Although emotional state and mood are sometimes used interchangeably, we distinguish them: mood represents the longer term emotional state, while affective state represents the instantaneous emotional state, and as is stated in [17]. Mood has an arousal level higher than emotion, i.e. mood changes slower than emotion; and, we think that both, emotion and mood, affect each other.

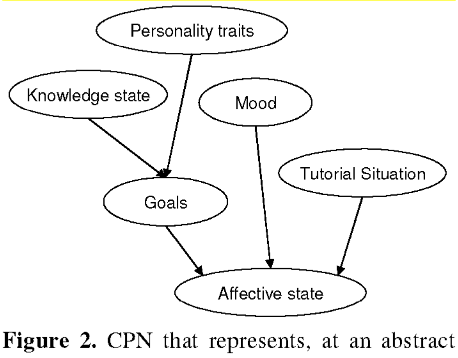

Figure 2. CPN that represents, at an abstract level, the affective student model.

Accordingly to the OCC model, the goals are fundamental to determine the affective state. In order to establish student goals, we have two options: to ask the student, or to infer them. We think that asking the student is not a good option because people, in general, tend to be kind and to give kinder responses, even if the counterpart is a computer [18]. Hence, we infer them by means of personality traits and student cognitive state. We based personality traits on the five-factor model [15], which considers five dimensions for personality: *openness*, *conscientiousness*, *extraversion*, *agreeableness*, and *neuroticism*. At this moment, we use only two of them (*conscientiousness*, and *neuroticism*) to establish goals, because in literature is reported a relation with this two dimensions with learning [19]; however, we think that all five dimensions influence the affective state. The goals for our domain are: 1) to learn the topics included in the experiment, 2) to perform the experiment successfully, and 3) to do the experiment as fast as possible. Based on the OCC model we consider four possible emotional states: *joy, distress, pride, shame*. These states are a subset of emotional states of the OCC model.

In our implementation, we obtain the student personality traits by means a personality test [20]. We applied this test to a group of 58 students with the aim to get a priori probabilities; for a detailed description of this previous study see [21]. The knowledge student state and the tutorial situation are obtained from the student interaction with the ITS; we have a relational probabilistic student model; for details this model see [22].

3. Affective Behavior Model

Once the affective student model has been obtained, the tutor has to respond accordingly; consequently, the tutor needs a model of affective behavior. The affective behavior model (ABM) establishes parameters that enable a mapping from the affective and cognitive student models to the responses of the tutor. Figure 3 shows a block diagram for the ABM.

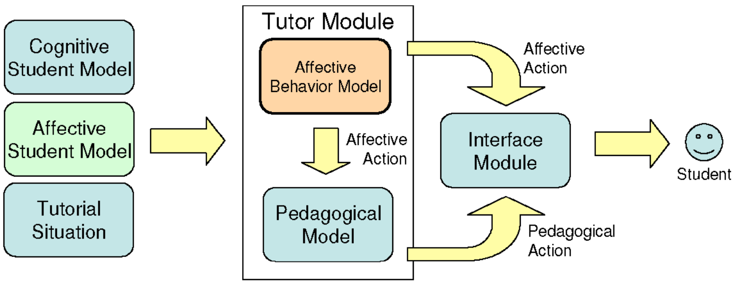

Figure 3. Block diagram of the affective behavior model.

The ABM receives information from three components: the affective student model, the cognitive student model and the tutorial situation. The ABM translates these components into affective actions for the tutor and interface modules. The affective action contains knowledge about the overall situation that will help the tutor module to determine the next response to the student, and also will advise the interface module to express the response in a suitable way.

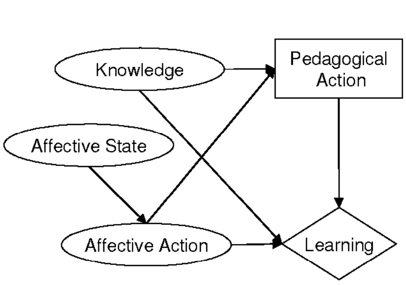

Figure 4. A high level decision network for the affective behavior model.

Based on the affective action, the tutor module can decide if it is necessary to provide another exercise or to change the topic in turn. For example, if the student's response is incorrect and his affective state is happy, the tutor can encourage the student with another exercise more suitable to the situation in order to maintain high motivation. In figure 4, we present an abstract representation of the ABM by means of a decision network. The affective action considers utilities in learning of the student. We are currently developing a more detailed representation for the ABM.

3.1 Affective Action

The affective actions are the product of the ABM. The affective action is composed of the pedagogical sub-action (knowledge to the tutor module) and interface sub-action (knowledge to the interface module). These sub-actions will be used in a way that will be determined by the specific ITS, and particularly by its tutor and interface modules; that is, the domain of the ITS and the technology used in the user interface. For the time being, we have identified three classes of affective actions: *neutral*, *moderate* and *strong*. Fundamentally, a neutral and a moderate action applies when the level of motivation is good (the motivation increases or remains at same level), and it determines that the tutor's next pedagogical action can employ the same pedagogical strategy used at that moment; i.e., the instruction is working. A strong action applies when the student's motivation decreases and it is necessary to execute some action to attract his attention; for example, to change the rhythm of instruction to faster or slower depending on the cognitive student model. At this time, the pedagogical sub-action is determined with base in the tutoring experience of the authors, and they represent the basic movements of a novice human tutor. The pedagogical sub-action tells the tutor module if it must continue on the same topic or move forward or backward, but the pedagogical movement (explanation, exercise, example, etc.) must be established by the tutor module. The interface sub-action specifies one of the following three levels of affectivity: 1) when the motivation increases or remains on the same level because the student is doing well; 2) when the motivation slightly decreases due to an error; and 3) when the motivation dramatically decreases because the student has had various errors. This will tell the interface module how the physical realization should be. The technology used in the user interface will determine what specific actions are delivered to the student and in which way.

In order to show some actions of the ABM, we present in table 1 some examples of its application to different situations. The table shows the affective action and sub-action, as well as the pedagogical response, for different cognitive states and tutorial situation. The ABM is being implemented in Elvira System [23].

Table 1. Examples of affective actions under different conditions.

Cognitive State	Tutorial Situation	Affective State	Affective Action	Affective Sub-action	Example of Pedagogical Response
Student knows the topic in turn	Positive	Joy	Neutral	Same topic	Present another exercise with higher difficulty level
	Neutral	Joy	Neutral	Same topic	Present another exercise with same difficulty level
	Negative	Distress	Strong	Same topic	Present another exercise with lower difficulty level
Student does not know the topic in turn	Positive	Joy	Neutral	Same topic	Present another exercise with higher difficulty level
	Neutral	Joy	Moderate	Same topic	Present another exercise with same difficulty level
	Negative	Distress	Strong	Same topic	Explain the topic again, in another way

4. Conclusions and Future Work

In this paper, we proposed an affective behavior model for an intelligent tutoring system coupled to a virtual laboratory. Our main contribution is establishing a pedagogical response given an affective state. We have presented an affective student model based on the OCC model, and an initial affective behavior model that combines the cognitive and affective states to establish pedagogical and affective responses.

Currently, we are constructing the affective student model, using questionnaires to obtain the prior probabilities; and integrating it to the cognitive student model used in the virtual laboratory [1]. We are also preparing some tests, such as Wizard of Oz experiments, that may provide insight for the formalization of the affective model. To validate the model we plan a summative evaluation. In the first phase of the evaluation, we will have a group of 20 students interacting with the ITS without affective behavior, and in a future phase, we will have another group of 20 students working with the ITS with affective behavior.

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References

[1] J. Noguez and E. Sucar, *Relational probabilistic model for virtual laboratories*, In IBERAMIA 2004, Workshop on Virtual Laboratories, pp. 381-389, 2004.
[2] R.W. Picard, *Affective Computing*, MIT Press, 1997.
[3] A.R. Damasio, *El error de Descartes*, Andrés Bello, Santiago, Chile, 1996.
[4] W.L. Johnson, J.W. Rickel, and J.C. Lester, *Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environment.* International Journal of Artificial Intelligence in Education, 11, 2000, pp. 47-78.
[5] C. Conati and X. Zhou, *Modeling students' emotions from Cognitive Appraisal in Educational Games*, 6th International Conference on Intelligent Tutoring Systems, Biarritz, France, pp. 944-954, 2002.
[6] A. de Vicente and H. Pain, *Informing the Detection of the Students' Motivational State: An Empirical Study*, In 6th International Conference on Intelligent Tutoring Systems, Biarritz,France, pp. 86-95, 2002.
[7] W.L. Johnson and P. Rizzo, *Politeness in Tutoring Dialogs: "Run the Factory, That´s What I'd Do"*, In 7th International Conference on Intelligent Tutoring Systems, Maceio, Alagoas, Brazil, pp. 67-76, 2004.
[8] J. D. Moore, K. Porayska-Pomsta, S. Varges and C. Zinn, *Generating Tutorial Feedback with Affect*, In 17th International FLAIRS Conference, FLAIRS 2004, Miami Beach, Florida, 2004.
[9] J. Pearl, *Causality: Models, Reasoning, and Inference*, Cambridge University Press, 2000.
[10] J. Self, *The defining characteristics of intelligent tutoring systems research: ITSs care, precisely.* International Journal of Artificial Intelligent in Education. Vol 10. pp. 350-364. 1999.
[11] R. Nkambou and V. Héritier, *Facial Expression Analysis for Emotion Recognition in ITS*, In 7th International Conference on Intelligent Tutoring Systems, ITS 2004, Workshop on Social and Emotional Intelligence in Learning Environments, Maceio, Alagoas, Brazil, 2004.
[12] A. Ortony, G.L. Clore, and A. Collins, *The Cognitive Structure of Emotions*, Cambridge University Press, 1988.
[13] C. Bartneck, *Integrating the OCC Model of Emotions in Embodied Characters*, Workshop on Virtual Conversational Characters: Applications, Methods, and Research Challenges, Melbourne.
[14] C. Elliott, Rickel, J. y Lester, J.C. (1999). *Lifelike Pedagogical Agents and Affective Computing: An Exploratory Synthesis*, Artificial Intelligence Today, pp. 195-211, 1999.
[15] P.T. Costa and R.R. McCrae, *Four Ways Five Factors are Basic, Personality and Individual Differences*, 1992, 13(1) pp. 653-665.
[16] G. S. Acton, *Great Ideas in Personality: Five Factor Model*, http://www.personalityresearch.org/, visited on may 2005.
[17] J. D. Velásquez, *Modeling Emotions and Other Motivations in Synthetic Agents*, In AAAI-97: Proceedings of the Fourteenth National Conference on Artificial Intelligence, pp. 10-15, 1997.
[18] B. Reeves and C. Nass, *The Media Equation: How people treat computers, television and new media like real people and places*, Cambridge University Press, 1996.
[19] J. Heinström, *The impact of personality and approaches to learning on information behaviour*, Information Research, Vol. 5 No. 3, April 2000, http://informationr.net/ir
[20] G. Boeree, *Personality Theories*, http://www.ship.edu/~cgboeree/, visited on September 2004.
[21] Y. Hernandez, J. Noguez, E. Sucar and G. Arroyo-Figueroa, *An Affective Model for Semi-open Learning Environments*, 10th International Conference on User Modeling, UM'2005, Workshop on Adapting the Interaction Style to Affective Factors, to be published.
[22] J. Noguez, L.E. Sucar and F. Ramos, *A probabilistic relational model for virtual laboratories.* In U. Hoppe, F. Verdejo, and J. Kay, editors*, International Conference on Artificial Intelligence in Education,* Sydney, Australia, IOS Press, Vol. 11, pp 533-534, 2003.
[23] J. Diez, The Elvira Project, http://www.ia.uned.es/investig/proyectos/elvira/, visited on April 2005.

Taking into account the variability of the knowledge structure in Bayesian student models.

Mathieu HIBOU
Crip5 Université René Descartes – Paris 5
45 rue des Saints-Pères 75270 Paris Cedex 06 France
mathieu.hibou@math-info.univ-paris5.fr

Abstract. Bayesian belief networks have been widely used in student and user modelling. Their construction is the main difficulty for their use in student modelling. The choices made about their structures (especially the arcs orientation) have consequences in terms of information circulation.
The analysis we present here is that the network structure depends on the expertise level of the student. Consequently, the evolution of the network should not only be numerical (update of the probabilities) but also structural. Hence, we propose a model constituted of different networks in order to take into account these evolutions.

Introduction

Bayesian networks have been successfully used for student modelling in many different systems. The purposes and functionalities of those systems vary a lot. Some of them are only dedicated to evaluate the student's competence [9], while some others make it possible to recognise the plan followed by the learner [5]. Moreover, they have been implemented in different framework : in "traditional" ITS, in Open Learning Environment [2] or as a base for inspectable models [15]. This variety of uses advocates for Bayesian networks in the implementation of student models.

A Bayesian network is a graphical knowledge representation in which each node of the network represents a random variable. The topology of the graph takes into account the dependencies between variables. More precisely [1], [13], a Bayesian network (or belief network) is a directed acyclic graph whose nodes are in a one-to-one correspondence with n random variables $X_1,\ldots,X_n$ such that

$$P(X_1,\ldots,X_n)=\prod_{i=1}^{n}P(X_i \mid Pa(X_i))$$

where $Pa(X_i)$ is the set of parents of X_i . The structure of the graph is in fact a translation of the conditional dependencies between the random variables, and thus it has an influence on the information circulation. Once the network specified, inferences can be made. The classical inference in a Bayesian network is an update of the probabilities, that is to say the calculation of the posterior probabilities of the unobserved variables when an evidence is observed. Whereas the abductive inference is the research of the most probable explanation of an evidence.

In this paper we present some issues raised by the development of the BSMod (Bayesian Student Modeler) project. The purpose of this project is twofold, first to highlight the problems that appear when Bayesian networks are used in learner modelling and propose solutions to solve them, secondly to implement a tool, focused on student modelling, to edit and run Bayesian networks.

Our key ideas are the following ones.

1. The traditional causal interpretation of the arcs orientation is not adequate in the case of cognitive tasks modelling. The analysis of the flow of information in the network, on the other hand, provides the most important clues to determine its structure.
2. A student model based on Bayesian network should be constituted of several networks, with different structures, in order to take into account the evolution of the student's knowledge structure.

The existence of structural differences between experts and novices knowledge and problems representations motivates the second point. These differences have been studied and highlighted in cognitive psychology [4], [12]. For instance, we present in figure 1 two semantic graphs: the first one is the quadrilaterals categorization made by a novice and the second one is the corresponding expert's knowledge representation. The novice sees the square as a particular quadrilateral, as the rectangle or the rhombus, whereas the expert knows that the square is at the same time a rectangle and a rhombus.

In the first section we discuss some of the issues raised by the use of Bayesian networks in student modelling, in section 3 we explain how to operate with different networks in the same model, and finally we present some conclusions and further developments.

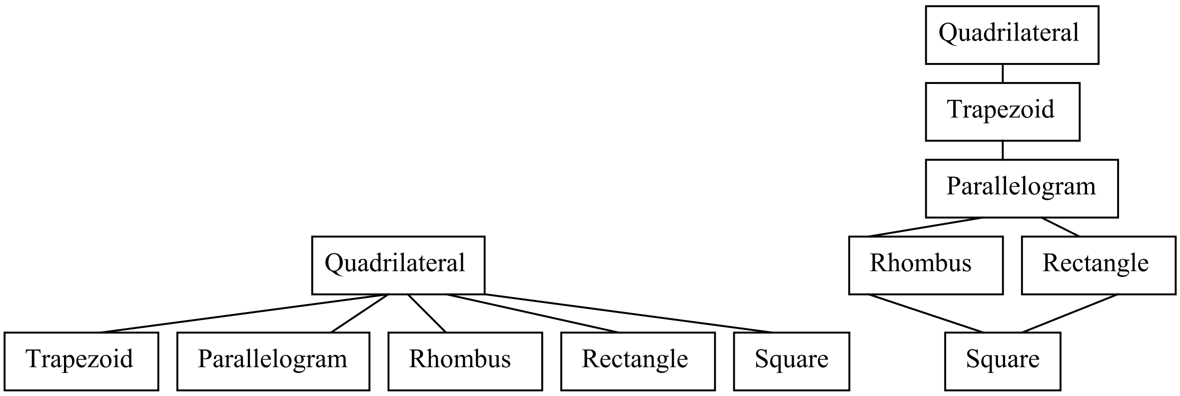

Figure 1. *Two different categorizations of quadrilatrerals*

1. Construction of the Bayesian networks in student modelling

1.1 Bayesian networks construction

The complete specification of a Bayesian network requires the definition of both its structure (a directed acyclic graph) and parameters (the probability tables). This can be done either by experts' knowledge elicitation, using machine learning, or even by mixing both approaches.

In the case of knowledge elicitation, the definition of the network structure begins with the collection of the possible nodes. A distinction is made between informational variables (the ones that can be observed) and hypothetical ones. The presence of an arc is the expression of the potential influence between two variables. Usually arc orientation is analysed in terms of causality : the existence of an arc from A to B means that A is one of the causes of B. In section 3 we will discuss the difficulty of such an interpretation in the case of learner modelling. The parameters are determined in an approximative way, using qualitative information.

There are two different manners to learn a network from data : the statistical one and the Bayesian one. In the case of the statistical learning, the maximum likelihood method is used, whereas in the case of the Bayesian learning it is the maximum a posteriori estimate that serves as a criteria for learning. The Bayesian learning consists in choosing the model that has the highest probability given the data. As we will explain later, we got inspiration from this approach because we want to take into account different Bayesian networks to model a student.

Even though there is one example (Capit [8]) of a Bayesian student model automatically built, Bayesian networks used in student modelling are most often determined by experts, hence we focus on this kind of building methods.

As a first approach we consider an overlay model with only three kinds of nodes : the knowledge nodes (representing the ability on a particular topic), the know-how nodes (representing the ability to implement a knowledge in a specific way) and the item nodes (representing the students answers). The knowledge nodes and the know-how nodes are hypothetical, whereas the item nodes are informational.

1.2 Influence of the network structure on the propagation of information

As we have already explained, the existence of an arc form A to B is the translation of a causal relation between A and B. The problem is that it is not easy to make an analysis in terms of causes and consequences when one deals with the modelling of cognitive tasks. So we think that it is useful to look at the orientation of the arcs from the information circulation point of view.

We illustrate our ideas with two examples.

1. It seems obvious that there must be an arc between the variables Geometry (G) (representing the general competence in geometry) and Pythagora (P) (representing the ability in using Pythagora's theorem), but it is difficult to say which one is the cause of the other. In other words, is a student competent in a particular topic because he/she is competent in all its sub-topics, or vice-versa ?
2. Does one master a particular know-how because one can solve many problems that require using it, or is the ability in this know-how the results of many achievements ?

In the first case, let us consider a third variable, Thales (T) (representing the ability in using Thales's theorem). There are two options : either the arcs are oriented from topic to sub-topic, or the vice-versa [6]. Figure 2 illustrates the circulation of information obtained with the bayes-ball algorithm [13] in both cases (system 1 on the left and system 2 on the right). In the case of a student who would have attended a complete geometry class the first structure is satisfying : an information about his/her ability to use one of the theorems has an influence on our beliefs about his/her ability to use the other one. Whereas if the student is a beginner, the evaluation of a lack of knowledge about Thales' theorem would make system 1 infer that he/she may also have difficulties with Pythagora's theorem, even though in reality he/she may not have learnt anything about Thales's theorem yet, but may be really good already at using Pythagora's. Consequently we think the system 2 offers a better representation of the student knowledge structure for a beginner : an information about his/her ability to use one of the theorems has no influence on our beliefs about his/her ability to use the other one. Hence, we conclude that the orientation of the arcs between knowledge nodes depends on the expertise level of the student.

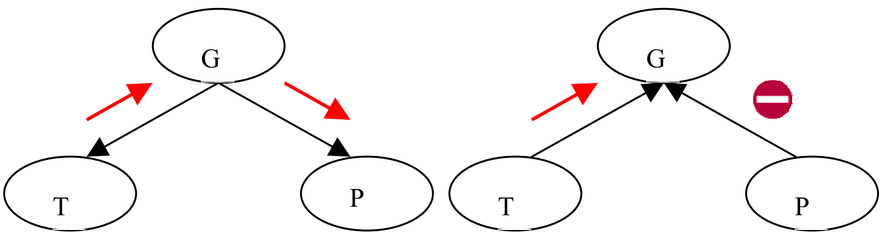

Figure 2

In the second case, if different items are the expression of the same know-how, information on any of them has consequences on our beliefs on the others. For instance, the observation of the student's capacity to use Thales' theorem to calculate a length, makes us believe that another use of this theorem for the same task will be successful. Consequently the arcs have to be oriented from the know-how nodes to the item nodes.

These two examples explain why in the case of student modelling the analysis of the network in terms of information flow is more adequate than the traditional causal interpretation. It is also a strong argument in favour of the construction of models with different networks that could take into account the plurality of students knowledge structures.

1.3 Parameters

Different solutions have been proposed to deal with the problem of probability tables determination [14]. For instance, the systematic use of “noisy and” nodes and “noisy or” nodes [5] makes the network more readable and facilitates its construction. In this case, the subjectivity of the parameters has often been the object of discussion [10], but we do not consider it to be a bias or a default. These figures are subjective, they are the reflection of the pedagogical and didactical conceptions of the experts. For instance, $P(Item / Know - How)$ represents the difficulty assigned to an item.

2. The BSMod project

2.1 A model constituted of different networks

Usually the probabilities of a Bayesian network based student model are adapted on-line, using dynamic Bayesian network techniques [5] in order to take into account the evolution of the student's performance. We have explained why we think that there is a relationship between the structure of the network and the level of expertise of the student. During his/her training, his/her expertise level should vary and consequently, the numerical update we have just mentioned is not sufficient. There should be an evolution not only of the network parameters but also of its structure to reflect the changes in the student's knowledge structure.

To take into account these changes, the structure of the model have to vary. The issue is that the structure of a Bayesian network is fixed. So, in order to deal with this problem, the idea is to consider a model that is constituted of different sub-models, each one of them being a Bayesian network. The selection of the most appropriate sub-model is made using abductive inference. After observation, the most probable explanation is figured out for each network, $v_i^{abd} = \arg\max_{v \in V \backslash e}(P(V = v|e))$, where *i* denotes the network and *e* the evidence observed. Each of those explanations has a probability $P(V = v_i^{abd}|e)$, and this probability is the criteria used for the determination of the sub-model that fits the best. In other words, the model selected is the one that presents the most probable configuration of its variables with the highest probability among the models. This approach is close to the Bayesian learning approach (*cf. 1.1*), the main difference is the criteria used to measure the sub-model accuracy. We decide to use the criteria described above instead of the maximum *a posteriori* to avoid giving probabilities to the sub-models.

2.2 the BSMod tool

We plan to implement a tool dedicated to the use of the Bayesian networks for student modelling, BSMod (Bayesian Student Modeler) which is based on BNJ (Bayesian Network for Java), an open source application mainly developed by the Kansas State University. The BSMod GUI is presented in figure 4. The colours of the nodes (shades of grey in figure 3) represent their natures (knowledge; know-how or item nodes), and the network depicted here is organized in two layers : the domain layer (knowledge and know-how nodes) and the activity layer (item nodes).

This tool implements all the functionalities to edit and run a Bayesian network, but it must also be able to handle generic or typed nodes, such as the "noisy and" nodes or the knowledge nodes. We will have to specify a special saving format (XML based) in order to store the specific kinds of information described above. For instance, once a Bayesian network is loaded, one should be able to change the parameters globally.

Moreover, BSMod should enable us to test our hypothesis about multi-networks model. We plan to use data taken from the use of PEPITE [7], a diagnosis system, and we will test whether or not it is possible to detect different sub-models.

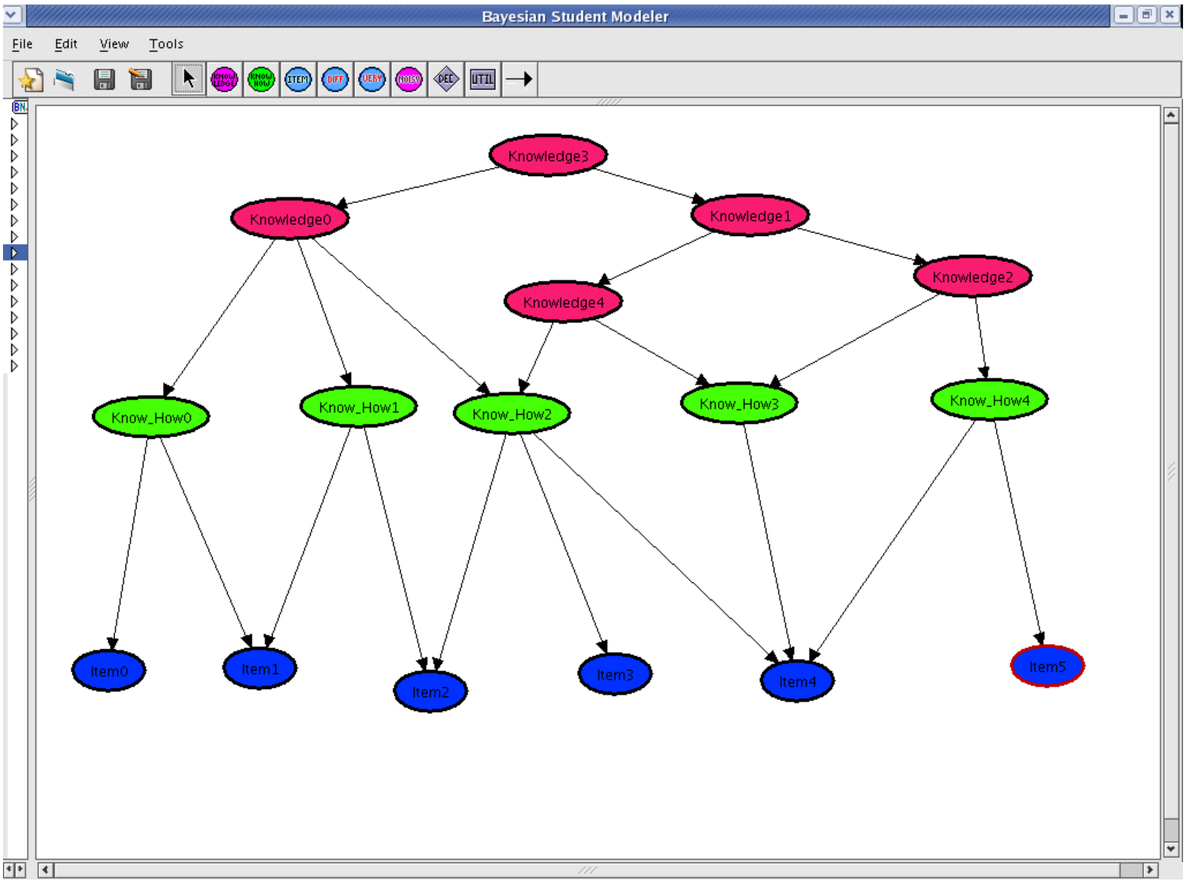

Figure 3. *The BSMod GUI*

3. Conclusion

The ability of the Bayesian networks to manage uncertainty in student modelling, as shown by the implementations of different systems, justify the development of a dedicated tool such as BSMod. This tool should make it possible to find more easily solutions to the problems of Bayesian networks building in student modelling more easily and to manage the plurality of networks in the same model.

We think that the notion of a student model constituted with different networks is really important. It should make it possible to take into account not only quantitative changes but also structural changes in the student knowledge. The expert is not only the one who knows more, but also the one who knows differently, whose knowledge is organised differently. At this stage of our research, we suggest that only the arcs orientation will vary from one sub-model to another, but one could decide to change the nodes as well.

The paradigm of multi-networks student model can be extended by allowing the sub-models not to be confined to Bayesian networks. Hence different conceptions could be embedded in the same student model.

References

[1] A. Becker, P. Naïm. *Les réseaux bayesiens, modèles graphiques de connaissances*, Eyrolles, 2001.

[2] A. Bunt, C. Conati. Probabilistic student modelling to improve exploratory behaviour, *in Journal of User Modeling and User-Adapted Interaction*, volume 13 (3), pages 269-309, 2003.

[3] W. L. Buntine. Operations for learning with graphical models, *Journal of Artificial Intelligence Research*, volume2, n°, pages159-225, 1994.

[4] Chi, M.T.H., Feltovitch, P.J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5,* 121-152.

[5] C. Conati, A. Gertner, K. Vanlehn. Using Bayesian networks to manage uncertainty in student modeling, in *Journal of User Modeling and User-Adapted Interaction*, volume 12 (4), pages371-417, 2002.

[6] A. Jameson. Numerical uncertainty management in user and student modeling: an overview of systems and issues, in *User- Adapted Interaction*, volume 5 (3-4), n°5, pages193-251, 1996.

[7] S. Jean. *PÉPITE : un système d'assistance au diagnostic de compétences*, Thèse de doctorat de l'Université du Maine, 2000.

[8] M. Mayo, A. Mitrovic. Optimising ITS behaviour with Bayesian networks and decision theory, in *International Journal of Artificial Intelligence in Education*, n°12, pages124-153, 2001.

[9] R. Myslevy, D. Gitomer. The role of probability-based inference in an intelligent tutoring system, in *User-Modeling and User- Adapted Interaction*, n°5, pages 253-282, 1996.

[10] R. Mislevy, G. Almond,D. Yan, L. Steinberg. Bayes nets in educational assessment: Where the numbers come from, in *Proceedings of the Fifteenth Conference on Uncertainty in Artificial Intelligence*, K.B. Laskey & H.Prade Eds, pages 437-446, 1999.

[11] J. Pearl. *Probabilistic Reasoning in Intelligent System*, Morgan Kaufmann, 1988.

[12] E. Rosch, Principles of categorization, in *Cognition and categorization*, E. Rosch & B.B. Lloyd (Eds.),pages 27-48, Hillsdale, NJ: Erlbaum, 1978.

[13] R. D.Shachter. Bayes-Ball: The Rational Pastime (for Determining Irrelevance and Requisite Information in Belief Networks and Influence Diagrams), in *Uncertainty in Artificial Intelligence: Proceedings of the Fourteenth Conference*, pages 480-487, San Francisco, CA: Morgan Kaufmann 1998.

[14] K. Vanlehn, Z. Niu, S. Silver, A. Gertner. Student modeling from conventional test data: a Bayesian approach without priors, in *Lecture Notes in Computer Science*, n°1452, 1998.

[15] J.-D. Zapata-Rivera, J. Greer. Student Model Accuracy using Inspectable Bayesian Student Models, in *Proceedings of the Eleventh Conference on Artificial Intelligence in Education*, U. Hoppe, F. Verdejo, J. Kay eds, IOS Press, pages 65-72, 2003.

Subsymbolic User Modeling in Adaptive Hypermedia

Young Research Track paper (YRT)

Katja HOFMANN

Math and Computer Science Department,
California State University, East Bay,
25800 Carlos Bee Blvd., Hayward, CA 94542, USA
Phone +1(510) 885-7559
E-mail khofmann@horizon.csuhayward.edu

Abstract. This paper describes ongoing research on adaptive online-tutorials. I want to find out how subsymbolic machine leaning techniques can be used to cluster users according to their browsing behavior, and if the resulting clustering can be used to adapt the navigation of online tutorials to students' characteristics like background knowledge, learning style, and learning goals. Results of this research will help to adapt to a users' characteristics without explicitly modeling a complete decision making process. The presented research builds on the Adaptive Collaborative UNIX Tutorial (ACUT) that was designed to support collaborative learning of topics on the UNIX operating system. ACUT uses social navigation and aims at increasing retention of Computer Science students without extensive knowledge on UNIX, especially women and minority students. User modeling using sub-symbolic clustering uses self-organizing techniques to learn about the inherent clusters in user behavior. I will use a combination of neural networks and fuzzy sets to form clusters according to student behavior. Empirical evaluation will be used to verify the validity of the resulting clustering and adaptation mechanism. Its results will give evidence on whether and how subsymbolic clustering can be applied to user modeling and adaptation.

Keywords: adaptive hypermedia, social navigation, collaborative learning, fuzzy systems, neural networks

1. Introduction

The goal of adaptation in educational hypermedia is to provide customized content, navigation, presentation, or feedback, in order to improve the user's learning and retention. An example for adaptivity would be to adapt the provided content to the learning style of each user: some users learn better from textual information, some prefer a lot of pictures, and others might learn best from examples. To prevent new users from getting lost in a large amount of information, an adaptive tutorial could customize navigation to fit the goals and characteristics of the user [9].

To adapt to these characteristics, a hypermedia system needs to maintain a user model and make decisions about the user interface of the system. The student model can contain information about the user's learning process, skills, knowledge, goals or preferences [14].

Instead of explicitly modeling the user's attributes, the system could also use clustering techniques to build a non-symbolic student model. This approach recognizes patterns in user behavior. It groups users with similar behavior, and then makes decisions for members of a certain group. This means that the system automatically matches the user's behavior to a set of clusters and creates individual system responses according to the recognized behavior.

Other approaches that can be used to improve learning with hypermedia systems are collaborative learning and social navigation. Collaborative learning includes the learning companions of a user explicitly in the learning process. For example the system can show when other students are using the system, allow contacting other students, or give support for forming study groups.

Social navigation is a phenomenon of human interaction: when we have difficulties making decisions we tend to imitate the behavior of others. In 'real life' this can mean that we see people sitting inside a restaurant and decide to go there, rather than to the empty restaurant next door (implicit social navigation). Another example would be if we ask a friend for advice about which digital camera to buy (explicit social navigation). In adaptive hypermedia implicit social navigation would include visualization of the number of visits other students made to a certain page of the tutorial. An example for explicit social navigation would be to allow students to make comments, or give feedback about whether they found a piece of information helpful or not [2], [11].

2. Symbolic and Subsymbolic User Modeling in Adaptive Hypermedia

The most frequently used approach to user modeling in adaptive hypermedia is the use of symbolic machine learning techniques. This approach tries to infer explicit information about a student's knowledge, preferences, or characteristics from the student's actions while using a hypermedia learning system. Sison and Shimura [10] and Weber and Brusilovsky [15] describe a number of current systems, which use for example decision trees, probabilistic learning, or case-based reasoning to infer student models.

However, many researchers in the field have come to the conclusion that the applicability of symbolic machine learning to adaptive learning systems is inherently limited because these techniques do not perform well on noisy, incomplete, or ambiguous data. Symbolic learning uses single actions (answering a question, visiting a website) to infer complex characteristics of the user in the form of IF…THEN rules (e.g. "IF the user can answer these questions correctly, THEN she knows the underlying concept"). This is problematic because data on user behavior tends to be very noisy: The user might just have guessed the correct answer without really understanding the topic. Or a wrong answer might be just a slip, or inattentiveness, rather then a indicating that the student does not know the underlying concept. Also, the rules for inferring information are not completely known. A student's long visit to a certain website could mean that she is really interested in the topic, but she might also just have left her computer to get coffee. It is very hard to infer complex information about the user based on the observation of single actions [1].

3. Researching a Neuro-Fuzzy Approach to User Clustering

Neural networks and fuzzy systems are subsymbolic machine learning techniques and are a very promising approach to deal with the characteristics of data obtained from observing user behavior. The two techniques complement each other and have inherent characteristics that make them suitable to deal with incomplete and noisy data inherent to user behavior in hypermedia systems [12]. Most importantly, this approach can identify similarities in underlying patterns of complex, high-dimensional data.

I want to find out how subsymbolic machine learning can be used to adapt navigation of web-based tutorials to the goals, knowledge level and learning style of the student. The first step towards this adaptation is to cluster tutorial users based on their interaction behavior. I will implement a cluster mechanism that automatically recognizes a specific behavior pattern and matches it to a cluster or a set of clusters. For clustering techniques I will consider neural networks, fuzzy systems, and combinations of these techniques as described by Tettamanzi and Tomassini [12]. The students' interactions with the tutorial (websites visited, time spent there, use of tools, etc.) will be recorded and form the input to the clustering mechanism [4].

After implementing the clustering technique in ACUT I will analyze the resulting clusters and compare them to the students' goals, knowledge level and learning style. I will consider the academic level, experience in the problem domain, the student's own assessment, and also the investigator's assessment of the student's behavior. This data will be collected in focused interviews. The results will show if and how soft computing techniques can be used to find patterns in user behavior.

The resulting clustering will group similar student behavior, which is a representation of the patterns underlying this behavior. For example students who have never used the tutorial before might show similar behavior in that they are insecure, spend a lot of time on each page they look at, and tend to prefer links many other students visited before. My hypothesis is that students with similar goals, background knowledge and learning style will show similar behavior and will thus be grouped in the same or adjacent clusters.

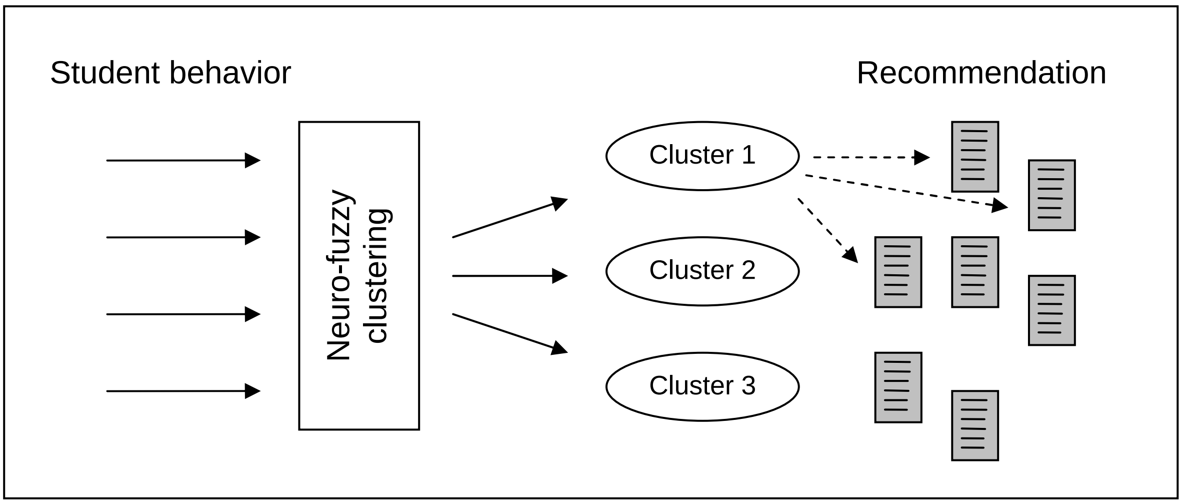

Figure 1: Navigational Adaptation based on subsymbolic clustering

By implementing and evaluating a clustering mechanism based on fuzzy systems and neural networks I want to test the following hypotheses:

1. Experience in using online tutorials: The user behavior of students with similar levels of experience in using online tutorials can be clustered by using subsymbolic machine learning.

2. Knowledge about the subject: The user behavior of students with similar levels of knowledge about the subject matter presented in an online tutorial can be clustered by using subsymbolic machine learning.

Based on the clustering of a student's behavior the tutorial will recommend documents that will probably be most helpful to the student. These documents will be selected by considering which documents other students in the same or adjacent clusters used most and found most helpful. If the hypotheses are correct, students will receive personalized recommendations for documents, which students with similar background preferred. This will allow navigational adaptation based on implicit social navigation.

4. ACUT

I will base the implementation of the suggested clustering techniques on the existing Adaptive Collaborative UNIX Tutorial (ACUT). Rosta Farzan developed ACUT during her thesis work.

With her thesis work Rosta Farzan addressed the problem of insufficient access to informal computer education of non-traditional Computer Science students. For non-traditional CS students it is difficult to learn computer skills required for successful CS studies. Traditional students obtain this knowledge through informal education but it is not possible to adequately teach these skills in a formal classroom setting [13], [9].

The idea behind ACUT is to increase retention of non-traditional Computer Science students by forming learner communities and using social navigation in a just-on-time learning system to emulate informal education. Farzan analyzed that two reasons for low enrollment and high drop-out rates of female and minority students are the lack of informal education on functional knowledge about computers and the lack of integration into learning communities.

In task based interviews Rosta evaluated student's use of online tutorials to analyze current online tutorials and induce design principles for the development of ACUT. She identified features and methods that would help improve the learning process of less experienced learners. Methods for collaborative learning, and social navigation (trail following) were developed and implemented in a prototype system [3].

5. Evaluation

After implementing the clustering mechanism I will use empirical evaluation to test my hypotheses. Approaches to evaluating a student's interaction with a learning system and the systems impact on the user are not very well developed in the adaptive hypermedia research community. Developed evaluation methods can be found in Human Computer Interaction research [8], [5].

Focused interviews will be used to obtain data on student behavior, as well as background knowledge and learning style, which are needed to test the clustering mechanism. The user will first be asked to answer a number of questions and will then be asked to solve a set of tasks using ACUT. While the subject is solving the tasks the interviewer will observe the subject's interaction with the ACUT tutorial. In addition to the notes the interviewer takes during the session, the user's interaction with the system, as well as her questions and comments, will be videotaped. The system's logging mechanism also keeps track of the user's actions, which will give us realistic training data for the system. All interviewed persons will be students of CSU Hayward. The population will consist of 15-20 students, including female and male students from a variety of academic levels and age groups.

The Results of the evaluation will give both information about the effectiveness and applicability of the clustering mechanism, and the chosen method for evaluation.

The interview begins with questions about basic statistics and the participant's experience with UNIX and the use of online tutorials. Following are examples for the questions that will be asked:

- How old are you?
- What is your academic level (college year)?
- Rank your knowledge about UNIX on a scale from 1 to 5 (1 – no knowledge, 5 - expert).
- How much time per week do you spend surfing the Internet?
- How often do you use search engines to find information on the Internet? Which search engines do you use?
- How often do you use the UNIX operating systems?
- Have you ever learned how to use UNIX in a class? Which? How much time was spent learning about the use of UNIX?

After answering these questions the participant will be asked to answer three questions about the UNIX operating system. The participant will be asked to use the tutorial to answer the questions and to explain her thought process during finding these answers.

- What is a "home directory"?
- How do you change the access rights of a file?
- How can you display all files in your home directory that contain the phrase "Hello, World!"?

I will use different tasks of different difficulty. The tasks to solve will be matched with the participant's experience in using the UNIX operating system. Ideally the participant does not know the answer right away, but is able to solve the task with the help of the online tutorial.
Finally, I will ask the participant to asses the difficulty of the tasks she had to solve, and the usability of the overall system:

- Rank the difficulty of each of the tasks you performed on a scale from 1-5 (1 – very easy, 5 – very hard).
- Rank the difficulty of finding the required information within this tutorial on a scale from 1 to 5 (1 – very easy, 5 – very hard).
- For which situations would you recommend the use of this tutorial?

Figure 2: Example interview protocol for the evaluation of ACUT

6. Conclusion

The presented research is a work in progress. Its results will help understand if and how users of online tutorial systems can be clustered according to their interaction behavior. This will help to create adaptive online tutorials that can automatically adapt to the user, or provide feedback to the user. The results will be applicable to the design and development of computer based learning systems.

Future research is needed to carefully evaluate and compare the efficiency of current technologies and subsymbolic clustering for user modeling in adaptive hypermedia systems. Only systematic evaluation can determine out how learners interact with a tutorial, whether online tutorials and collaborative learning can improve knowledge acquisition and increase student motivation and retention, and how these systems compare to traditional approaches to education.

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References

[1] Brusilovsky, P. (2001). Adaptive Hypermedia. *User Modeling and User-Adapted Interaction.* Vol. 11, 87-110.

[2] Dourish, P. (2001). *Where the action is: the foundations of embodied interaction.* Cambridge, MA: MIT Press.

[3] Farzan, R. (2003). *Adaptive Collaborative Online Unix Tutorial for Computer Science Students.* Hayward, CA. Retrieved February 09, 2004, from CSU, Adaptive Hypermedia and Assistive Technologies Web site: http://acc.csuhayward.edu.

[4] Goecks, J. & Shavlik, J. (2000). Learning Users' Interests by Unobtrusively Observing Their Normal Behavior. *Proceedings of the 5th International Conference on Intelligent User Interfaces.* 129 – 132.

[5] Hayes, R. (2000). Exploring Discount Usability Methods to Assess the Suitability of Online Course Delivery Products. *The Internet and Higher Education,* Vol. 2, 119-134.

[6] Kurhila, J., Miettinen, M., Nokelainen, P. & Tirri, H. (2002). Enhancing the Sense of other Learners in Student-Centered Web-Based Education. *Proceedings of the International Conference on Computers in Education.* 318-322.

[7] Kurhila, J., Miettinen, M., Nokelainen, P. & Tirri, H. (2005). *Use of Social Navigation Features in Collaborative E-Learning.* Retrieved February 25, 2005, from CoSCo – Educational Technology: http://cosco.hiit.fi/edutech/publications/elearn2002.pdf

[8] Rosson, M. B. & Carroll, J. M. (2001). *Usability Engineering: Scenario-Based Development of Human Computer Interaction.* San Francisco, CA: Morgan Kaufmann.

[9] Rumetshofer, H. & Wöß, W. (2003). An Approach for Adaptable Learning Systems with Respect to Psychological Aspects. *Proceedings of the 2003 ACM Symposium on Applied Computing,* 6, 558-563.

[10] Sison, R. & Shimura, M. (1998). Student Modeling and Machine Learning. *International Journal of Artificial Intelligence in Education,* Vol. 9, 128-158.

[11] Terveen, L. & Hill, W. (2001). *Beyond Recommender Systems: Helping People Help Each Other.* Retrieved February 25, 2005 from GroupLens Research Home Page: http://www.grouplens.org/papers/pdf/rec-sys-overview.pdf.

[12] Tettamanzi, A. & Tomassini, M. (2001). *Soft Computing: Integrating Evolutionary, Neural, and Fuzzy Systems*. Berlin, Germany: Springer Verlag.

[13] Tully, C. J. (1996). Informal Education by Computer – Ways to Computer Knowledge. *Computers & Education,* Vol. 27. 12, 31-43.

[14] Webb, G. I., Pazzani, M. J. & Billsus, D. (2001). Machine Learning for User Modeling. *User Modeling and User-Adapted Interaction.* Vol. 11, 19-29.

[15] Weber, G. & Brusilovsky, P. (2001). ELM-ART: An Adaptive Versatile System for Web-based Instruction. *International Journal of Artificial Intelligence in Education,* Vol. 12. 33, 351-384.

The Effect of Multimedia Design Elements on Learning Outcomes in Pedagogical Agent Research: A Meta-Analysis

Soyoung Kim
Instructional Systems Program
RITL – PALS
http://ritl.fsu.edu
Florida State University
syk02c@fsu.edu

Abstract. This pilot study was designed to systematically synthesize the results of research on pedagogical agents in the aspect of multimedia design elements, by using a meta-analysis technique. A categorical fixed model was applied and a total of five different predictors including moderate variables (author group, duration and subject matter) as well as main variables (treatment, outcome) were investigated. Results in this study suggested that the presence of a pedagogical agent transmitted the effect of multimedia design elements, which were created by technological support consistently across the studies, on learning outcomes, even though the effect of each variable could not be verified. Discussion focused on pedagogical agents in the context of the reciprocal relationship between psychology and technology and its impact on learning outcomes.

Introduction

This study aimed at synthesizing the results of experimental research on the effect of multimedia elements in pedagogical agents on learning outcomes by using a meta-analysis technique. While a meta-analysis technique is often involved with a large sample size encompassing over 100 studies sometimes, this study intended to incorporate a relatively small sample size, as a pilot study. This pilot study targeted the overall effects of treatments that varied according to design elements and learning outcomes.

1. Reciprocal Relationship between Technology and Psychology

The advance of technology has been proven to facilitate learning activity and enhance learning outcomes in various instructional settings. As Salomon and Almog have pointed out [1], technology and instruction have recently entered into an alliance of reciprocal influences. Technologies do not just serve education, but have been challenging it and demanding new psychological explanations and pedagogical justifications.

It is natural for the instructional technologist to desire to get the strongest possible effect of technology on learning outcomes and make it last longer in learners' cognition and affection. Salomon and Almog classified the effect of technology into two types, *effects with* and *effects of* [1]. A distinction between *effects with* a technology and the more lasting *effects of* it can be introduced for conceptual and practical clarification. More clearly, whereas the former pertains to the immediate changes that take place while students engage in an intellectual partnership with a helpful tool, the latter pertains to the more lasting changes that this partnership may lead to. Instructional technologists and designers aim at getting both *effects with* and *effects of*.

A pedagogical agent is the most advanced and integrated form of technology application in that it enhances both *effects with* and *effects of* through the social interaction between interface and learners. Research has verified that pedagogical agents have the tendency to facilitate human-computer interaction through their faces, gestures and voices, and affect learners' cognition and emotion [2,4,6,8,11].

A pedagogical agent can be defined as a lifelike autonomous character which cohabits learning environments with students to create rich, face-to-face learning interactions [2]. In 1996, the work of Reeves and Nass demonstrated a life-like agent by using anthropomorphizing software [3]. This first attempt has rapidly evolved into a three-dimensional, animated agent that shows human-like characteristics such as gender, role, ethnicity and personality through its image and voice [4,9]. Previous research suggests that lifelike agents have a strong motivational effect [4], promote learners' cognitive engagement [2], and that the presence of an agent with voice can have a positive effective on learning and motivation [5]. Instructional designers consider the effect of these multimedia design elements to represent different persona on learning outcomes including perception, attitude, and motivation as well as recall and transfer.

However, the results of research on pedagogical agents are somewhat varied across studies due to the nature of the embryo stage. For instance, no agent condition would be better than an agent with gesture condition in recall and retention [6], while the narration with the presence of pedagogical agent affected learning and motivation positively [7]. In addition, Moreno and Mayer (unpublished) insisted that both visual and auditory elements in pedagogical agents affected learners' recall and near-transfer positively[8], while there were several articles showing no significant influence of a pedagogical agent on learning including recall and transfer [9]. More importantly, there has been an argument regarding the split-attention effect versus the presented modality effect of visual and auditory design elements. The split-attention effect occurs when students must split their attention between multiple sources of information, which results in a heavy cognitive load, while presentation-modality effects suggest that working memory has partially independent processors for handling visual and auditory material [10].

This study intended to clearly explain the overall effect of multimedia elements across studies on pedagogical agents and to try to find a consensus regarding the role of multimedia elements in the effectiveness of pedagogical agents.

2. Multimedia Design Elements

2.1 Auditory Elements

The auditory effects of pedagogical agents provide learners with the chance of social dialogue as a type of human-computer interaction. The condition including auditory elements in experimental research frequently contrasts with the text-only condition to verify the cognitive load theory. When we provide text with auditory effects, it is more effective in getting and keeping students attention [11]. However, students' recall degrades after being exposed to text with voices [7].

2.2 Visual Elements

The researchers in instructional technology have studied the effect of visual aspects of pedagogical agents. On the one hand, the images of pedagogical agents have been studied by encompassing the differences of their colors and shapes. As the gestalt of visual formation, agent appearances constructed by different colors and shapes represent role, gender and ethnicity [4]. Pedagogical agents' gender and ethnicity influence learners' preference, and agents' instructional roles, such as mentor, expert and motivator, as well as their personality, could affect learners' achievement and motivation. In addition to the image as agent appearance, the effect of animation can be also considered as a type of visual element. The dynamic movement of pedagogical agents also influenced learners' motivation [4].

3. Learning Outcomes

Learning outcomes that researchers have investigated in pedagogical agents can be divided into five subcategories: recall, transfer, preference, perception and motivation. In addition to this, recently, the affective aspect of learning, as well as the cognitive aspect, has been highlighted. When we consider the affective aspect of learning outcomes as well as the cognitive aspect, Bloom's taxonomy of learning outcomes would be useful for a better explanation. Bloom's taxonomy provides a traditional framework of understanding learning outcomes with two categories: cognitive outcomes and affective outcomes [12]. According to this classification of learning outcomes, the various results of pedagogical agent research can be incorporated and interpreted in a more systematic way, with a meta-analysis technique.

However, learners' motivation could not be classified simply as either cognitive or affective outcomes because motivation arouses learners' thoughts as well as emotion.

Methods

A meta-analysis was used for this study to synthesize the results of pedagogical agent research. Through the coding process, the conceptual aspect of multimedia design elements and learning outcomes can be more clearly identified. The results of this meta-analysis can provide in-depth understanding about pedagogical agent research in a more systematic way.

1. Data Collection

1.1 Literature Searches

Twelve different experimental studies of pedagogical agents by five different authors were included in this meta-analysis. All retrieved articles were about the multimedia element in pedagogical agents. In the first step, 8 articles were considered based on the recommendations of colleagues who were experts in pedagogical agent studies. For the second step, references in these articles were reviewed as sources of additional studies. In the next step, the five different computer data bases (ERIC, Psychinfo, Kluwer, ProQuest, and ABI) were used to search articles with keywords (pedagogical agent, multimedia, visual and audio, etc.). Finally, through the Google search engine, hard-to-find literature, such as unpublished manuscripts, was retrieved. Unpublished manuscripts as well as published articles were used for this meta-analysis to avoid biased retrieval of searching only the major journals, which may selectively publish only the results characterized by lower p values and larger effect sizes [13].

1.2 Criteria for inclusion

A total of 48 articles were retrieved, which investigated the effect of visual and auditory design elements of pedagogical agents on learning outcomes. Among them, experimental studies were selected and qualitative studies were excluded. Studies which reported mean, standard deviation, and sample size appropriately were included so that the effect size could be calculated. Non-significant results as well as significant results were incorporated as long as appropriate descriptive data were reported to avoid selection bias.

2. Study Characteristics

During the coding process, publication year, journal/conference title, type of source (journal article, conference proceeding, unpublished manuscript, etc.), and authors characteristics were recorded on the coding sheet. Table 1 shows a brief summarization of the characteristics of the primary studies. Three variables, author group, duration and subject matter were examined as moderate variables in this study.

Table 1. Study Characteristics

No.	Year	Type	Sponsored by	Population Major	Subject matter	Duration (min.)	Assignment
1	2002	Published	Naval Research	Educational Psychology	Mathematics	50	Random
2	2003	Unpublished	NSF	Education	Instructional Planning	90	Random
3	2003	Unpublished	N/A	Education	Instructional Planning	75	Random
4	2003	Published	NSF	Education	Instructional Planning	90	Random
5	2004	Unpublished	NSF	Mixed	Instructional Planning	20	Random
6	2002	Unpublished	N/A	Psychology	Lightning	5	Non-random
7	2002	Published	Naval Research	Psychology	Lightning	5	Random
8	2001	Unpublished	N/A	Psychology	Design a Plant	15	Random
9	2003	Unpublished	NSF	Psychology	Blood pressure	15	Non-random
10	2002	Published	NSF	Psychology	Design a Plant	15	Random
11	2003	Unpublished	N/A	Mixed	Instructional Planning	20	Random
12	2004	Unpublished	N/A	English (Japanese)	English idiom	15	Random

During the coding process, it was established that there were two pedagogical research groups in this study. The first group was the interface design oriented group and the second group was the psychological theory oriented group. The first group conducted research based on various theories encompassing education, sociology and psychology. For example, this group was concerned with Bandura's self efficacy theory, social interaction, gender issues, etc. The second group conducted their research based on the cognitive load theory and examined the effect of different design elements.

The duration of the experiment, which varied from 5 minutes to 90 minutes, was also an interesting issue in this meta analysis. In experimental research, the treatment effect cannot be guaranteed with the duration, whether it is long or short. However, it would be better to examine whether the duration of the experiment affected effect size or not.

The coding sheet indicated that there would be some discrepancy between participants' major and the subject of the instructional material. For example, one study used instructional material regarding basic metrology to students in a psychology major. This also needed to be investigated because the material which was new to participants could either arouse more curiosity or deteriorate their motivation.

A quality assessment coding sheet was developed separately to keep an objective point of view in evaluating the quality of studies. There were several issues regarding study quality. Three studies among twelve conducted random assignments; most studies used a single item to measure one construction such as motivation or recall with five Likert scale and did not report the reliability; five studies out of twelve did not use preset alpha; one study reported 5 different alpha levels.

3. Selection of Variables

3.1 Treatment: Multimedia design elements

The treatment variable was classified into four different levels; (1) auditory, (2) visual image, (3) visual image plus animation, (4) visual image plus social meaning (role, gender, ethnicity, etc.). The voice effect of the pedagogical agent was focused and mainly contrasted with text-only in condition. The visual effect of pedagogical agents had different levels of application: (1) the effect of the visual presence of pedagogical agents (2) the effects of animated pedagogical agents (3) the effects of social meanings that the visual image contained, such as instructional role (expert vs. motivator), gender, and ethnicity.

3.2 Learning outcomes

As learning outcomes, research on pedagogical agents considered cognitive outcome, affective outcome and motivation.

The positive effect of pedagogical agents on learners' motivation has been proved through almost all studies in the field of pedagogical agents. No primary studies in this meta-analysis ignored motivation as a learning outcome. However, learners' motivation has both cognitive and affective aspects [14, 15]; therefore, it was treated as a separate learning outcome in this analysis.

4. Effect Size Estimates

The key to meta-analysis is defining an effect size statistic capable of representing the quantitative findings of a set of research studies in a standardized form that permits meaningful numerical comparison and analysis across the studies [16]. In brief, effect size estimates are the meta-analytic coin of the realm [13]. Effect sizes in this meta-analysis were estimated as *g*-statistics by using mean and standard deviation. A total of 28 different effect sizes from 12 different studies were obtained and incorporated in this data set.

Results

Through the process of model specification, a categorical fixed model was applied and a total of five different predictors including moderate variables (author group, duration and subject matter) as well as main variables (treatment, outcome) were investigated in this study.

1. Preliminary Analysis

Four outliers were detected based on the standardized residuals and confidence interval plot. The confidence interval plot also suggested that there would be possible outliers (refer to Figure 1.) After cleaning four outliers, Q statistics were changed from 316.10 ($p<0.05$) to 56.26 ($p<0.001$) and Birge's ratio was changed from 11.71 to 2.45. Therefore, it was concluded that eliminating four outliers would be reasonable for further analysis.

Figure 1. Confidence Interval Plot

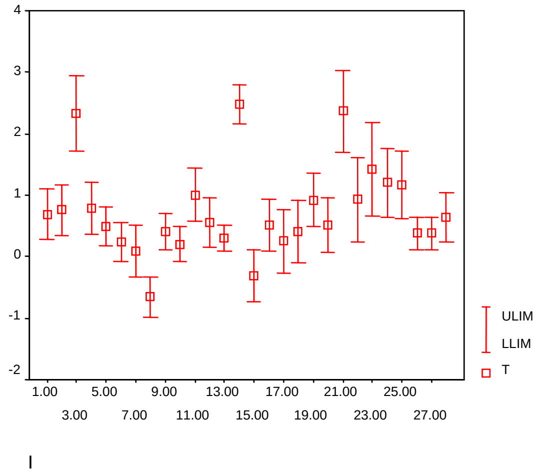
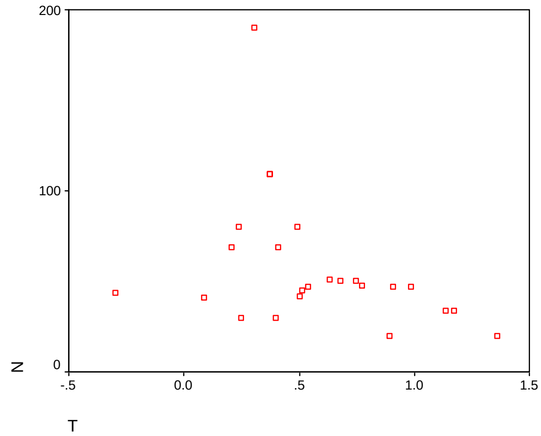


Figure 2. Funnel Plot



*T= effect size
*ID= identification number for each effect size

A funnel plot is used for the detection of publication bias. Publication bias occurs when studies reporting statistically significant results are published and studies reporting less significant results are not [13]. This plot was constructed by using the sample size (n) with corresponding effect size. The data set was created to avoid publication bias by incorporating unpublished manuscripts as well as non-significant results. The overall shape looks roughly like a funnel so that we can conclude that there was no publication bias in this meta-analysis.

Overall homogeneity analysis is conducted to test whether the results appear similar across studies with Q statistics. The Q total in this study is 56.258 and the associated *p*-value is 0.0001. Therefore, we can reject the null in which there would be no difference among effect sizes at the preset alpha 0.05. This means that the variability of the effect sizes is larger than would be expected from sampling error [16].

2. Categorical Fixed Model

A categorical fixed model deals with the meta-analytic data as analogue to ANOVA [16]. Treatment (Multimedia design elements) was investigated first. The ground mean for group 1 (auditory) is 0.531, for group 2 (visual image) is 0.292, for group 3 (visual image plus animation) is 0.518 and for group 4 (visual image plus social meaning) is 0.583. This indicates that the group 2 mean is obviously lower than others. Q_{total} is 27.830, $Q_{between}$ is 4.408, and Q_{within} is 23.422. Each Q statistic is compared with the critical chi-square value. The result indicates that the mean effects in all four groups are equal. $Q_{between}$ is not significant.

Table 2 shows the results of investigating the overall effect of outcomes, author group, duration, and subject matter. None of the Q statistics were rejected, whether $Q_{between}$ or Q_{within}.

Table 2. Test for each Factor

	Q statistics	*Chi-square value*	*Results*
Treatment			
$Q_{between}$	4.408	7.82 (df=3, α=.05)	Fail to reject
Q_{within}	23.422	31.41(df=20, α=.05)	Fail to reject
Q_{total}	27.830	35.17(df=23, α=.05)	Fail to reject
Outcome			
$Q_{between}$	2.044	5.99 (df=2, α=.05)	Fail to reject
Q_{within}	25.786	33.92(df=21, α=.05)	Fail to reject
Q_{total}	27.830	35.17(df=23, α=.05)	Fail to reject
Author			
$Q_{between}$	3.635	5.99 (df=2, α=.05)	Fail to reject
Q_{within}	24.195	33.92(df=21, α=.05)	Fail to reject
Q_{total}	27.830	35.17(df=23, α=.05)	Fail to reject
Duration			
$Q_{between}$	1.736	5.99 (df=2, α=.05)	Fail to reject
Q_{within}	26.094	33.92(df=20, α=.05)	Fail to reject
Q_{total}	27.830	35.17(df=23, α=.05)	Fail to reject
Subject			
$Q_{between}$	3.426	3.84 (df=1, α=.05)	Fail to reject
Q_{within}	24.405	33.92(df=22, α=.05)	Fail to reject
Q_{total}	27.830	35.17(df=23, α=.05)	Fail to reject

Discussion

This pilot study attempted to find the overall effect of multimedia elements and learning outcomes through a meta-analysis technique. A meta-analysis is a systematic cognitive work to better understand both the background of studies and the main issues within them.

Even though the results of this study could not verify the strong overall effect of each variable with $Q_{between}$ statistics, it suggested possible factors and, most of all, it has improved the understanding of the pedagogical agent research. Results in this pilot study suggested that the presence of a pedagogical agent showed the effect of multimedia design elements, which were created by technological support consistently across the studies, on learning outcomes, even though the effect of each variable could not be verified. This implied that the presence of a pedagogical agent could enhance the *effect of* technology as well as the *effect with* it.

Furthermore, it would be recommended for the follow up study to get more predictors and more samples to acquire more meaningful results. Larger size sample should be required for a better meta-analysis. In addition, more studies about affective domains should be incorporated.

References

[1] G. Salomon and T. Almog. Educational psychology and technology: a matter of reciprocal relations. *Teachers Record*, 100 (1), pp. 222-241, 1998.
[2] W. L. Johnson, J. W. Rickel, & J. C. Lester. Animated pedagogical agents: face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education,* 11, pp. 47-78, 2000.
[3] B. Reeves, & C. Nass. *The media equation.* Stanford, CA: CSLI Publications, 1996.
[4] A. L. Baylor, & J. Ryu. Does the presence of image and animation enhance pedagogical persona? *Journal of Educational Computing Research*, 28(4), 2003.
[5] R. K. Atkinson. Optimizing learning from examples using animated pedagogical agents. *Journal of Educational Psychology, 94*(2), 416-427, 2002.
[6] S. Craig, B. Gholson, & D. Driscoll. Animated pedagogical agents in multimedia educational environment: Effects of agent properties, picture features and redundancy. Journal of Educational Psychology, 94(2), 2002.
[7] R. Moreno, Pedagogical agents in virtual reality environments. Proceedings in ED-MEDIA, Denver, Colorado, 2002.
[8] R. Moreno, & R. Mayer, Pedagogical agents in constructivist multimedia environments: The role of image and language in the instructional communication. Unpublished manuscript, 2001.
[9] Y. Kim, A. L. Baylor, and G. Reed, The impact of image and voice with pedagogical agents. Presented at E-Learn (World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education), Phoenix, Arizona, 2003.
[10] S. Mousavi, R. Low, and J. Sweller, Reducing cognitive load by mixing auditory and visual presentation modes," *Journal of Educational Psychology*, 87, pp. 319-334, 1995.
[11] S. Craig, & B. Gholson, Does an agent matter? The effects of animated pedagogical agents on multimedia environments. Proceeding in ED-MEDIA, Denver, Colorado, 2002.
[12] M. Driscoll, *Psychology of learning for instruction* (2nd ed). Needham Heights, MA: Allyn & Bacon, 2000.

[13] R. Rosenthal, Writing meta-analytic reviews. *Psychological Bulletin*, 118(2), 183-192, 1995.
[14] K. Murphy and P. Alexander, A motivated exploration of motivation terminology, Contemporary Educational Psychology, 25, pp.3-53, 2000.
[15] J. Keller, J. (2002). *Learner's motivation.* Unpublished course material.
[16] M. Lipsey, and D.Wilson, *Practical meta-analysis*. Thousand Oaks, CA: SAGE Publications, Inc, 2001.

An ITS that provides positive feedback for Beginning Violin Students

Orla LAHART

School of Informatics, National College of Ireland
olahart@ncirl.ie

Abstract: Feedback is highly important within any learning environment. Providing feedback in a manner which enhances, rather than damages students self-esteem is an important skill that is seldom taught. The art of good feedback is highly complex and this complexity is further heightened when the domain is music. Beginning violin students are faced with a steep learning curve due to the complex nature of the instrument and they may find it difficult to believe that mastery of the instrument is possible. Shinichi Suzuki believed that talent is a product of environment rather than heredity. The research proposed in this paper involves the development of an Intelligent Tutoring System that provides an individualised positive learning environment for beginning violin students practicing at home. The pedagogical framework that informs the system is the Suzuki method as it is based on the premise that through positive feedback students can reach their potential. Formative evaluation is carried out to determine if the employment of positive feedback can increase learning.

Introduction

Feedback is a valuable and personal way of improving individual learning outcomes and developing rapport between teacher and student. Feedback, when given correctly can increase motivation and indeed learning. Feedback is important within all educational domains, however due to the complex nature of music good feedback is of the utmost importance. Research suggests that skill acquisition is most efficient with immediate feedback [1]. The Suzuki method is based on the premise that talent is a product of environment rather than heredity. It encourages students to reach their potential through the use of positive feedback.

The research proposed in this paper is concerned with the development of an Intelligent Tutoring System (ITS) that uses the Suzuki method to inform its pedagogical framework. The system monitors the student, infers a student model and delivers feedback on the basis of explicit teaching strategies.

The system provides guidance for the student when practicing by identifying melodic and rhythmic inaccuracies, providing positive feedback and presenting additional exercises where appropriate. Comparing their performance to the expert model assesses the student's performance. The pedagogical model employs a number of heuristics and a priority scale to identify which aspect of the performance needs improvement. For example, generally a violin teacher will correct pitch mistakes before rhythmic mistakes. If necessary the system presents the student with extra exercises to combat underlying difficulties. The student model captures completed exercises and student progress. The students will be provided with feedback which highlights their strengths and uses positive reinforcement to overcome any weaknesses they may have.

This paper will firstly describe related research that exists to date. The core philosophy and concepts of the Suzuki method will be discussed, followed by a description of the overall architecture of the system and the research plan.

1. Background

Practicing is of high importance when learning to play an instrument. One common problem is that students practice incorrectly and through the practicing mistakes become ingrained in the playing. An ITS has the potential to prevent false practice by emulating the role of the teacher. Little research has been carried out to date in the design and development of ITS to improve music performance through the provision of positive feedback. However, there are some research strands and related systems that are valuable for identifying relevant attributes for an intelligent practicing support:

First, there are a number of systems that support music education in general which do not contain AI components, including ear training and music theory systems. For instance, there are several music editors, sequencers, analysis tools, innovative musician interfaces, computer aided composition tools and multimedia reference CDROMs on masterworks. A good example of the later is Voyager's [2] interactive CDROM for Beethoven's Ninth Symphony or Hofstetter's [3] ear training system called GUIDO. GUIDO consists of a series of interactive ear training exercises where the student is asked to listen to and understand performances by the computer. A more recent development is the commercial package Music Ace, similarly to GUIDO, Music Ace uses programmed learning as well as drill and practice instructional strategies to teach the basics of music theory in particular ear training.

Second, a number of ITS for music education (opposed to instrument playing) have been developed. An example of an ITS is Vivace, a rule based expert system for the task of four part chorale writing, created by [4]. See Brandão, Wiggins & Pain [5] for an overview. MOTIVE, created by Smith and Holland [6], is a constraint-based learning tool intended for beginning students who wish to explore music composition through an iconic interface

Third, there are standardized and tested teaching strategies for playing the violin without technical support. These can serve as basis for defining heuristics and a priority scale to identify which aspect of the performance needs improvement. In particular, the so-called Suzuki method [7] is informative in this respect.

Finally, some work has been carried out in the area of technology and music performance. Kirshbaum's Tunemaster [8] presents students with a number of different melodies which they must play back using a touch tablet. This arcade-like computer game aims to improve the student's ability of "playing by ear". The area of visual feedback is explored in [9, 10]. Both approaches try to address the difficulty that students experience making fine adjustments in their own performance. The difference between them is that the latter also presents a graphical display of the expert performance. The Piano Tutor [11] is a computer-based system for teaching beginners how to play piano. This system contains music recognition software to follow student performances, a variety of input and output devices to enhance interactivity and a number of instructional design techniques. INTERPRET [12] and pianoFORTE [13] aim to improve students interpretive abilities. Baker's system is limited to pre-stored example pieces, while pianoFORTE contains a model for expressiveness in performance which was developed with the help of piano teachers this allows the system to give visual feedback on performance aspects such as tempo.

Research carried out to date is very informative in some respects. However, little work has been carried out on technology that improves music performance through the provision of positive feedback. Therefore, the author proposes the development of an ITS that aids beginning violin students learn the instrument. The system will focus on the provision of positive feedback using the Suzuki method as the pedagogical framework.

2. Suzuki Method

The Suzuki Method is based on the premise that talent is a product of environment rather than heredity [14]. Dr. Shinichi Suzuki (1898-1998) believed that every child has talent, which can be developed if the proper environment exists. All children learn to speak their own language with relative ease and if the same natural learning process is applied in teaching other skills, these can be acquired as successfully. In the Suzuki Method, the learning process is broken down to the smallest possible steps this allows the child to achieve success at every level and learn at their own pace. The keys to the success of the Suzuki Method include motivation, repetition, listening, positive reinforcement, and parental involvement.

The actual process of teaching the young child to play the instrument involves a trio of players: the child, the teacher and the "Suzuki parent". The "Suzuki parent" will teach the child at home on a daily basis, the one who has been learning the fundamentals of the instrument. People have described this three-way relationship as a tripod: if one leg is missing nothing can be achieved.

Suzuki lessons allow for a creative and enjoyable environment. For beginning students lessons consist of a number of very small steps, which are presented in a playful way. This motivates the young student and encourages full participation. The "Suzuki parent" works at home with the student and tries to mimic the lesson environment by presenting small achievable steps, which focus on one thing at a time. Repetition and review are key features.

As the student grows older and becomes more competent the Suzuki instruction is modified. Students gradually gain some independence. The Suzuki parent is no longer required at the lessons. The student practices independently and learns how to read music notation. However, the pedagogical principles remain the same repetitive listening, the use of supportive encouragement, repetition and review.

Throughout this entire process the underlying philosophy remains: talent is a product of environment rather than heredity. The Suzuki method was selected as the author has extensive experience in both learning and teaching this method. Also, this method of teaching encourages the subdivision of tasks which lends itself to the area of e-Learning.

3. The System Architecture

The system architecture consists of three separate modules. The student assessment module monitors the student, records relevant multimedia input data and compares the input to the goal. The student model captures information on current skills, goals and practice history. The adaptive decision module applies teaching strategies to the student model and thus delivers concrete actions. Below is a diagrammatic representation of the system followed by a detailed discussion of each component.

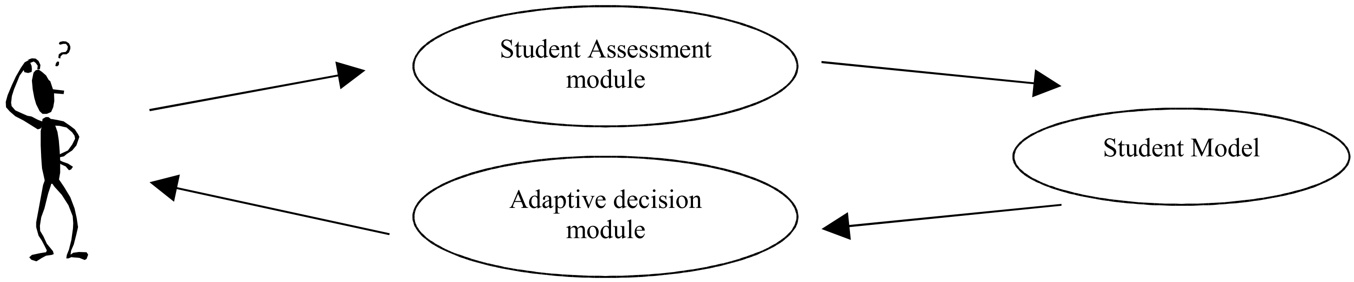


Fig. 1 System Architecture

4.1 Student Assessment module

The student assessment module monitors the student's performance. It analyses the student's playing and records important information. This module is concerned with gathering an estimation of the student's ability and strengths and weaknesses in their performance. The student will be asked to play a particular piece of music (most often the piece of music that they are currently learning) from the Suzuki repertoire. The student's performance is recorded using a number of multimedia input devices. The system contains expert knowledge in the domain area. The student's performance is compared to this expert knowledge and information is gathered. Information may also be gathered through the Suzuki parent's assessment of the student's performance. Typical information, which might be recorded, is melodic or rhythmic inaccuracies and incorrect movement or posture.

4.2 Student Model

The student model keeps track of the student's progress. It holds a record of their current piece. It also contains information on particular difficulties the student may be having. For example a beginning student may find string crossing particularly difficult. The student model also contains information on exercises, which the student may have previously carried out. This is to ensure that the student will not continually receive the same exercise to practice as this may result in lack of motivation. As mentioned previously the Suzuki teaching method is the pedagogical framework that informs the system. The Suzuki method encourages the use of positive rather than negative reinforcement there for the student model will be used to ensure that appropriate feedback is given.

4.3 Adaptive decision module

The adaptive decision module makes intelligent recommendations based on the student model. Due to the complex nature of the instrument a delicate learning environment must be created. Therefore it is important that the student's performance is corrected in an intelligent manner. The type of feedback, which the student is provided with, is very important. Feedback may be oral aural or visual depending on the student's need. If the student continues to make a similar mistake then the system adapts and may suggest alternative exercises based on the theme.

A number of heuristics and a priority scale are used to determine what action, if any, needs to be taken by the system. These heuristics and priority scale are gathered by closely monitoring a number of Suzuki teachers and their beginning violin students. For example, generally a violin teacher will correct pitch mistakes before rhythmic mistakes. There are also a set of heuristics associated with each learning component, these heuristics allows the system to decipher whether the student requires extra exercises or assistance in a given area. Of course incidental mistakes are overlooked but if a student continuously repeats the same mistake then the system will adapt and try to assist the student in correcting these mistakes before it becomes ingrained in the playing. It is important that the system is "intelligent" in so far as it knows when to intervene, how to intervene and what the necessary intervention is.

5 Research Plan

The research is divided into four key stages. The initial stage is concerned with observation and analysis of Suzuki teaching. This stage is of vital importance as it will inform the teaching strategies used within the ITS and the adaptive nature of the system. By monitoring Suzuki teachers, a greater idea of the type of feedback given and the nature of the feedback should be apparent. The second stage of the research involves the development of a prototype. The prototype will take input from the Suzuki parent, therefore omitting the need for music recognition software. At this stage the prototype will consist of a student model and adaptive decision module. Formative evaluation will consume the third stage of the research plan. These evaluations are based on two key questions: can an ITS increase learning during home practice and if the nature of all feedback is positive can the level of learning be increased? The fourth stage of the research will focus on the development of the music recognition software and student assessment module. Further formative evaluation will be conducted.

Research being conducted currently is concerned with the first stage of the research plan. The author is working with some Suzuki teachers. This research stage consists of observing the learning process between teachers and their young students. It is important that this learning environment is observed and analysed so that instructional strategies and processes can be understood and therefore mimicked within the system. Suzuki proposes that learning is a product of positive reinforcement. Therefore, particular emphasis is placed on the nature of feedback and the manner in which it is presented to the student.

The next stage of the research is concerned with the development of a prototype. The prototype will take input from the Suzuki parent, therefore omitting the need for music recognition software at this stage. Due to the simple nature of beginning Suzuki tunes, it is believed that given the expert performance it will be possible for the Suzuki parent to determine if the student has played correctly. The Suzuki parent may not be able to pinpoint what exactly is incorrect. However, as each Suzuki piece has a learning outcome associated with it the system will be able to determine the appropriate action. The prototype will cater for three types of feedback, verbal, musical and visual. The nature of all feedback will be positive.

Formative evaluation will be conducted during the third stage of the research plan. It is important that the ITS focuses on positive aspects of the student performance as to focus on the negative aspects would go against the philosophy of the Suzuki method. Correction must be presented in a positive manner. The formative evaluation will take into account two key considerations:

1. Is the ITS modeling the teacher's role correctly?
2. Is there a correlation between the type of feedback and the level of learning?

The fourth stage of the research involves the development of the music recognition component so input can also be gathered from student performance recordings. Also a number of research studies will be designed. These studies will allow us to determine the domain specific question, can an ITS improve learning during home practice for beginning violin students and the more general question, if the nature of feedback is positive is the level of learning increased?

6 Summary

The research proposed in this paper is concerned with the development of an ITS to aid beginning violin students learn the instrument. The system architecture consists of three modules a student assessment module, a student model and an adaptive decision module. The student assessment module analyses the student's performance. The student model captures information on the student's progress and the adaptive decision module makes intelligent decisions based on the student model. The system developed will determine if an ITS can improve learning during home practice and whether positive feedback can increase the level of learning?

References

[1] Corbett, A. T., Anderson, J. R. (2001). Locus of feedback control in computer-based tutoring: impact on learning rate, achievement and attitudes. Proceedings of CHI 2001, ACM, 2001 245 – 252

[2] Voyager (1989). *Beethoven's Ninth Symphony Interactive CD ROM*.

[3] Hofstetter, F. T. (1988). *Computer Literacy for Musicians.* Prentice Hall, Englewood Cliffs, NJ

[4] Thomas, M. T. (1985). Vivace: A Rule Based AI System for Composition. In *International Computer Music Conferenc*e, (pp. 267-274). San Francisco

[5] Brandão, M., Wiggins, G. & Pain, H. (1999). Computers in Music Education. *Proceedings of the AISB'99 Symposium on Musical Creativit*y

[6] Smith, M and Holland, S. (1993). MOTIVE - the development of an AI tool for beginning melody composers. In M. Smith, A. Smaill, and G. Wiggins, editors, *Music Education: An Artificial Intelligence Approach*, Workshops in Computing, pages 41–55. Springer-Verlag. Proceedings of a workshop held as part of AIED 93, Edinburgh, Scotland, 25 August

[7] Suzuki, S. (1999). *Suzuki Violin School, Violin Par*t, Volume 1-10, Miami: Summy-Birchard

[8] Kirshbaum, T. (1986). Using a touch-table as an effective, low-cost input device in a melodic dictation program. *Journal of Computer-Based Instruction*, 13(1):14–16

[9] Lamb, M. and Buckley, V. (1985). A user-interface for teaching piano keyboard techniques. In B. Schackel, editor, *Interact*

[10] Yoshinori, Y. and Nagaoka, K. (1985) Computerised methods for evaluating musical performances and for providing instruction techniques for keyboard instruments. *Computing and Education*, 9(2).

[11] Dannenberg, R., Sanchez, M., Joseph, A., Capell, P., Joseph, R. And Saul, R. (1990). A Computer-Based Multi Media Tutor for Beginning Piano Students. *Interface – Jounal of New Music Research*, 19(2-3), pp.155- 173.

[12] Baker, M. (1992). Design of an intelligent tutoring system for musical structure and interpretation. In K. E. M. Balaban and O. Laske, editors, *Understanding Music with AI: Perspectives on Music Cognition*, pages 467–489. The MIT Press, Cambridge, MA

[13] Smoliar, S. W., Waterworth, J. A. and Kellock, P. R. (1995). pianoFORTE: A system for piano education beyond notation literacy. In *Proceedings of ACM Multimedia 95*, pages 457–465. San Francisco, CA.

[14] Suzuki, S. (1986). Nurtured by Love: The Classic Approach to Talent Education 2nd edition. Suzuki Method International.

A Proposal of Evaluation Framework for Higher Education

Xizhi Li
The CKC honors School of Zhejiang University, P.R. China

Hao Lin
The CKC honors School of Zhejiang University, P.R. China

Abstract. In traditional education evaluation system, the goal is looking for appropriate methods (mostly numerical) to measure individual performance. While these highly compact measuring results provide some insights to the individual itself; they are less useful to other people and should avoid being used for public comparisons. By contrast, we propose an opposite approach, in which the focus of evaluation shifts from information regression to information aggregation. The philosophy behind this approach is to provide as much information about the individual as possible and reveal it in an ease-to-access manner to the individual as well as people who are interested in them. In the information age, it is technically possible to adopt information-rich evaluation system. We also designed a web agent based evaluation framework. It demonstrates one possible way to incorporate the new evaluation philosophy into the existing education evaluation system.

1. Introduction

In traditional education evaluation system, the goal is looking for appropriate methods (mostly numerical) to measure individual performance. While these highly compact measuring results provide some insights to the individual itself; they are less useful to other people and should avoid being used for public comparisons. An inadequate or unnecessary evaluation to the individual performance will usually lead to negative impact on the individual's learning and working experiences in a social environment. To summarize, the traditional evaluation system takes a synthetic or regressional approach in general. By contrast, we propose an opposite approach, in which the focus of evaluation shifts from information regression to information aggregation.

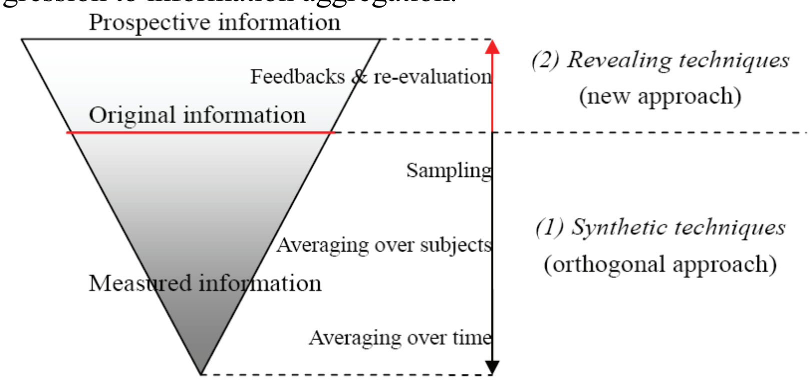


Figure 1. Two directions of evaluation techniques

Figure 1 recognizes the two aforementioned opposite directions in evaluation techniques. The triangle denotes all the information available, deducible and inferable from a certain individual. The line through the middle of the triangle denotes the original information from the information source (i.e. the individual being evaluated). The first (orthogonal) approach tries to reduce it to a minimum through several pre-designed irreversible filters such as sampling through tests, averaging over test marks and averaging over average test marks at different time. In contrast, the second approach works above the original information. It tries to reveal them in its integrity and generate new prospective information, which may be provided by formative feedbacks [7] from peers and other qualified individuals, etc.

The philosophy behind this approach is to provide as much information about the individual as possible and reveal it in an ease-to-access manner to the individual as well as people who are interested in them. In the information age, it is technically possible [1] [5] to adopt information-rich evaluation system. We also believe that the trend of education evaluation will be the emergence of various intermediate (intelligence) technologies and frameworks which make this new approach dominant in all education systems.

We envisage the future of education evaluation as building an information sharing space on the web, where each undertaking by the individual is, automatically or with minimum effort from the individual, recorded to the information space and available for other people to compare and use. It is like an annotated and recursively-written autobiography generation system with an intelligent interface. This aggregated evaluation database (or autobiography) will become an important product that both the individual and the education institute jointly deliver to the society and might continue to be useful after the individual starts his or her professional career.

In section 2, the learner model for undergraduate level college student is studied. In section 3, we propose a web agent based evaluation framework.

2. The Learner Model

Our student model is based on the engineering undergraduates in the CKC College, of which a short introduction is given in section 2.1.

2.1 Background of CKC College

Chu Kechen Honors College [2] (CKC College) is comprised of Mixed Honors Class (designed for engineering students), Science Honors Class and Art Honors Class，which are designed for elite students from the university. Special curricula are developed to help students build up a broad academic background in engineering, natural science or liberal arts. Students are encouraged to register for different courses in various departments and join graduate lectures in advance. They are also granted much chance in research at the graduate level under the instructions of distinguished professors.

A strict evaluation system is applied and only qualified students can accomplish the education program and be awarded the certificate. Both authors of this paper are students themselves in the college.

2.2 The Student Model

The study shows that students' education experiences differentiate very quickly as the time pass by. Hence, the evaluation for students' performance becomes harder, and the number of people who are qualified to evaluate the work of a student also dwindles.

Time line	1st year → 2nd year: **Knowledge acquisition and blind exploration**	**Need-driven or goal-driven creative development**	3rd year → 4th year: **Research-oriented or Professional undertakings**
Cooperation Style	Individual	Individual and/or Group	Group: leadership and membership
Education Focus	Foundation and Inspiration	Practices and Challenging goals	Self-directed learning, Research-oriented supervision, independent work and unique goals.
Most Needed Things	Good teachers, books, diverse curricula, special lectures, etc.	Good tutorials, Free time, Initiatives, Cooperation and Opportunity.	Information Acquisition and Work Sharing, Freedom to carry out independent research.
Least Needed Things	Exams and peer pressure	Restrictions on practices and Premature evaluation.	Deadlines and restrictions on the selection of research topic.
Major Evaluations In	Course works and understandings	Scientific, technical or organizational skills and experience gained.	Personal work publicized (but not necessarily published).
Primarily Evaluated by	Instructors and Agents	Peers And Friends	Colleagues and Supervisors
Best Graded by	Self Evaluation after problem solving and its feedbacks.	Self promotion And Peer Evaluation	Self promotion on sharable works

Figure 2. The learner model for evaluation
Note: The darker the colour in each cell, the more problematic the current approach is.

In Figure 2, a three-phase student model is presented. In phase (1) or during the freshman and sophomore years, students are mostly engaged in knowledge acquisition through rigorous course works almost in parallel. Students are usually inspired by things learned from books or instructors. Some talented students might explore a little bit deeper on a few selected topics than the average, but the explorations performed at this stage are mostly informal or blind. In phase (2) or the junior year, students are equipped with sufficient knowledge to carry out some practical projects. In other words, students are thirsty for practice of their newly acquired skills, and need internal or external motivations to participate in the development of some real projects. Many students can propose original frameworks to be implemented with their technical skills and through teamwork. Some also choose to participate in competitions such as Math Modelling Competition, ACM programming contest, Software development contest, etc. They are all need-driven or goal-driven projects. The difference is that some are driven by the goals of the individual; some are by goals in a competition or course project. In phase (3) or the senior year, students begin to carry out their own researches and wrote their own research papers and technology development reports. Some students may have roles in graduate-level research groups or internships elsewhere. Students mainly focus on an intensive research or technology development thesis experience. Independent works and unique personal goals at this phase will prepare the individual for innovative research and/or professional creative practices after its graduation.

2.3 Deficiencies in Current Evaluation Model

Compared to the student model, the current evaluation model is both monotonous and monopolistic. Several observed problems are described below.

First, the evaluation process is too short. At the time for evaluation, the college collects information such as test scores, competition awards, published research works, peer reviews, extracurricular activities and sports, and generates a synthetic report (almost always numerical) for classification or screening. Because of the short process, the accuracy and completeness of information collected can not be guaranteed.

Second, it overly emphasizes on test scores. Many students lose enthusiasm in other academic activities. The idea of information aggregation evaluation is to encourage students to actively evaluate and re-evaluate themselves, rather than relying on a vague and usually inaccurate "synthesized" result.

Third, students are passive subjects in the evaluation process. They are easily influenced by the change in the evaluation policies, which are set by college administrators. In our proposal, we try to build an environment in which one does not have to worry whether its research is "to the taste" of the appraisers.

Fourth, it lacks useful feedback mechanism. Currently, the students only receive evaluation from the college. Usually they are neither clear how the results are generated, nor have any chance to speak for themselves.

3. Web Agent based Evaluation Framework

This section describes a web agent based evaluation framework, which incorporates the new evaluation philosophy into the existing education evaluation system.

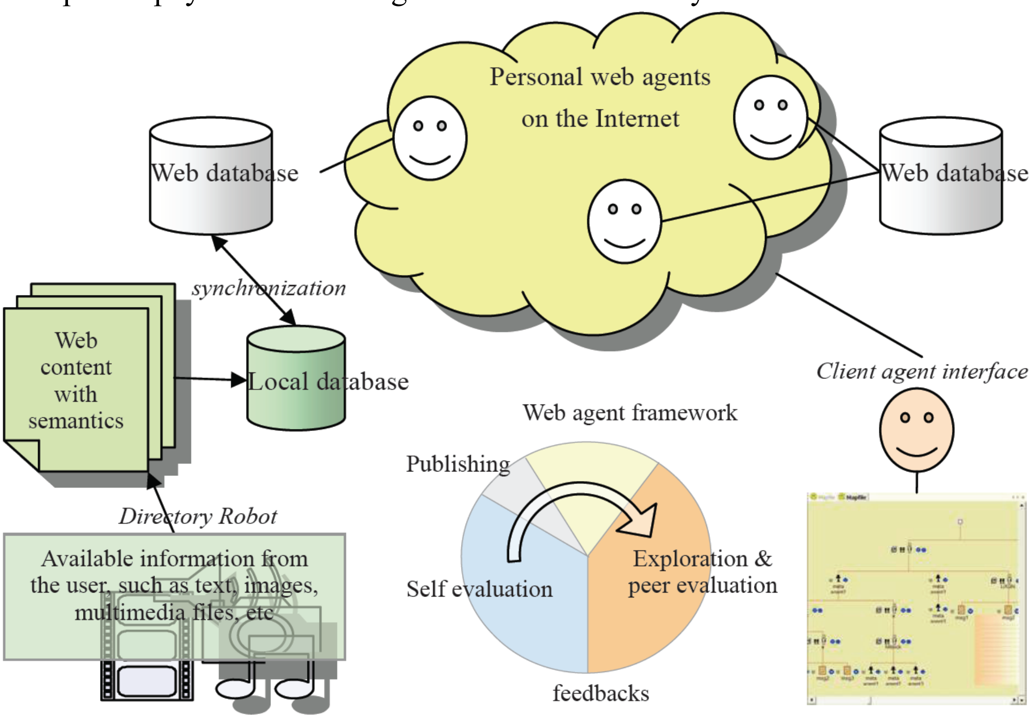


Figure 3. Illustration of the web agent based evaluation framework

Figure 3 shows an illustrative view of the framework. It is an iterative and open process of five phases as shown in the center disk of the figure. Around the disk are the underlying technological frameworks which enabled the corresponding tasks in each phase (colors are also matched between the evaluation tasks and their enabling technologies).

The evaluation process begins by *self evaluation*, in which a software agent helps the user to convert his information to web content in its local database. In the narrow sense, we define self evaluation in the framework to be the process of revealing personal information to the public. During self evaluation, the individual writes about (promotes) himself for the public and is responsible for the accuracy of what has been told. There are two constituents to supervise the accuracy of information during self evaluation. First is the publicity, because inaccurate information tends to be discovered quickly when it goes public. Second is the reference, because when information is referencing each other, fraudulency can be uncovered by traversing the reference graph. In the web agent framework, software tools are developed to facilitate these activities.

When the user's information has been prepared in the previous step, it can be published by a web agent on a public network such as the Internet or Intranet. To complete this task, we can use the web agent framework or WAF [3] [4] which we developed as a general agent framework. In WAF, a master can have one or several web agents which will represent this master on the web. Each web agent has an intelligent interface to provide information to users and other agents. Visitors (potential readers) could use a browser-like application (client agent application) to access the web agent framework. The user interface of the agent browser is designed in such a manner that the user feels like interacting with individual agent on the web. Web agents usually reference each other, therefore providing a mean of navigation (Figure 4).

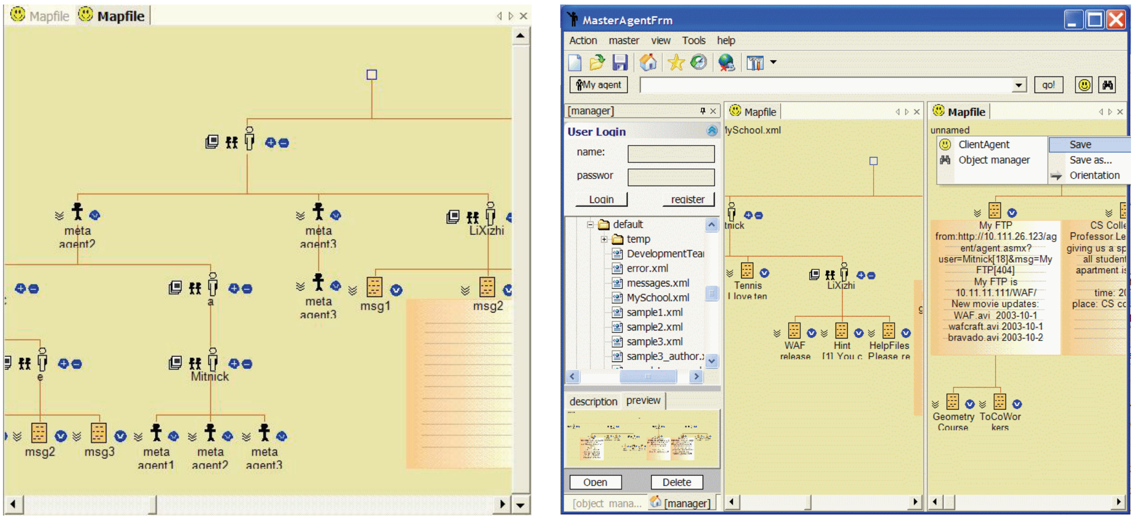


Figure 4. (Left) Users leave an off-line tree graph of visited agents and artifacts as they navigate through the agent network. (Right) Several map files and user's interaction with agents or managed information in these graph files.

Visitors can leave feedbacks to the web agents, which in turn will influence the self evaluation process. Hence, another cycle of evaluation begins. Most feedbacks are formative and offline. They are usually provided by human visitors or other web agents (on behalf of its users) in the form of comments to specific artifacts. Feedbacks provide a mean for people to hear opinions about their past works and change the attitude in their previous self evaluation. Feedbacks can also produce new references between individuals. It is likely that further relationships will be established between the two sides in the real world. In general, there are two kinds of people who will respond to self-evaluation: peers who conduct comparable research and professors who supervise student's works.

According to psychological and educational research [8], peer-assessment may result in friendship-marking (over-marking) and thus lack fairness or objectiveness. Therefore, comparable people outside a particular group are introduced into the review process. These outsiders might not have the same academic background, yet their opinions will increase the objectiveness. Peer review (from open groups of people) also adds value [9]. Timely and detailed feedback from peers would help people think from more perspectives and produce more meaningful thoughts.

Professors can also supervise their students' academic progress and perform most of their functions through WAF. With the use of agent technology, they can track the status of specific works carried out by their students, and provide comments, instructions and suggestions if necessary.

To conclude, the proposed framework is an information-rich and open system for evaluation and communication. It advocates self-evaluation and use a feedback and referencing mechanism to supervise and enhance the process. The students are encouraged to provide their information; and the evaluation system helps to increase it (information aggregation).

4. A Discussion and Conclusion

The psychological state and satisfaction of an individual consists both of its exploration process [6] and the expectation or result of the evaluation. Moreover, people tend to compare with each other in their comparable works. This automated comparison is a natural reaction of human being and is necessary for further communication among comparable people. Thus, the visibility of individual information and effectiveness of information sharing directly affect the satisfaction of people's internal needs for evaluation. To increase the comfort of people and foster active evaluation and communication, we need a more reasonable and open evaluation framework for people in the education systems.

In this paper, we have tentatively proposed a web agent based evaluation framework. We tried to answer the question: what current technologies will bring to the future evaluation system. And our conclusion is almost surprising: the focus of education evaluation will shift from information regression (synthetic approach) to information aggregation (revealing individual works and potentials).

Another characteristic of the proposed evaluation framework is that it is tightly integrated with personal and inter-personal development. E.g. it combines publication, discussion, assessment and re-evaluation in a single place and enables (also encourages) students to satisfy their own natural needs. We hope that our work would draw the necessary attention of education reformers and that more concrete actions could be carried out in the near future.

References

[1] Paul Penfield,Jr. and Richard C.Larson. Education via Advanced Technologies. IEEE Trans on Education. Vol. 39, No. 3, Aug 1996.

[2] CKC homepage, http://ckc.zju.edu.cn

[3] Xizhi Li, Qinming He. WAF: an Interface Web Agent Framework. International Conference on Information Technology. 2004.

[4] Xizhi Li. DHCI: an HCI Framework in Distributed Environment. 11th International Conference on Human-Computer Interaction. 2005.

[5] David McCann, et al. Educational technology in higher education. Higher education division, Mar 1998.

[6] Critina Conati and Jill Fain Lehman. Toward a Model of Student Education in Microworlds. CogSci'93.

[7] Robert S. Thompson. Relative Validity Of Peer And Self-Evaluations In Self-directed Interdependent Work Teams. ASEE/IEEE Frontiers in Education Conference (2001).

[8] D. Sluijsmans, F.Dochy and G.Moerkerke. Creating a New Learning Environment by Using Self-, Peer-, and Co-assessment. Learning Environment Research（1998）

[9] Jack McGourty, et al. Incorporating Student Peer Review and Feedback into the Assessment Process. Proceedings of Frontiers In Education Conference (FIE'98)

Supporting collaborative medical decision-making in a Computer-based learning environment

Jingyan Lu
Dept. of Educational and Counselling Psychology, McGill University
3700 McTavish Street, Montreal, Canada H3A 1Y2
Email: jingyan.lu@mail.mcgill.ca

Abstract: The use of computer-based learning environments (CBLEs) to support individual and collaborative learning in educational settings is expanding rapidly. My research goal is the design of a theoretically driven and pedagogically grounded CBLE to generate naturalistically compelling Emergency Room (ER) scenarios requiring medical students to collaborate in medical knowledge building and decision-making. The CBLE in this study provides visual representation and collaborative argumentation to support both individual and collaborative learning.

Introduction

Medical problem solving and decision-making are complex and difficult processes [1]. These processes become even more complicated in medical emergencies whose solution demands efficient deployment of relevant knowledge, experience and skills in dynamic, highly stressful contexts. During medical emergencies, the physician must simultaneously stabilize the patient or patients, monitor detected problems and rapidly diagnose life-threatening diseases under conditions of great uncertainty. Thus, preparing medical students to make fast and accurate decisions during medical emergencies is of great value.

In the mean time, computers and networks have been widely used in educational settings to support both individual and collaborative learning. It has been maintained that it is not technology per se, but pedagogical methods and theoretical rational that most directly influence learning. Sharing this belief, this proposed research is focused on designing a computer-based learning environment (CBLE) in which medical students practice decision-making in emergency scenarios that are empirically interesting and theoretical driven, and facilitate collaborative knowledge building.

1. Research questions

My research goal is the design of an empirically driven CBLE to generate naturalistically compelling Emergency Room (ER) scenarios requiring medical students to collaborate in medical knowledge building and decision-making. It is based on two years of observing and investigating the clinical teaching of medical decision-making in a busy ER. Clinical teaching for senior students is usually in small group format. Because of time limitation, normally only some students have the chances to practice their problem solving or decision-making skills. It is hard to tell if other group members (observers) are actively involved in thinking. In order to involve all the students in decision-making processes, we design a CBLE in which they can construct knowledge collaboratively.

However, in collaborative learning environment, most research has dealt with the discourse and social relations, or with cognitive and metacognitve aspects of problem solving. Association between individual cognitive processes and group social interaction has rarely been examined. I will investigate how students' decision-making activities, and thereby their conceptual understandings, change as a function of the collaborative learning processes. I will look at how individual cognition affects social interaction and how social interaction affects individual cognition. Furthermore, I will examine how CBLE shape individual and collaborative learning.

2. Background

2.1 Emergency education

ER provides unique training in several areas that not taught elsewhere in the undergraduate program. There are different requirements for students in each year training. Junior students can be taught basic first aid and emergency medical services system in their area. Senior students can hone their history taking and physical examination skills in ER [2]. This proposed study is to examine and facilitate senior medical students to practice basic rules and knowledge during their rotation in ER. At this level, issues related to patient management and decision making are best evaluated in small groups, such as simulation or problem-based learning (PBL) [2]. In addition to know what to do in the practice, students should know how and why they are doing as well [3]. This requires the designed learning context provide students with opportunity to elaborate and explain their decisions to others. In my design, these factors are considered.

2.2 Collaborative learning

A number of instructional approaches have developed that correspond to the increasing need for collaborative knowledge building in learning and working environment. A prerequisite for collaborative learning is a common ground which can initiate the construction of shared knowledge [4]. It is necessary to gain a deeper understanding of how knowledge is processed as individuals collaborate with each other. In collaborative knowledge building, two important cognitive processes, elaboration and co-construction, lead to deep understanding.

Elaboration means that students explain or justify their statements [5]. It can take place during group learning as the processes of considering a piece of knowledge in a richer, wider context [6]. It has been found that in PBL, elaboration is an important contributor to the cognitive effects [7, 8].

Co-construction occurs while two or more students contribute to resolving a conflict by arguing about the solution [5]. Collaborative argumentation is a medium for co-construction. In effective collaborative argumentation, participants focus on the same issues, and learn to negotiate conflicting opinions, until they accept or share the same answer or solution. It is regarded as a tool for promoting critical thinking as well as an essential quality of the discourse that is to be acquired in academic education [9]. Thus, collaborative argumentation during problem solving promotes the externalization, negotiation and reconstruction of knowledge [10].

3. CBLE as collaborative tools

Computer and network afford many features to support collaborative learning. One promising feature is to serve as computer-based representation tools [11]. These representations could be concept maps, graphics, or diagrams that allow group members to construct knowledge visually or elaborate and argument.

3.1 Visualization tools

Visual representations have been found to aid individual understanding and problem solving [12, 13] and computer can afford multiple knowledge representations for learning [14]. Visualization tools could be categorized into content-specific and content-unspecific [15]. Content-unspecific visualization tools are graphics editors that are not fixed to a special knowledge domain [16]. Most approaches, such as concept mapping or shared whiteboards, are content-unspecific graphics editors and are not constrained to specific knowledge domain. Using such approaches has shown promising effects on collaborative learning in different fields, such as chemistry [17] and mathematics [18].

Visualization tools have also been used with different formats. *Concept mapping* is an effective way to support collaborative problem solving design [19]. More interactive dialogues are fostered between learners while using *electronic diagrams* to develop educational programs [20] because the shared view of the diagram could help students track and overview the complex problem solving process under discussion. *Text representation*, such as threaded discussion, may facilitate conceptual understanding of color [21].

3.2 Argumentation tools

Argumentation is a key step for collaborative problem solving and knowledge building. It is a complex and variable activity, ranging from negotiation, justification, to convincing [22]. Computer environments can support collaborative argumentation by providing the opportunities for explanation and reflection, scaffolding the argumentation processes, and helping students keep track of their ideas. Computer supported argumentation could be represented as computer mediated communication, structured interaction, and argument representations.

Computer-mediated communication can be either synchronous or asynchronous. The immediacy of synchronous interaction has social advantage of motivating participants to engage and carry out interpersonal negotiation. Asynchronous interaction leaves some time for students to reflect before composing a response. The interactive and collaborative nature of this asynchronous communication allows students to establish relationship and seek assistance [23] and promote sustained and in-depth discussions [24].

Structuring can improve participants' orientation on subject matters, reduce off-task talks, lead to more coherence in discussing subject matters and focusing on topics [25]. In synchronous communication, structuring can be in the form of communication acts [26] or using sentence openers [27]. In asynchronous communication, structuring is determined by the processes required by a task, such as posting notes and making comments [15].

The production of a visual representation of an argument can serve as an external frame for knowledge construction and problem solving [16]. Visual representation may encourage exploration and negotiation in a way that is more explicit, thus improving the effectiveness of knowledge construction. Hence, the form of representation could influence the content of learners' argumentation.

4. Framework of CBLE

The proposed CBLE includes two activities: dynamic decision-making and structured synchronous discussion. Visualization and argumentation tools are embedded in CBLE to support these activities.

4.1 Dynamic decision-making: This is a role-playing decision-making activity between a medical student and the teacher. Students play the role of doctor and the teacher plays the role of ER nurse or patient. As ER nurse, the teacher provides patient's information when asked. As patient, he demonstrates the patient's deteriorating vital signs when a student doctor fails to take the right procedures. Communications about deteriorating vital signs and student's actions, plans, and results are entered into a computer and projected on the wall in the form of a diagram (Figure 1) that the role-playing student, teacher, and observing student can consult at any time. This representation also helps simulates a stressful environment in which students must make decisions quickly and effectively.

Case one: *Mr. Smith, 80 year old man, admitted to hospital because of melena, which was found to be secondary to Peptic Ulcer Disease (PUD), proved by gastroscope. His past medical history (PMHx) includes hypertension, diabetes type II, coronary heart disease, he had myocardial infarction in 1999. It is Saturday evening, you are on call, it's 10:00 o'clock in the evening. The nurse calls you because Mr. Smith 'doesn't look good'. What will you do?*

Decisions	Vital Signs					Prescriptions
	T	RR	HR	BP (mmhg)	O2 Sat	
General appearance: normal						
Airway: normal						
Consciousness: confused						
	37	30	120	210/80	95%	
						Give some fluid

Figure 1: Shared representation for dynamic decision making

4.2 Structured synchronous discuss: One major goal of this study is to involve observing students in the decision-making processes. Observers are asked to comment on role-playing student decisions in a structured discussion forum that is based on the ER algorithm. For example, the observer could choose "E" which represents Endo-metabolism and comment 'I think at this moment the major problem is diabetes instead of high blood pressure'. Observers can also comment on each other's comments. Discussions are shared by observers and only will be shown to the decision-maker when he gets stuck and asks for help. The decision-maker can access the discussion board so that he can adjust his decisions. He can also ask observers to elaborate on their comments. This collaborative knowledge building activity needs CBLE to visually represent discussion information in a synchronous, structured format. The CBLE facilitates collaborative knowledge construction and joint decision-making by enabling decision-makers to quickly and easily access well structured peer feedback.

5. Methods and data source

This paper proposes a design framework for the development of a CBLE for ER decision-making and collaborative knowledge building. This environment will incorporate visualization tools and argumentation tools to support these activities in a naturally distributed learning environment. Data that will be collected for analysis includes computerized decision-making processes and online and face-to face discussion. Cognitive task analysis (CTA) and discourse analysis (DA) are used for studying and assessing students' decision-making processes and collaborative knowledge construction. The relationship between individual and collaborative learning and how these processes are facilitated by collaborative tools will be studied based on the results from CTA and DA.

Reference

1. Elstein, A., L. Shukman, and S. Sprafka, *Medical Problem Solving*. 1978, Cambridge, MA: Harvard University Press.
2. Coates, W.C., *An educator's guide to teaching emergency medicine to medical students.[see comment].* Academic Emergency Medicine, 2004. **11**(3): p. 300-6.
3. Burdick, W.P., et al., *Emergency medicine in undergraduate education. SAEM Education Committee, Undergraduate Subcommittee, Society for Academic Emergency Medicine.* Academic Emergency Medicine, 1998. **5**(11): p. 1105-10.
4. Baker, M., et al., *The role of grounding in collaborative learning tasks*, in *Collaborative learning: Cognitive and computational approaches*, P. Dillenbourg, Editor. 1999, Pergamon: Oxford, UK. p. 31-63.
5. Visschers-Pleijers, A.J.S.F., et al. *Group interaction processes in problem-based learning: Elaborations and co-constructions*. in *JURE Conference*. 2002. Amsterdam, Netherlands.
6. van Boxtel, C., J. van der Linden, and G. Kanselaar, *Collaborative learning tasks and the elaboration of conceptual knowledge.* Learning and Instruction, 2000. **10**(4): p. 311-330.
7. Schmidt, H.G. and H.P.A. Boushuizen, *On Acquiring expertise in medicine.* Educational psychology Review, 1993. **5**: p. 205-221.
8. Schmidt, H.G., et al., *Explanatory models in the processing of science text: the role of prior knowledge activation through small-group discussion.* Journal of Educational Psychology, 1989. **81**: p. 610-619.
9. Veerman, A., J. Andriessen, and G. Kanselaar, *Collaborative argumentation in academic education.* Instructional Science, 2002. **30**(3): p. 155-86.
10. Savery, J.R. and T.M. Duffy, *Problem based learning: An instructional model and its constructivist framework.* Educational Technology, 1995. **35**(5): p. 31-37.
11. Roschelle, J. and R. Pea, *Trajectories from today's WWW to a powerful educational infrastructure.* Educational Researcher, 1999. **28**(5): p. 22-25. + 43.
12. Zhang, J., *The nature of external representations in problem solving.* Cognitive Science, 1997. **21**(2): p. 179-217.
13. Okada, T. and H.A. Simon, *Collaborative discovery in a scientific domain.* Cognitive Science, 1997. **21**(2): p. 109-146.
14. Jonassen, D.H. and C. Carr, *Mindtools: Affording multiple knowledge representations for learning*, in *Computers as cognitive tools II: No more walls: Theory change, paradigm shifts and their influence on the use of computers for instructional purposes*, S.P. Lajoie, Editor. 2000, Lawrence Erlbaum Associates: Mahwah, NJ. p. 165-196.
15. Fischer, F., et al., *Fostering collaborative knowledge construction with visualization tools.* Learning and Instruction, 2002. **12**(2): p. 213-232.
16. Hron, A. and H.F. Friedrich, *A review of web-based collaborative learning: factors beyond technology.* Journal of Computer Assisted Learning, 2003. **19**(1): p. 70-79.

17. Wu, H.-K., J.S. Krajcik, and E. Soloway, *Promoting Understanding of Chemical Representations: Students' Use of a Visualization Tool in the Classroom.* Journal of Research in Science Teaching, 2001. **38**(7): p. 821-42.
18. Baker, M., J.L. Cohen, and B. Moeller. *KidCode: Using Email to Structure Interactions for Elementary Mathematics Instruction*. in *Second International Conference of Computer-Supported Collaborative Learning (CSCL 97)*. 1997. Toronto, Canada.
19. Stoyanova, N. and P. Kommers. *Learning effectiveness of concept mapping in a computer supported collaborative problem solving design*. in *First European International Conference on Computer-Supported Collaborative Learning*. 2001. Maastricht, Nethereland.
20. van Boxtel, C. and A. Veerman. *Diagram-mediated collaborative learning: Diagrams as tools to provoke and support elaboration and argumentation*. in *first European Conference on Computer-Supported Collaborative Learning*. 2001. Maastricht, Netherlands.
21. Hoadley, C.M. and M.C. Linn, *Teaching Science through Online, Peer Discussions: SpeakEasy in the Knowledge Integration Environment.* International Journal of Science Education, 2000. **22**(8): p. 839-57.
22. Andriessen, J., M. Baker, and D. Suthers, eds. *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments*. Computer-supported collaborative learning. 2003, Kluwer Academic: Dordrecht, Netherlands.
23. Chong, S.M., *Models of asynchronous computer conference for collaborative learning in large college class*, in *Electronic collaborators*, C.J. Bonk and K.S. King, Editors. 1998, Lawrence Erlbaum: Mahwah, NJ. p. 157-182.
24. Guzdial, M. and J. Turns, *Effective Discussion Through a Computer-Mediated Anchored Forum.* Journal of the Learning Sciences, 2000. **9**(4): p. 437-469.
25. Hron, A., et al., *Implicit and explicit dialogue structuring in virtual learning groups.* British Journal of Educational Psychology, 2000. **70**(1): p. 53-64.
26. Baker, M., *Computer-mediated argumentative interactions for the co-elaboration of scientific notions*, in *Arguing to learn: Confronting cognitions in computer-supported collaborative learning*, J. Andriessen, M. Baker, and D. Suthers, Editors. 2003, Kluwer Academic: Dordrecht, Netherlands. p. 47-78.
27. Hirsch, L., et al., *A structured dialogue tool for argumentative learning.* Journal of Computer Assisted Learning, 2004. **20**(1): p. 72-80.

Role-based integration of evaluation and regulation in collaborative learning environments

José Antonio MARCOS GARCIA
GSIC, Intelligent and Collaborative Systems Group
Department of Computer Science, University of Valladolid
jamarcos@ulises.tel.uva.es

Abstract. Interaction analysis has become a basic function in the field of collaborative learning, as a means for supporting both *self-regulation* for the students and *formative evaluation* for the teachers. In spite of the fact that these processes rely on the same basic functionalities, there is a lack of proposals or systems that integrate them. This paper presents a research proposal that argues for a role-based approach for the integration of these functions. The experience of awareness systems in CSCW that use roles to decide the type and amount of information they show suggests that this is an appropriate approach. A review of the concept of role in CSCL environments has shown a lack of common vocabulary to describe it and a great diversity of classifications. In order to solve these problems, we have begun to design a framework for the description of roles and we have proposed a new classification of roles which takes into account the dynamic nature of interactions in real collaborative systems. We plan to apply this framework and concepts to the definition of a tool for the analysis of interactions, able to adapt to the changing needs of roles at a given moment. This will eventually lead to the integration of evaluation and regulation support functions in a single tool.

1. Introduction

During the first years the main research efforts within the CSCL (*Computer Supported Collaborative Learning*) field were directed towards the development of CSCL environments. Nevertheless, at present, the evaluation of these systems, and the learning that is promoted with them, are priorities of research in the area. For this purpose, the researches propose the elaboration of powerful tools and methods for interaction analysis for the study of collaboration [1],[2].

Our GSIC (*Collaborative and Intelligent Systems*) group at the University of Valladolid participates in several research initiatives related to the evaluation of collaboration and analysis of interaction. Our group has been interested in the evaluation and the analysis of interactions in CSCL for a number of years. Our main research effort in recent years has focused on the development of a method and tools for supporting formative evaluation in CSCL [3]. This method was oriented to support the evaluation of the collaborative activities once they are finished, in an off-line fashion. The validation of this previous proposal outlined the need of integrating regulation functions, i.e., to provide on-line support to the participants of a collaborative experience while they are collaborating. At present, the group is focusing on the refinement of this method and the tools that support it. More concretely, the work reported in this paper aims at integrating evaluation and regulation processes in collaborative environments.

A revision of interaction analysis tools shows that several proposals exist whose functionalities could be applied for one or another purpose [4],[5]. For example, some authors state that the information obtained by the teacher with an evaluation tool can be presented to the students to obtain self-regulation [6], as if it were a regulation tool. Nevertheless, these two approaches have so far been considered separately, as it can be observed by the lack of methods and tools that integrate them. However, this distance is not so clear if we consider that both approaches rely on the same basic functions [1],[3]. We argue that the main difference between the two approaches relies on the roles played by the actors to which these functions (and the corresponding tools) are oriented. Then, a tool able to adapt to different roles would be able to perform both functionalities. This leads to the idea that adopting a role-based perspective could help to integrate and extend the functionalities provided by interaction analysis in CSCL.

The rest of the paper is structured as follows: the next section exposes the main objectives and steps established for this research work. Then, section 3 shows the developed work until this moment. The section includes an integrated view of regulation and evaluation in collaborative environments and provides a systematic analysis of the different role classifications found in the literature. Next, section 4 presents the first approaches of research, on the one hand a new classification of roles and on the other hand a framework for describe roles in learning environments. The paper concludes with some open questions and an overview of our future research plans related to these topics.

2. Research purposes

The main objective of this ongoing research is to design and to develop interaction analysis tools capable to integrate evaluation and regulation processes in CSCL environments, taking in account the roles of participants at a given time.

To achieve it, the first step was to analyze the main differences and similarities between regulation and evaluation in CSCL and try to verify their possibilities of integration. As an outcome of the analysis we have argued that the main difference between the two approaches relies on the roles played by the actors to which these functions (and the corresponding tools) are oriented [7]. Then, a tool able to adapt to different roles would be able to perform both functionalities.

Thus, next step of research was to carry out a critical review of the types of roles proposed in the literature, in order to identify the roles that can appear in a collaboration management process together with the requirements that these roles pose to the analysis of interactions [8]. We have detected a lack of common vocabulary to describe roles, multiple definitions and different classifications of roles, many of them domain-dependent. Moreover, the majority of proposals are based on a static approach, that is, the roles are established initially and they ignore the dynamism of learning and the possibility that roles change during the activity.

In order to face these problems, we have begun to elaborate two proposals. On the one hand, we have identified two new dimensions that classify roles according to their appearance in the collaborative process (pre-established and emergent) and according to their variability (static and dynamic). These dimensions help us to identify the roles established before the beginning of activity and to detect the changes of roles during its development. A consequence of this approach is the need to define *indicators* and the values that identify the transitions between the different roles.

On the other hand, we have designing a framework that permits to establish a common vocabulary to define and to characterize roles in learning scenarios. At the same time, we have to go further in the description of the roles that are involved in collaborative learning scenarios, and establish their functional and user-interface needs. These needs will define the type of support that the different roles will need, which must me achieved by the interaction analysis functions.

Later, with the requirements established in the previous work, we will try to design and develop tools capable to integrate different functionalities depending on the roles that their potential users can play. Initially we take into account the needs of teachers and students in different contexts. This phase will imply to take decisions related to the interaction data representation model, the data analysis techniques and the format for the display of results.

Finally, the supporting tools will be tested in real situations in order to validate them. We plan to apply the proposals to two scenarios in different contexts. We will carry out the validation into different contexts: An asynchronous scenario, with university students and a synchronous environment, with students of secondary school.

3. Developed work

This section presents the results obtained from the work carried out up to this moment. They include the study of the possibilities to integrate regulation and evaluation processes, and the review of roles in learning systems into the literature.

3.1 Possibilities to integrate regulation and evaluation processes

To achieve our main objective of research, the first step was to analyse the main differences and similarities between regulation and evaluation in CSCL and try to verify their possibilities of integration. We have compared *the collaboration management cycle* [1], a generic framework of the systems oriented to scaffolding that support the collaboration, with *the extended cycle of collaboration management* [3], that include the aspects related to the evaluation support systems. We can state that both activities (i.e., regulation and evaluation) rely on the same basic functions. Moreover, these two approaches have so far been considered separately, as it can be observed by the lack of methods and tools that integrate them. We argue that the main difference between the two approaches relies on the roles played by the actors to which these functions (and the corresponding tools) are oriented (i.e. regulation to students, evaluation to teachers). This leads to the idea that adopting a role-based perspective could help to integrate and extend the functionalities provided by interaction analysis in CSCL [7]. A similar approach can be found in the effort to adapt awareness tools to different users in the CSCW field [9],[10]. From the experience of these systems we can state that the collaborative learning tools in would benefit from considering this aspect, in order to improve the collaborative processes in genuine environments. The problem would consist of detecting the needs of the participants in every moment, i.e., what information is needed and how it will be showed. Thus, a critical review of the types of roles proposed in the literature is necessary in order to identify these needs. Next subsection presents an outline of the main conclusions obtained after this review.

3.2 A review of roles in learning systems

We have done a revision of works that study the roles in fields related to collaborative learning scenarios, including CSCL, CSCW, e-learning, classroom-based research, group dynamics and adaptive hypermedia environments [7]. We have detected a lack of common vocabulary to describe roles, multiple definitions and different classifications of roles, many of them domain-dependent.

We have detected that there is a rather high consensus with respect to the generic roles that can be identified in a learning scenario, such as the teacher, the student, the designer, etc. In this generic classification the categories proposed by different authors are similar ([11],[12], [13],[14],[15],[16]).

On the contrary, this review shows that teachers' and students' roles depend very much on the approach and on the context of each work, and that there is no such consensus between the different authors ([13], [17], [18], [19], [20], [21], [22], [23], [24]). For example, while [17] includes the next teachers' roles: "facilitator, creator of consensus, animator, event of changes and supervisor'', [22] considers the "facilitator, designer, technician, evaluator, and administrative", and [19] "facilitator, guide and co-learner".

Also we have found divergences on the description of the functionality and needs of the same role. For example, [17] states that "the facilitator must create learning situations and improve the motivation of learners", but [18] considers that "they monitor the collaboration activities within a group, detect problems and intervene". Moreover, the majority of proposals are based on a static approach, that is, the roles are established initially and they ignore the dynamism of learning and the possibility that roles change during the activity.

4. Initial results

This section presents two initial proposals obtained from the work described in the previous section. On the one hand, we have identified a new classification of roles that takes in account dynamic aspects of learning, and, on the other hand, we have begun to design a framework for the description of roles in learning environments.

4.1 Towards a framework to define and describe roles in learning systems

It is necessary to establish a common vocabulary to define and to characterize roles in learning scenarios. In this line we have begun to design a framework that initially would have these four dimensions: actor, functions, needs and indicators.

An ***actor*** represents a generic role, that is, a human, an agent or any combination of them [15]. (i.e., the *teacher* and the *student* roles have been pre-established roles in a traditional classroom [18]).

A ***function*** is a characterization of an actor. With a function we could specify their activities, duties and responsibilities (i.e., as a *facilitator*, a teacher perform a minimal pedagogical intervention in order to redirect the group work in a productive direction or monitor which members are left out of the interaction [25]).

A ***need*** is a requirement for each pair role-function. These requirements relate to the necessary information (amount and type) and the functionalities of tools, and they are influenced by diverse parameters related to the context, as the scenario or educative level of students. For example, the interventions of the teachers will be produced on-line in a synchronous scenario, while in a asynchronous system these interventions can be produced by the next session, when the teacher may have studied previously the student's dialogue and action based interactions [2]. If we refer now to the educative level, we can state that the type and amount of information that will need a K-12 student will not be the same than the needed by a high-school student, for example [8].

An ***indicator*** is a parameter that helps to identify the transitions between the different roles. Each indicator is composed by a dimension name and the values that delimiter one possible change of role. The values can be different depending of the specific context.

4.2 A proposal of classification of roles that considers dynamic aspects of collaboration

We have identified two dimensions that classify roles takes in account the dynamic aspects of collaboration. Regarding *the moment of their appearance* we define **pre-established** and **emergent roles**. *Pre-established roles* are those that are assigned before the beginning of the collaborative activity (for example by task or by position in organization). *Emergent roles* are those that are not assigned in advance, but that appear spontaneously during the development of the activity [26].

According to their *variability* we define **static** and **dynamic roles**. *Static roles* are those that remain invariable from the moment of their appearance until the collaborative activity finishes. *Dynamic roles* are those that vary during the development of the collaborative activity, either due to a rotation of roles among the members of group, or because a change of task results in the assignment of new roles, or because the new roles arise spontaneously.

As a consequence of this approach, we can see that it will be necessary to define *indicators* and the values that identify the transitions between the different roles. These results in a two-way relationship between roles and analysis of interactions. First, analysis of interactions helps to identify roles, and then, these roles (i.e., the people representing them) will be supported by interaction analysis functions. So, this will lead eventually to the integration between regulation and evaluation based on the analysis of roles.

5. Conclusions and Future Work

This paper has presented the possibilities for the integration of evaluation and regulation processes in CSCL with a role-based approach. Motivated by existing proposals of awareness systems in CSCW, we have presented the need of considering roles when designing tools and systems for interaction analysis, in order to develop systems capable to integrate different functionalities depending on the roles that their potential users can play.

An initial review of the concept of role in the literature has shown many different definitions of this term and very diverse classifications, the majority of which are very domain-dependent and ignore situational dynamics of learning. Due to this diversity, we have initiated two new approaches. On the one hand, the identification of two dimensions that classify roles according to their appearance in the collaborative process (pre-established and emergent) and according to their variability (static and dynamic). These dimensions help us to identify the roles established before the beginning of learning activities and to detect the changes of roles during its development. On the other hand we have begun the design of a framework for description of roles in learning environments.

We have to advance in the description of the roles that are involved in collaborative learning scenarios and establish their functional and user-interface needs. These needs will define the type of support that the different roles will need, which must me achieved by the interaction analysis functions. Moreover, we have to define indicators and the values that identify the transitions between the different roles. At same time we should decide other questions as the results representation form, aspect directly related to the interface needs of users. Once it obtained this, we will begin to design and to develop tools for these purposes. Finally, the developed tools will be tested with real users in order to validate them.

Acknowledgements

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References

[1] Jermann, P., Soller, A., & Muehlenbrock, M. (2001). "From Mirroring to Guiding: a Review of the State of the Art Technology or Supporting Collaborative Learning". *Proceedings of European Conference of Computer Support Collaborative Learning (EuroCSCL´2001).* Maastricht.

[2] Dimitracopoulou, A. & Petrou, A. (2003). "Advanced Collaborative Learning Systems for Young Students: Design Issues and Current Trends on New Cognitive and Metacognitive Tools." *In THEMES in Education International Journal.* , 60 pages

[3] Martinez, A., Dimitriadis, Y., Gomez, E., Rubia, B., & de la Fuente, P. (2003). "Combining Qualitative and Social Network Analysis for the Study of Classroom Social Interactions". *Computers and Education, Special Issue on Documenting Collaborative Interactions: Issues and Approaches*, vol. 41, no. 4, pp. 353-368.

[4] Martínez, A. (2003). "Method and Model to computational evaluation support in CSCL" (in Spanish). Department of Computer Science. University of Valladolid. Valladolid, Spain

[5] Avouris, N. & Komis, V. (2002). "OCAF:An Object-Oriented Model of Analysis of Collaborative Problem Solving". *Proceedings of International Conference on Computer Support for Collaborative Learning (CSCL´2002).* Colorado, G.Stahl (ed)Lawrence Erlbaum Associates.

[6] Avouris, N., Komis, V., Fiotakis, G., Margaritis, M., & Tselios, N. (2003). "Tools for Interaction and Collaboration Analysis of Learning Activities". *Proceedings of the 6th CBLIS Conference.* Nicosia, Greece.

[7] Marcos, J.A., Martínez, A., & Dimitriadis, Y. (2005). "A classification of roles that considers dynamic aspects to integrate evaluation and regulation". Submitted to the 12th International Conference on Artificial Intelligence in Education (AIED, 2005).

[8] Marcos, J.A., Martinez, A., & Dimitriadis, Y. (2004). "The Role of Roles in the Analysis of Interactions in Collaborative Environments". *Proceedings of ECAI'2004. Workshop on Artificial Intelligence in Computer Supported Collaborative Learning.* Valencia, Spain, E.Gaudioso & L.Talavera (eds). pp. 23-25

[9] Drury, J. & Williams, M.G. (2002). "A Framework for Role-Based Specification and Evaluation of Awareness Support in Synchronous Collaborative Applications". *Proceedings of the 11th International Workshops on Enabling Technologies for Collaborative Enterprises (WETICE02).* Carnegie Mellon University, Pittsburgh, IEEE Computer Society Press.

[10] Dourish, P. & Belloti, V. (1992). "Awareness and Coordination in Shared Workspaces". *Proceedings of the Computer Support for Collaborative Working (CSCW) Conference.* Toronto, Canadá, ACM Press.

[11] Lund, K. (2003). "Human Support in CSCL". Netherlands: Kluwer Academic Publishers.

[12] Tongdeelert, P. (2003). "A Proposed Collaborative Computer Network-Based Learning Model for Undergraduate Students With Different Learning Styles." *Turkish Online Journal of Distance Education (TOJDE).*

[13] Denis, B. (2004). "Roles and Competencies of the E-Tutor". *Proceedings of Networked Learning Conference.* Lancaster University, England.

[14] Mizoguchi, R. & Inaba, A. (2004). "Learners' Roles and Predictable Educational Benefits in Collaborative Learning. An Ontological Approach to Support Design and Analysis of CSCL.". *Proceedings of 7th International Conference, ITS 2004.* Maceió, Alagoas,Brazil, J.C. Lester et al. (ed). pp. 285-294

[15] ISO/IEC JTC1 SC36 N0065. (2001). "Expertise and Role Identification in Learning Environments." *Information Technology for Learning, Education and Training.*

[16] Lijnse, P. (2000). "Didactics of science; the forgotten dimension in science education research?". *Improving science education: the contribution of research*. Buckingham, UK:Open University Press.

[17] Marín, M. & Pérez, G. (1985). "Social Teaching and Sociology of the Education: Roles of Teacher as the Leader of Classroom" (in Spanish). pp. 228-48. Madrid, Spain: UNED Publications

[18] Tinzmann, M. (1990). "What Is the Collaborative Classroom". *Proceedings of NCREL.* Oak Brook.

[19] Jones, B., Valdez, G., Nowakowski, J., & Rasmussen, C. (1995). "Designing Learning and Technology for Educational Reform". Washington, EEUU: the North Central Regional Educational Laboratory.

[20] Gisbert, M. (2000). "The Teacher of 21th Century". *New Technologies for Learning Imporve*, (*J. Cabero et al ed*). pp. 315-30. Sevilla, Spain: Kronos.

[21] Lee, M. (2000). "Collaborative Learning in Three British Adult Education Schemes". *Proceedings of Adult Education Research Conference, (AERC,2000).* University of British Columbia, Vancouver, Canada..

[22] Shank, P. (2004). "Competences for Online Instructors." *Learning Peaks LLC.*

[23] Singley, M., Fairweather, P., & Swerling, S. (1999). "Team Tutoring Systems:Reifying Roles in Problem Solving". *Proceedings of the Computer Support of Collaborative Learning Conference (CSCL'99).* C.M.Hoadley & J.Roschelle (ed)Hillsdale, NJ: Lawrence Erlbaun Associates. pp. 538-548

[24] Plety, R. 1996. *Cooperative Learning*. Lyon, France: ARCI PUL.

[25] Chen, W. (2004). "Supporting Teachers Intervention in Collaborative Knowledge Building". *Proceedings of ECAI'2004. Workshop on Artificial Intelligence in CSCL.* Valencia, Spain, E. Gaudioso &L.Talavera (eds). pp. 1-5

[26] Strijbos, J.W. (2003). "Functional Versus Spontaneous Roles During Computer-Supported Collaborative Learning". *Proceedings of Second International Conference on Multimedia and ICTs in Education (m-ICTE 2003).* Badajoz, Spain.

Logging, Replaying and Analysing Students' Interactions in a web-based ILE to Improve Student Modelling

Manolis Mavrikis [a,1]

[a] *The University of Edinburgh*

M.Mavrikis@ed.ac.uk

Abstract. This paper describes work in progress on logging, replaying and analysing students interactions with a web-based environment in order to inform the design of a student model that takes account of students' affective characteristics as well as cognitive ones. With the main goal of recording as realistic interactions as possible, an agent was developed that has the ability to record every student action. Employing the agent while students are working in real situations and with learning goals that are linked to their usual studies, helps us to collect data which are more representative of the way in which the final intelligent system would be used. The interactions can then be replayed to experts to provide information and mappings about the actions the system should take. Analysis is still at its early stages but we discuss preliminary results and the types of actions identified that can help to determine the best level of abstraction, identify useful moments for replaying, and ease future computational analysis.

1. Introduction

With the advancement of computers in education and the emergence of e-learning, interactive (and intelligent) learning environments (ILEs) are becoming more and more integrated in the classroom. This provides an opportunity for conducting research under more genuine situations. For example, studies can be linked (if carefully designed) to the usual material students have to learn or the assessments they have to take (eg. [11]). By conducting studies in realistic didactic situations and the same medium that students are using for their learning we can achieve a better understanding of the learning process, of the students' behaviour and the actions that make sense in this particular context.

It is reasonable to expect that students interact differently when they are working on their own than when they are observed or take part in a study. This is indeed what we have observed so far (see [12]) and what similar research suggests. For example, [6] describes a set of non-learning-oriented strategies termed 'gaming the system' that students manifest as responses to the feedback and support that an ITS offers. Our preliminary observations of students working in a web-based ILE were similar not so much on the direction of gaming the system but general aspects of interactions that pertain to motiva-

[1] Correspondence to: JCMB, Mayfield Road, Edinburgh EH9 3JZ, UK. Tel.: +44-131-6505076

tion and affect and are directly hindering learning. The fact that the actual use of ILEs is something for which we know little about, is a significant factor which can compromise the design of important components of the system like the student model. In particular, if one is interested in affective and motivational characteristics of students then it is quite difficult to separate confounding factors (see [7] for similar examples of obscuring problems in user modelling). Therefore, research conducted in realist conditions has the potential to yield more accurate data and help in fine tuning the system accurately.

Our interest lies primarily in identifying subtle aspects of the interaction that can be taken into account to improve the system's diagnosis and the appropriate actions it could take. To achieve that we need to have access to data that can be analysed in different levels of granularity. Recording fine grained data, as [13] notices, yields more opportunities for research. The multiple granularity means that we can conduct similar analyses as the ones that have been highly successful so far (for example, [2,3]). In fact, the more detailed the data are the better the analysis. For example, one of the problems reported during the knowledge elicitation interviews in [8], for obtaining rules that refined the system's knowledge, was that experts had quite a limited input bandwidth as they could only see students' chosen topic and the final selections they made in MCQs.

This paper, after briefly presenting the technology behind an agent for logging detailed students' interactions in a web-based ILE., discusses preliminary results from studies conducted under realistic situations. We describe ways of visualising the data and relevant results that can help us see what to expect and how to conduct future analysis.

2. Recording students' actions

There are several ways to record students' actions when they are working in a predefined environment or a lab where an experiment or study is set up. On the other hand, it is very difficult to set up and use equipment (such as cameras, tape recorders or even screen capture software) let alone have an observer to study what students are doing when they are interacting in their time and place. Of course, one can analyse the log files of the web server that provide information on the pages and the time they were accessed but, especially when the environment involves client-side interactions, the data logged can be quite limited for the research purposes in the field of ITS.

In addition, most of the approaches for logging and analysing interactions make prior decisions about what behaviour is relevant to log, and tend to log at a coarser granularity. When this fits the intended analysis it leads to very interesting and successful results (see for example [4,5]). However, we wanted to go a step further and record as much information as possible with a two-fold purpose. On one hand, to be able record enough unbiased information in the least intrusive way possible; in the same way that we would like our ITS to track and analyse students' activity. On the other hand, we need to find which kinds of actions are important and what actions the system should take. Recording the interactions and having the ability to replay them can help in eliciting knowledge from experts and identify useful patterns that can inform the design of the student model.

In order to log and replay the students interaction with the web-based system an agent that can be added to an ILE was developed. The agent records *every* student action including mouse movements, mouse and keyboard clicks etc. A piece of JavaScript code adapts the elements (buttons, divs, input boxes etc.) of every (X)HTML page that the

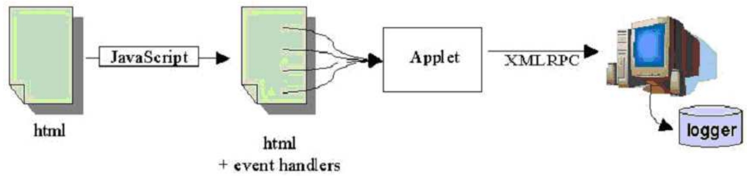

Figure 1. The architecture of the agent which logs students' interactions

system delivers adding event handlers to all of them so that they can send messages to a hidden Java applet. The applet in turn sends them, every so often (or just before the student logs out), to a server where they are logged (see figure 1). The data logged serve several purposes and give us the opportunity not only to replay accurately the student's interaction with the system but also permit data-mining of information that would not be accessible otherwise (eg. cancelled submissions or clicks). In addition, having developed the agent for the logging is a step towards the agent that will be added to the ILE to inform the student model about the actions the student takes.

The agent has been added to a web-based educational environment called WaLLiS (see [10]) which has been integrated into the teaching of science and engineering students studying mathematics at the University of Edinburgh. In this context, students are often asked to interact with the system and explore the material either for the purposes of a project or an assessment. Therefore, it is reasonable to assume that the data collected are representative of the true and realistic usage that the final ILE would have.

3. Replaying and analysing the log files

As already mentioned, the data collected involve every student action from page selection to page abandonment and from mouse movements and clicks to key presses. The full interaction makes it easier for experts and tutors to engage with the situation and comment on the student's state and on the actions that they, as tutors, would have taken. Of course, an additional layer of information could be added by, for example, showing video of the students and having talk aloud protocols. However, this would require a controlled study and would also change the bandwidth of information that are available to the expert compared to that of the system. Although we intend to combine and contrast our results with that of other empirical studies, where interactions are recorded in more constrained environments, the primary goal here is to see what knowledge we can extract from this situation with limited information. Our hypothesis is that detailed log files allow subtle aspects to be manifested. These will provide enough cues based on which one can take decisions regardless of the lack of information. If that is the case, we could design the tutoring system to take account of the same information. Components of the ITS could then use this information to take appropriate tutorial actions (eg. adapt the following page, provide different feedback, intervene etc.).

The added benefit of this kind of data is that data-mining is now easier. Based on suggestions in [13] we were particularly careful to record the context of each interaction. This includes, apart from information of the particular student (background, academic achievement), goals that they were asked to achieve, feedback given by the system, pre and post assessment results. This way, the data need no reification at all and they contain the same kind of information that the final ITS would have access to.

3.1. Replaying and visualising interactions

In order to test our hypothesis and elicit knowledge for the student model, we will be replaying the full interaction to human tutors asking them to comment on the actions they would have taken and the factors which influence their decisions. We have only conducted preliminary analysis at this stage and pilot studies that can inform the design of the final study and help in automating the log file analysis. We have separated three types of actions so far and these include:

- students' page selection process (eg. speed, order)
- local actions in interactive pages (eg. reading theory, hint or solution requests)
- 'micro' actions (keyboard and mouse actions like hovering over buttons, deleting their input, cancelling a button click, actions in the input editor etc.)

All these are user actions based on which the tutor could adapt subsequent actions. For example, page selection and abandonment shows what the student is interested in, selection of easier tasks can provide information about the students' motivation, confidence, interest and learning style. More importantly, local actions such as reading carefully the theory, then asking for help and insisting on attempting to answer (instead of immediately asking for the solution) can be used to inform the student model about persistence. These kinds of actions, in particular, differ significantly from interactions that occur in controlled situations. For example, students often abuse the help provided by the system, provide random answers, exhaust the available hints in order to get the solution.

As we mentioned already, this is the first step of analysis and more research needs to be conducted. Developing the right tools and being able to replay and visually represent the data was a precursor to analysing them in a coherent way. The most difficult part now is to identify the best level of abstraction for the various interactions and determine the most interesting ones to replay. We have developed ad-hoc parsers which, depending on the level of the desired analysis, build graphs to help us visualise the data.

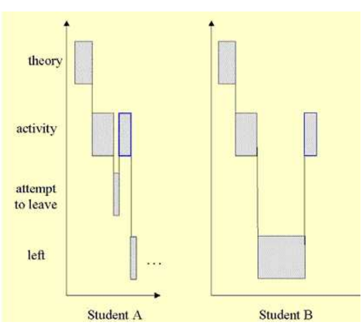

Figure 2. Navigation actions

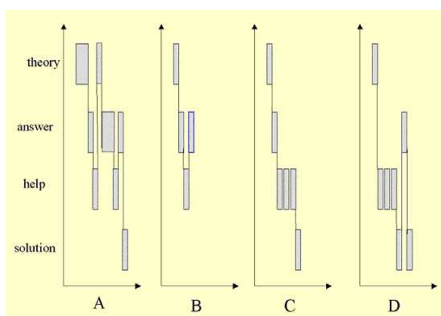

Figure 3. Local actions

For instance, figure 2 illustrates two users with different behaviour. Student A attempted to leave but under the system's guidance (see [12]) did remain at the page to complete the activity. Student B left, visited other pages and then returned to complete it. Similarly, local actions may also have an effect on the tutor's diagnosis. For example, the interactions of student A, C and D (fig. 3) are quite different despite the fact that they all ask for the solution at the end of the activity. So far, we have seen several sequences of actions which provide evidence of what we could call ‘meaningful interaction’. Finally, ‘micro’ actions can add to the overall picture of the student. For instance, holding down a button and then releasing it after a while shows signs of hesitation. Similarly cancelling the decision to click the submit button may show uncertainty on the correct answer. Results from other human-to-human studies that take place in a constrained computer-mediated environment show that tutors do intervene when students seem hesitant to reply and modify their strategy trying to increase their confidence. Without tools that can record most (if not all) actions this information would have been lost.

3.2. Preliminary data-mining

So far, we have focused on a study designed around a particular context when WaLLiS was used as part of the usual assessment that students have to undertake in the ‘Geometry and Convergence’ course of the School of Mathematics of the University of Edinburgh. From the 126 students the interactions of 87 were useful to analyse[1]. Although their performance was improved overall [11] we observed, perhaps not surprisingly and consistent with similar findings in [1], that there is no significant evidence that high help seeking correlates with the students’ performance when we partial out the effect of their ability in particular questions in the prerequisite course; $F(2, 84) = 2.8$, $p = .066$, and partial $r = 0.16$, $t(84) = 1.5$, $p = .137$. Similar lack of evidence applies for the level of interaction; $F(2, 84) = 1.834$, $p = .166$, partial $r = .06$, $t(84) = .632$, $p = .529$.

After replaying some of the data it was made clear that our model of interaction should take into account factors such as confidence, persistence, and effort. Similar findings are also reported in [4,1,6]. Our hypothesis is that some of these factors can be inferred from the student’s interactions. For example, by identifying interesting aspects of the interactions, which preliminary replays suggest they could hinder learning, we have separated students who engage in particular interactions. Due to space limitations we cannot list here all the details of the rules that group students but they include aspects like asking for help sooner than a threshold of standard deviations below the mean time of hint requests across all students in particular steps, exhausting help and requesting solution without attempting to answer first, providing a random answer etc.

There is evidence that belonging to this group is correlated with performance orientation as identified by interviews of 21 of them; $F(1, 19) = 4.571$, $r = .44$, $p = .046$. It is also significantly correlated with their immediate attempt to access the related assessment sooner than having finished all the learning material $F(1, 85) = 24.767$, $p < .01$, $r = .475$. These particular aspects of the interaction are related to theories (e.g. [9]) in educational psychology which classify students according to performance and learning orientation. Performance-oriented students try to avoid making mistakes or just try to perform well without necessarily learning. Both of these goals can be achieved by the interactions reported above. Our results provide evidence for the hypothesis stated in [6] on the relation of gaming the system and performance orientation and shows that these aspects of the interaction are interesting and should be investigated further.

Of course, as we mentioned before, it is important to investigate what the exact response to this diagnosis should be. Aspects of the interactions can be subject to different interpretations by different people. This is when replaying the log files to human tutors and cross validating the results can provide more coherent results.

[1] Due to security issues, network noise, or other problems some logs are not useful for statistical analysis

4. Conclusion

We discussed how the advent of ILEs and their integration into classroom provides an opportunity to conduct research in more realistic situations, and inform the design of more effective student models. Especially when one is interested in motivational, affective and generally behavioural characteristics of students, research can easily be compromised by Hawthorne-like effects. To overcome these limitations we developed an agent that records the full interaction of students even when they are working in their own time and location. We have established differences in the interactions when they are working without being observed that show that their interest, motivation and effort play a crucial role in the way they interact. While searching for patterns and other ways to computationally analyse the data, we are replaying the recorded interactions to human tutors in order to elicit knowledge that would be otherwise diffi cult to obtain. The data analysis is still in progress. Having identifi ed types of actions (navigation , local and micro actions) and specifi c instances of them that potentially hinder learning will help us identify interesting moments to reply in order to elicit diagnostic rules from experts that will inform the design of the student model and the actions the system should take.

References

[1] V. Aleven, E. Stahl, S. Schworm, F. Fischer, and R. Wallace. Help-seeking and help design in interactive learning environments. *Review of Educational Research*, 77(3):277—320, 2003.

[2] J.R. Anderson, F.G. Conrad, and A.T. Corbett. Skill acquisition and the lisp tutor. *Cognitive Science, 13, 467-506*, 1989.

[3] I. Arroyo, J. Beck, B. Woolf, C. Beal, and K. Schultz. Gender and cognitive differences in learning with respect to hint interactivity and symbolism. *International Conference on ITS, Montreal*, 2000.

[4] I. Arroyo, T. Murray, B.P. Woolf, and C.R. Beal. Inferring unobservable learning variables from students' help seeking behavior. *Workshop on Analysing Student-Tutor Interaction Logs to Improve Educational Outcomes in Intelligent Tutoring Systems 2004 Brazil*, 2004.

[5] R.S. Baker, A.T. Corbett, and K.R. Koedinger. Detecting student misuse of ITS. *Proceedings of the 7th International Conference on ITS*, pages 531–540, 2004.

[6] R.S. Baker, A.T. Corbett, K.R. Koedinger, and A.Z. Wagner. Off-task behavior in the cognitive tutor classroom: When students 'game the system'. *Proceedings of AMC CHI 2004: Computer-Human Interaction*, pages 383–390, 2004.

[7] D. Chin. Empirical evaluation of user models and user-adapted systems. *User Modeling and User-Adapted Interaction*, 11:181–194, 2001.

[8] A. de Vicente and H. Pain. Eliciting motivation diagnosis knowledge. In S. P. Lajoie and M. Vivet, editors, *Proceedings of the 9th World Conference on AIED*, pages 651–653, 2003.

[9] J. M. Harackiewicz, K. E. Barron, and A. J. Elliot. Rethinking achievement goals: When are they adaptive for college students and why? *Educational Psychologist*, 33:1–21, 1998.

[10] M. Mavrikis and A. Maciocia. Wallis: a web-based ILE for science and engineering students studying mathematics. *Supplement Proc. of the International Conference on AIED*, 2003.

[11] M. Mavrikis and A. Maciocia. Incorporating assessment in a web-based ILE. *Computer Assisted Assessment Series by Learning and Teaching Support Network*, 2004.

[12] M. Mavrikis, A. Maciocia, and J. Lee. Targeting the affective state of students studying mathematics on a web-based ILE. *YRT of 11th International Conference on AIED*, 2003.

[13] J. Mostow. Some useful design tactics for mining ITS data. *Workshop on Analysing Stu-dent-Tutor Interaction Logs to Improve Educational Outcomes in ITS 2004 Brazil*, 2004.

How do Features of an Intelligent Learning Environment Influence Motivation? A Qualitative Modelling Approach

Jutima METHANEETHORN[1]
The SCRE Centre,University of Glasgow, Glasgow, UK, G3 6NH
jutima@scre.ac.uk

Abstract. Recent research points to the notion that motivation is a crucial factor when creating Intelligent Learning Environments (ILEs). Yet the research in motivation in tutoring systems has not considered relationships between features of ILEs and components of learners' motivational structure. Several interesting questions can be addressed: (1) How do these features/ingredients impact on the motivational structure of learners? (2) What is the evidence that cause-effect relationships exist between those ingredients and the components of learners' motivation? (3) If so, what is the nature of these relationships? This paper proposes to use a qualitative modelling approach to model motivational characteristics of learners while interacting with an ILE, particularly within the context of educational game and narrative. Some parts of work in the modelling process are presented. The model is also described in the aspect of process based on qualitative process theory. We outline an approach to validate the model at the end of the paper.

Introduction

Learners' motivation is now regarded as a crucial aspect in developing an intelligent learning environment. The work by del Soldato & du Boulay [1] was foundational in that it dealt with motivational aspects of Intelligent Tutoring Systems (ITSs), in particular by including a motivational module which can perform motivational state modelling and motivational planning. de Vicente & Pain [2] also dealt explicitly with motivation in ITSs. They detailed an interesting approach to the detection of motivation and the outcome of their study was a set of 85 inferred motivational rules.

However, the above research has not focused on how the communication method, particularly its components/elements, impacts on learners' motivation. We define 'communication method' as the context for presenting learning instructions to learners (e.g. online learning, Virtual Reality (VR), educational game, etc.). An educational game with a strong narrative was chosen to use as the communication method for modelling motivational characteristics of learners while interacting with an ILE because both combined together can have a strong impact on learners' intrinsic motivation [3].

In section 2, we present the aim of our research including our research questions. Next, we describe a qualitative modelling approach to modelling the motivation of learners. We then end with our future steps and an illustration of how to validate our model.

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[1]The author is a PhD student under the supervision of Prof. Paul Brna. Many thanks to him for his advice during the writing of this paper.

1. Modelling the Motivational Characteristics for an ILE

Since there are no explicit models of how learners are motivated while using an ILE, we have chosen to research the construction of a learner's motivational structure and this initiates the aim of our research: to create a predictive model of motivation for an ILE in a particular context. We believe that such a model will be potentially of great benefit when creating tutoring systems that take into account the motivational aspects of the learners.

We narrow down our attention to the educational game context as our communication method to learners because from the literature, the association of motivation, educational game and narrative seems to be strong [4-6] and it appears that if we can determine a motivational structure for any intelligent instruction in a particular context, the structure might not be the same as in other contexts. In other words, by varying contexts, motivational structure seems to change accordingly. Hence, our main research questions upon which this paper is centred are: given a specific context for an ILE, can we determine a motivational structure for learners during their interaction? Can we make progress in determining the way this might change during the interaction?

We chose to investigate the relationship between the ILE features which we define as the basic elements that make up an ILE, and a learner's motivational characteristics which we define as motivational variables of the learners which can be placed into two categories: trait (permanent characteristics) and state (transient characteristics) (adopted from de Vicente & Pain's motivation model [2]) because we believe that there is a strong relationship between them.

2. Qualitative modelling and motivation

Qualitative modelling has a history which goes back much further than 20 years. At that time there was a great deal of interest within the Artificial Intelligence (AI) community in developing a qualitative physics that predicts and explains the behaviour of mechanisms in qualitative terms. The goals for the development of the qualitative physics are (1) to be much simpler than conventional physics, (2) to produce causal descriptions of physical mechanisms that are easy to understand, and (3) to provide the foundations for common-sense models for the next generation of expert systems [7-8].

Qualitative Modelling has been brought to the AIED community as a valuable way for students to learn conceptual knowledge. An example of using qualitative modelling to support learning is a development of model-building environments, VMODEL and HOMER/VISIGARP which help learners in constructing conceptual models of systems including their behaviour [9]. Another example is the use of qualitative modelling to capture and simulate commonsense theories about population and community ecology [10-11].

The motivation for applying the qualitative modelling approach to model motivation of learners stems from our consideration of motivation as a dynamic and complex system which is difficult to inspect. The qualitative approach can be used as a tool for dealing with such a system. It can be used for building conceptual models of complex systems, grounding explanations on explicit representations of the causal influences, implementing easy to change assumptions, testing different hypotheses and complementing numerical models. From the literature, one technique used for modelling affective states of learners is based on Bayesian approach; for example, Conati & Zhou [12] use Dynamic Decision Networks (DDN) which is an extension of Bayesian Networks to model emotional states of the user during interactions with a computer-based educational game, aiming to help students learn number factorization. We consider that using the Bayesian approach can produce a numerical probabilistic model but it cannot easily provide information about the dynamics of the learners' motivation. We are interested in providing a better cognitive account of what is going on when learners are motivated, so we can seek to manipulate that in a sound ethical and pedagogical manner. From our point of view, there are methodological advantages in developing a qualitative model before a quantitative one.

When creating a qualitative model in an ILE, there are some main characteristics needed to be identified such as the structure of the model, the behaviour and dependencies & causality [13]. A major focus of our research is a preliminary causal model that shows the cause-effect relationship between a learner's motivational characteristics and ILE features. The current version of the model is shown in Figure 1.

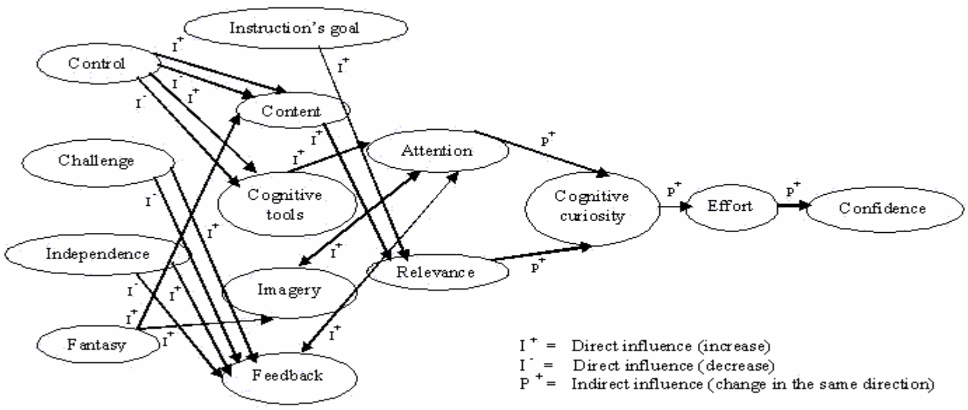

Fig 1. Causal model showing the relationship between a learner's motivation and ILE features

de Vicente & Pain's motivation model [2] has two motivational variables (sensory curiosity and satisfaction) which we did not incorporate to our model because we consider that the notion of sensory curiosity and attention is nearly the same and for satisfaction we believe that if the motivational structure of a learner looks like the model in Figure 1, the final state of the learner will be satisfaction.

The above preliminary model comes from our intuition about the cause-effect relationships between the learner's motivational characteristics and the components of the ILE. While these intuitions are based on a reading of the literature, these links ultimately need to be justified. We believe that a learner's trait can influence the use of those ILE features directly either increasing or decreasing the use of them, so the ILE components should be able to adapt themselves according to the traits of the learner. Consequently, by designing the ILE that contains adaptive capabilities, this can positively impact on two states of the learner (attention and relevance). This will, then, leads to changes in the same direction for the rest of the states in the model (cognitive curiosity, effort and confidence) accordingly. Even though we expect that the states of the learner should be positive if it is the case that the ILE impact on the learner's state negatively; for instance, feedback given to a learner might not provide important details for completing a task and this can reduce his/her motivational level in learning in certain circumstances, some features of the ILE should be able to adapt themselves according to the learner's state to increase his/her motivational level again. The features we have considered are imagery and feedback which have influences on the attentional state of the learner. So, we use a two-way arrow to represent this kind of relationship. There is also another point in the model that is deserving of attention - the relationship between traits and the goal of the instruction. Notice that there is no link between them because we consider that in the real world when we develop any tutoring systems according to a specific curriculum, the goals of an instruction are fixed rather than flexible.

2.1 Qualitative Process Theory and motivation

We consider that our model should be further described in terms of process, the ways in which things change over time, because the means by which motivation actually changes have not been provided so far; and we also suspect that motivation seems not to be just about relationship or value, but also some sort of function incorporated with it. Hence, we employ qualitative process theory [14], which appears to be useful as a language in which to write dynamical theories, to define a simple notion of process among elements in our motivation model. Our central assumption within this theory framework is ‘All changes in motivational system are caused directly or indirectly by processes’.

Applying the qualitative process theory with our model, several process descriptions could be created. We define the term ‘process description’ as a description of process that causes motivaion. A process can be specified by five parts: (1) the individuals (objects/elements) it applies to, (2) a set of preconditions, statements about the individuals and their relationships, (3) quantity conditions, statements of inequalities between quantities of the individuals or statements about the status of processes, (4) relations, the process imposes between the parameters of the individuals, (5) Influences imposed by the process on the parameters of the individuals. An example of the process description in our context is shown in Figure 2 (Adapted from modelling fluids and fluid flow [14]). There is another important idea in the theory which we think is crucial when modelling motivational characteristics of learners – determining changes in quantities of each individual because we consider that changes in quantities of the elements in the model can result in the process changing. To determine these changes, the D_s – values need to be created along with the limit analysis[2]. According to the theory, determining the D_s – values is called resolving the influences among the individuals in the process. An example of resolved influences[3] in the process and the limit analysis is shown in Figure 3 (Adapted from modelling fluids and fluid flow [14]).

process feedback-motivation
Individuals:
- fdb an ILE feature
- attn a motivational characteristic
- cog_cu a motivational characteristic
- efft a motivational characteristic
- confd a motivational characteristic
- chlg a motivational characteristic
- indp a motivational characteristic

Precondition:
- Given (fdb)

Quantity Condition:
- A[amount-of (fdb)] > ZERO

Relations:
- A[amount-of (cog_cu)] α_Q^+ A[amount-of (attn)]
- A[amount-of (efft)] α_Q^+ A[amount-of (attn)]
- A[amount-of (confd)] α_Q^+ A[amount-of (attn)]

Influences:
- I^+ (amount-of (fdb), A[amount-of (chlg)])
- I^- (amount-of (fdb), A[amount-of (chlg)])
- I^+ (amount-of (fdb), A[amount-of (indp)])
- I^- (amount-of (fdb), A[amount-of (indp)])
- I^+ (amount-of (attn), A[amount-of (fdb)])
- I^+ (amount-of (fdb), A[amount-of (attn)])

Key: fdb is an acronym for feedback.
attn is an acronym for attention.
cog_cu is an acronym for cognitive curiosity.
efft is an acronym for effort.
confd is an acronym for confidence.
chlg is an acronym for challenge.
indp is an acronym for independence.

Fig 2: A process description of how feedback can cause motivation

[2] Limit analysis is used to determine how the quantity of the process structure can change.

[3] Resolved influences are used to determine what changes are occurring. These changes can be represented using the D_s – values (‘D_s – value = -1’ means the quantity is decreasing; ‘D_s – values = 1’ means the quantity is increasing; ‘D_s – values = 0’ means the quantity is uninfluenced)

D_s [amount-of (chlg)] = -1
D_s [amount-of (chlg)] = 1
D_s [amount-of (indp)] = -1
D_s [amount-of (indp)] = 1
D_s [amount-of (attn)] = -1
D_s [amount-of (attn)] = 1
D_s [amount-of (cog_cu)] = 1
D_s [amount-of (efft)] = 1

D_s [amount-of (fdb)] = 1
D_s [amount-of (fdb)] = -1
D_s [amount-of (fdb)] = 1
D_s [amount-of (fdb)] = -1
D_s [amount-of (fdb)] = 1
D_s [amount-of (cog_cu)] = 1
D_s [amount-of (efft)] = 1
D_s [amount-of (confd)] = 1

Key: LH is an acronym for limit hypotheses.
IS is an acronym for the individuals in the situation.
PS is an acronym for the process structure.

Limit Analysis:
IS: {chlg, indp, fdb, attn, cog_cu, eff, confd}
PS: {feedback-motivation (chlg, indp, fdb, attn, cog_cu, eff, confd)}

LH: A[amount-of (attn)] = medium v A[amount-of (attn)] = high
IS: {attn}
PS: { }

LH: A[amount-of (attn)] = A[amount-of (cog_cu)] = A[amount-of (efft)] = A[amount-of (confd)]
IS: {chlg, indp, fdb, attn, cog_cu, eff, confd}
PS: { }

Fig 3: Resolved influences and limit analysis

3. The Future Steps

The research presented in this paper is ongoing, with future work including not only the development of prototype - the simulation of the model, but also validation for the plausibility of the model

As an illustration of the approach described so far, we are applying our model in the context of an educational game with a strong narrative. The particular type of game that we are focusing on is role-playing games (RPG) in which human players assume the characteristics of some person or creature type. We chose to construct the RPG as a prototype used in the experimental study because from the literature, RPGs have characteristics that support the new concept of narrative, emergent narrative which is the narrative generated by interaction between characters in the style of improvisational drama, rather than the authored narratives in more widespread use [15-16]. We consider that this kind of narrative can have a great impact on the learner's motivation. The domain knowledge that we aim to teach is the concept of entity type and attribute type which are the two main concepts for Entity Relationship Modelling (ERM). A story line for our prototype is already created and the story theme is to help recover a character called Emma from her serious illness by taking drugs prescribed by a cold-hearted doctor. Currently, we are looking for the engine which can be used with the game to predict the learner's motivation.

As part of the model validation, we plan to deploy our system with a group of students to estimate values of their motivation. The methodology used for capturing these values must take into account the problems of interrupting participants while they are working with the system as this might make it difficult to keep on track with what they are doing. Hence, we need to specify points at which we can easily interrupt the processes and use absolute questions about the variables of interest or probably more productively, relative questions to get some data for verifying our model in terms of the total model and the separate components. By 'validating the components of the model' we mean to check whether these components are plausible for an ILE within a specific context whereas 'validating the total model' means to check whether the relationships among those components really exist. The data collected from the experiment will then be used to compare with the model's behaviour to see if it needs to be changed to make it more consistent.

References

1. del Soldato, T. and du Boulay, B., Implementation of Motivational Tactics in Tutoring Systems. I*nternational Journal of Artificial Intelligence in Education*, 1995. **6**: p. 337-378.
2. de Vicente, A. and Pain, H., Informing the Detection of the Students' Motivational State: An Empirical Study. *Lecture Notes in Computer Science*, 2002. **2363**: p. 933-943.
3. Waraich, A., Designing Motivating Narratives for Interactive Learning Environments. *PhD Thesis*, 2002, University of Leeds, UK.
4. Malone, T.W., What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games, 1980. XEROX Palo Alto Research Center.
5. Malone, T.W. and Lepper, M.R., Making learning fun: a taxonomy of intrinsic motivations for learning. In *Cognitive and Affective Process Analyses*, M.J. Farr, Editor, 1987. Hillsdale: New Jersey. p. 223-253.
6. Luckin, R., et al., Narrative Evolution : Learning from Students' Talk about Species Variation. *International Journal of Artificial Intelligence in Education*, 2001. **12**: p. 100-123.
7. Brown, J.S. and de Kleer, J., A framework for a qualitative physics. *In Proceedings of the Sixth Annual Conference of the Cognitive Science Society*, 1984.
8. de Kleer, J., Qualitative Physics. In *Encyclopedia of Artificial Intelligence*, 1986. John Wiley & Sons, Inc.
9. Bredeweg, B. and Forbus, K., Qualitative Modeling in Education. *In AI magazine*, 2003. p. 35-46.
10. Salles, P. and Bredeweg, B., Building Qualitative Models in Ecology. *In Proceedings of the Eleventh International workshop on Qualitative Reasoning (QR' 97)*, 1997. Italy.
11. Salles, P. and Bredeweg, B., Qualitative Reasoning about Population and Community Ecology. *In AI Magazine*, 2003. p. 77-90.
12. Conati, C. and Zhou, X., Modeling Students' Emotions from Cognitive Appraisal in Educational Games. *Lecture Notes in Computer Science*, 2002. **2363**: p. 944-954.
13. Bredeweg, B. and Winkels, R., Qualitative Models in Interactive Learning Environments: An Introduction. *Interactive Learning Environments*, 1998. **5**(1-2): p. 1-18.
14. Forbus, K.D., Qualitative Process Theory. *Artificial Intelligence*, 1984. **24**: p. 85-168.
15. Louchart, S. and Aylett, R., Solving the narrative paradox in VEs - lessons from RPGs. *In Proceedings of the forthth International Conference on Intelligent Virtual Agents (IVA 2003)*, 2003. Irsee, Germany.
16. Louchart, S. and Aylett, R., The Emergent Narrative theoretical investigation. *In Proceedings of the Third International Conference on Narrative and Interactive Learning Environments (NILE 04),* 2004. Edinburgh, Scotland.

Relation-based heuristic diffusion framework for LOM generation[1]

Olivier Motelet [2]
DCC - Universidad de Chile

Abstract. Learning Object Metadata (LOM) intends to facilitate the retrieval and reuse of learning material. However, the fastidious task of authoring them limits their use. Motivated by this issue, we introduce an original method for LOM generation based on relations between LOM documents. These relations significantly influence the attribute values. We formulate this influence with heuristics of acquisition, suggestion and restriction. A diffusion framework for these heuristics is suggested. In the context of relation-based graphs of LOM documents, this framework models the recursive processing of the heuristics. The generated values could then be used to assist users in generating LOM documents.

Keywords. learning material reuse, learning object metadata, metadata generation

1. Introduction

Since a few years, reuse of learning material is becoming a leitmotiv for researches on computer-aided education. A first obvious motivation is the economic interest of reusing learning material instead of authoring it indefinitely. Other motivations can be found in the pedagogical area. For instance, learner centered education focuses on the individual needs of learners. In such a pedagogical context, both the teaching and the learning material should adapt to a large variety of situations. In order to cope with this task, various researches aims at providing intelligent adaptation of didactic material to the learner profile (see [Mur99,Mer01,Bru96] for a sample). Despite very interesting results, these approaches imply an important bootstrapping cost due to the building of content-specific rules. For a setting in which the teacher remains responsible for learning material adaptation, literature suggests material should be easily adaptable during the class. It supposes the material to be sufficiently varied in order to precisely suit learners' profile. If such a generic material remains difficult to build from scratch, it could reasonably be the result of an emergent collaborative effort of teachers. To achieve this goal, the storage and the retrieval of learning material is needed. Most efforts in this area deal with the concept of *learning objects* referring to shared digital educational material [Wil00]. Learning objects (LOs) are described and referenced by *Learning Object Metadata* (LOM). LOM documents and their associated LOs are stored and retrieved in *Learning Object Repositories* (LORs).

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[2]Correspondence to: Olivier Motelet, DCC - Universidad de Chile, Avenida Blanco Encalada 2120, Tercer Piso, Santiago, Chile , C.P. 837-0459, Tel (+56 2) 678.4365, E-mail: omotelet@dcc.uchile.cl

Sharing learning objects is presently related with the fastidious task of instantiating the almost 60 metadata attributes of the IEEE LTSC LOM specification[1]. However, if we aspire to see regular teachers sharing and reusing learning material, the use of learning material distribution system should remain as light as possible. For this reason, the research community seriously focuses on the metadata generation issue [DH04,SDM$^+$04,Dow04]. Following this direction, our work introduces an original framework to facilitate LOM instantiation.

First, this article presents researches about metadata generation. Then, it states that the relations between LOM documents influence the attribute values of these documents. Some heuristics are defined to formulate this influence. Next, a framework for diffusing recursively the effects of these heuristics is presented. Finally, the model is discussed.

2. Metadata Generation

Today, most tools for authoring LOM documents are form-based. Even if a form facilitates the use of the hierarchical syntax of XML, it does not support the instantiation of the LOM attributes. Most researches agree on the fact that metadata should be automatically generated [SDM$^+$04].

Almost half of the LOM specification refers to the work of the Dublin Core Metadata initiative (DCMI[2]). Recent tools dedicated to the automatic generation of DCMI attributes give considerable results [Irv04]. They typically extract the information from the document content. However, most attributes of LOM are not processed by such generation tools and in particular those concerning educational topics. Indeed, the educational information generally remains implicit in the learning material. Recently, natural language processing was used to efficiently generate the educational attributes of LOM [YFL04]. However, this work is dedicated to the processing of particular learning objects describing lesson plans.

Duval et al. [DH04] suggest to extract educational information from the course authoring tools. During a same authoring session it is expected that some characteristics are shared by all the learning objects (e.g. author, educational context, typical age range, or language). Therefore, the authoring tool could hold this information so that it should properly be diffused to the metadata of learning material. Pinkwart et al. [PJO$^+$04] study another source of information for generating metadata; they relate various versions of a same learning material. Nevertheless, this approach focuses on a specific context of collaborative learning.

In [Gre04], Greenberg affirms that the best metadata generation option remains to integrate both human and automatic processes. According to this trend, metadata suggestion emerges as another important topic in the field of metadata generation. Crystal's studies [Cry03] confirm the benefits of context exposition during metadata authoring. In practice, Hatala et al. [HR03] extract suggestions for metadata values from inheritance, accumulation, content similarity, and semantic similarity between learning objects.

Other works focus on limiting the set of possible values (scope and vocabulary) (1) to ensure the quality and consistency of the metadata [Dow04], and (2) to facilitate machine processing of the results [QH04]. This consideration is directly related to the concerns

[1] http://ltsc.ieee.org/wg12/
[2] http://dublincore.org

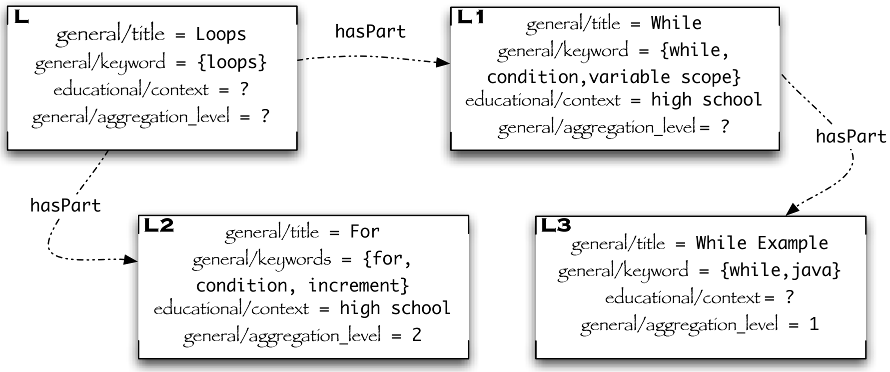

Figure 1. Sample of LOM documents in completion process.

of the semantic web. In this sense, the definition of an ontology for LOM [QH04] is a forward step.

3. Relation Influence on LOM documents

This section describes how the context drawn by the relations between learning objects can be used to generate, suggest and restrict the instantiation of LOM documents.

LOM not only describes learning object content but also its learning style and its intended learning context. This pedagogical information is particularly useful for teachers for retrieving appropriate material. It typically refers to the learners' profile, the learning environment and the global lesson surrounding the associated learning object. The relations with other learning objects are also part of this pedagogical context. For that reason, these relations are explicit in the LOM documents.

We state that a specific relation between two LOM documents could imply that the value of the attributes of one will influence the value of the attributes of the second. Let consider the four LOM documents pictured in figure 1. In this example, the LOM documents L and $L1$ are respectively linked to $L1$ and $L2$, and $L3$ with an hasPart relation. According to the definitions of the general/keyword attribute and the hasPart relation, it seems logical that L could also hold the keywords of $L1$ and $L2$. Similarly, $L1$ could inherit the keywords of $L3$. This logic is based on a subjective interpretation of the LOM specification and a generalization of this statement remains out of the scope of this work. Nevertheless, it is obvious that such an heuristic could facilitate LOM instantiation. In the same example, we also observe that the value of the educational context of document L have significant possibilities to be the same that the educational context of $L1$ and $L2$. As argued in the previous section, such a suggestion is of interest for the user instantiating LOM documents. Finally, the definitions of the general/aggregation_level attribute and the hasPart relation impose that the aggregation level of L cannot be inferior to the aggregation level of $L1$ or $L2$. Similarly, the aggregation level of $L1$ cannot be inferior to the aggregation level of $L3$. LOM document instantiation should also consider such restrictions. In this example, three types of heuristics have been illustrated. They are heuristics of acquisition, suggestion and restriction. Note that the specific values of our examples did not influence the definition of these heuristics. In fact, each heuristic depends only on a specific attribute and a specific relation type.

4. Heuristic Diffusion Framework

This section defines a framework describing how the acquisition, suggestion and restriction heuristics are processed. We call it diffusion framework for its recursive nature.

In the previous section, we introduced an acquisition heuristic for the LOM attribute general/keyword and the relation hasPart. This heuristic applied on the LOM document L of figure 1 returns the keywords of all the documents linked to L with an hasPart relation, concretely {while,condition,variable scope,java,for,increment}. Consider a function ϕ_{Acq} returning the general/keyword values of the LOM documents associated to the document L with the hasPart relation. Then,

$$\phi_{Acq}(L, \text{general/keyword, hasPart}) = \{ (L1, \{\text{while,condition,variable scope,java}\}), (L2, \{\text{for,condition,increment}\})\}$$

With such a function, the acquisition heuristic for general/keyword and hasPart can be formulated for any LOM document l:

$$AcqHeur(\text{general/keyword,hasPart})(l) = \bigcup v_i$$

where the vis are in the set of generic values provided by $\phi_{Acq}(L, \text{general/keyword, hasPart})$

This definition is tight to the couple (general/keyword,hasPart). For instance, an acquisition heuristic for (educational/semantic_density,hasPart) would not implement a union but a mean balanced by the values of an additional attribute[3].

For all LOM documents, the original value of an attribute and the value due to heuristic processing are conceptually different. The first will be invoked with a function $AcqVal$. The second will be retrieved with a function $AcqDif$. The latter is a union of the original value of the attribute and the acquisition heuristic results for this attribute. Concretely, applying these functions on the document L and its general/keyword attribute gives:

$$AcqVal(L, \text{general/keyword}) = \{\text{loops}\}$$
$$AcqDif(L, \text{general/keyword}) = \{\text{loops,while,condition,variable scope,java,for,increment}\}$$

We formally define an acquisition heuristic diffusion framework as the set of the functions introduced in this section.

Definition 4.1 (Acquisition Heuristic Diffusion Framework) *Let $\mathbf{A}$ be the set of attributes of the LOM specification, $\mathbf{T}$ the set of relation type between LOM documents, $\mathcal{L}$ the set of LOM documents, $\mathcal{V}$ the set of generic values, and $\mathcal{R} = \mathcal{L} \times \mathbf{T} \times \mathcal{L}$ the set of existing relations between LOM documents, then*

- $AcqVal : \mathcal{L} \times \mathbf{A} \rightarrow 2^{\mathcal{V}}$
- $AcqDif : \mathcal{L} \times \mathbf{A} \rightarrow 2^{\mathcal{V}}$. *With $l \in \mathcal{L}$, and $a \in \mathbf{A}$,* $AcqDif(l, a) = AcqVal(l, a) \cup \bigcup_{t \in \mathbf{T}} AcqHeur(a, t)(l)$
- $AcqHeur : \mathbf{A} \times \mathbf{T} \rightarrow \mathcal{L} \rightarrow 2^{\mathcal{V}}$
- $\phi_{Acq} : \mathcal{L} \times \mathbf{A} \times \mathbf{T} \rightarrow 2^{\mathcal{L} \times 2^{\mathcal{V}}}$. *With $l \in \mathcal{L}$, $a \in \mathbf{A}$, and $t \in \mathbf{T}$,* $\phi_{Acq}(l, a, t) = \{(l', AcqDif(l', a))/l' \in \mathcal{L} \bigwedge (l, t, l') \in \mathcal{R}\}$

[3]Such complex heuristics can be found at http://www.dcc.uchile.cl/∼omotelet/heuristics.pdf

The recursive aspect of the framework is introduced by ϕ_{Acq} calling recursively the diffusion function $AcqDif$ on the related LOM documents. If this version of ϕ_{Acq} suits our simple example, in a more realistic context it also needs to manage with recursion depth and cycle prevention, but this is part of future work.

A suggestion heuristic diffusion framework is similar to the acquisition framework except the definition of ϕ_{Sug}. In this case, both the suggestion diffusion and the acquisition diffusion should be recursively called. With $a \in \mathbf{A}$, $t \in \mathbf{T}$, and $l \in \mathcal{L}$,
$\phi_{Sug}(l, a, t) = \{(l', AcqDif(l', a) \cup SugDif(l', a))/l' \in \mathcal{L} \bigwedge (l, t, l') \in \mathcal{R}\}$

A restriction heuristic diffusion framework differs from the previous frameworks since a restriction consists of couples operator-value. The previous section introduced a restriction heuristic tight to the couple (general/aggregation_level,hasPart) (noted (Agg,hasPart)). In the LOM document set of figure 1, we can observe that $ResHeur(\text{Agg,hasPart})(L1) = \{(\text{'}\geq\text{'}, 1)\}$ and $ResHeur(\text{Agg,hasPart})(L) = \{(\text{'}\geq\text{'}, max(1,2))\}$. Such results can be obtained thanks to a function ϕ_{Res} processing recursively not only the restriction diffusion but also the acquisition restriction. Let $\mathbf{O}$ be the set of operators for characterizing constraints. Then,
$\phi_{Res} : \mathcal{L} \times \mathbf{A} \times \mathbf{T} \rightarrow 2^{\mathcal{L} \times 2^{\mathbf{O} \times 2^{\mathcal{V}}}}$. With $l \in \mathcal{L}$, $a \in \mathbf{A}$, and $t \in \mathbf{T}$,
$\phi_{Res}(l, a, t) = \{\big(l', \{(\text{'='}, AcqDif(l', a))\} \cup ResDif(l', a)\big)/l' \in \mathcal{L} \wedge (l, t, l') \in \mathcal{R}\}$
With this function, the restriction heuristic of (Agg,hasPart) can be defined for any LOM document l:

$$\begin{aligned} ResHeur(\text{Agg,hasPart})(l) = &\big\{(\text{'}\geq\text{'}, max(v_{ij}))/o_{ij} = \text{'}\geq\text{'} \vee o_{ij} = \text{'='}\big\} \\ &\big/(l_i, (o_{ij}, v_{ij})) \in S, l_i \in \mathcal{L}, o_{ij} \in \mathbf{O}, v_{ij} \in 2^{\mathcal{V}} \\ &\text{where } S = \phi_{Res}(l, \text{Agg, hasPart}) \end{aligned}$$

5. Discussion

The theoretical advantage of LOM documents for reusing learning material is limited by the difficulty to generate them. Motivated by this issue, this work introduced an original method for metadata generation based on relations between LOM documents. These relations offer relevant information for LOM attribute instantiation. In practice, this information is generated by three types of heuristics: acquisition, suggestion, and restriction. A diffusion framework models the recursive processing of these heuristics on a relation-based graph of LOM documents. An existing work on rule-based metadata generation [HR03] focused on analyzing LOM packaging frameworks like SCORM and IMS-LD, and the similarities between LOM documents. These analysis result in sets of suggested values. Since our approach studies a different mechanism, i.e. a relation graph, it is complementary to this work. Moreover, our system not only suggests values for LOM instances but also restrictions for these values.

Further work is needed in order to consolidate and implement the system. In particular, recursion depth and cycle prevention should be controlled. Since our approach takes benefits of relation-based graphs of LOM documents, a consistent set of relation types should be defined in order to increase the generation potential of the system. Moreover, it is necessary to define sound heuristics which may be based on a LOM ontology. Finally, well-defined taxonomies for LOM attribute values would increase the potential of our system.

Another perspective for our heuristic diffusion framework stands in the retrieval of learning objects. In a course authoring system based on graphs of LOM documents (e.g. [BPM03]), a LOM node without reference to a concrete learning object could be considered as a query on a learning object repository. Since this node is part of a relation graph, it could receive acquisition and restriction values from our system. This feature could significantly precise the query with the pedagogical context of the lesson being authored. Moreover, the suggestion values available in our framework could be used to effectively refine the query result ranking.

References

[BPM03] Nelson A. Baloian, José A. Pino, and Olivier Motelet. Collaborative authoring, use, and reuse of learning material in a computer-integrated classroom. In *CRIWG*, pages 199–207, 2003.

[Bru96] Peter Brusilovsky. Methods and techniques of adaptive hypermedia. *User Modeling and User-Adapted Interaction*, 6(2-3):87–129, 1996.

[Cry03] Abe Crystal. Interface design for metadata creation. In *CHI '03: Extended abstracts on Human factors in computing systems*, pages 1038–1039. ACM Press, 2003.

[DH04] E. Duval and Hodgins. Metadata matters. In *International Conference on metadata and Dublin Core specifications*, 2004.

[Dow04] Stephen Downes. Ressource profiles. *Journal of Interactive Media in Education*, Special Issue on the Educational Semantic Web.(ISSN: 1365-893X), 2004.

[Gre04] Jane Greenberg. Metadata extraction and harvesting: A comparison of two automatic metadata generation applications. *Journal of Internet Cataloging: The International Quarterly of Digital Organization, Classification, and Access*, 6(4):58–82, 2004.

[HR03] Marek Hatala and Griff Richards. Value-added metatagging: Ontology and rule based methods for smarter metadata. In *RuleML*, pages 65–80, 2003.

[Irv04] K. Irvin. Comparing information retrieval effectiveness of different metadata generation methods. Master's thesis, UNC SILS, 2004.

[Mer01] D. M. Merrill. *Knowledge objects and mental models*, chapter The Instructional Use of Learning Objects. Association for Instructional Technology, 2001.

[Mur99] Tomas Murray. Authoring intelligent tutoring systems: an analysis of state of the art. *International Journal of Artificial Intelligence in Education*, 10:98–129, 1999.

[PJO+04] Niels Pinkwart, Marc Jansen, Maria Oelinger, Lena Korchounova, and Ulrich Hoppe. Partial generation of contextualized metadata in a collaborative modeling environment. In *2nd International Workshop on Applications of Semantic Web Technologies for E-Learning*, 2004.

[QH04] Jian Qin and Naybell Hernández. Ontological representation of learning objects: building interoperable vocabulary and structures. In *WWW (Alternate Track Papers & Posters)*, pages 348–349, 2004.

[SDM+04] Bernd Simon, Peter Dolog, Zoltán Miklós, Daniel Olmedilla, and Michael Sintek. Conceptualising smart spaces for learning. *Journal of Interactive Media in Education*, Special Issue on the Educational Semantic Web.(ISSN: 1365-893X), 2004.

[Wil00] David Wiley. *learning object design and sequencing theory*. PhD thesis, Brigham Young University, June 2000.

[YFL04] Ozgur Yilmazel, Christina M. Finneran, and Elizabeth D. Liddy. Metaextract: an nlp system to automatically assign metadata. In *JCDL '04: Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries*, pages 241–242. ACM Press, 2004.

From Representing the Knowledge to Offering Appropriate Remediation – a Road Map for Virtual Learning Process

Mehdi NAJJAR
Department of Computer Science, University of Sherbrooke,
2500, B$^{ld.}$ de l'Université, Sherbrooke QC J1k 2R1, Canada

Abstract. This paper describes a proposal of a '*from A to Z'* virtual learning process and its preliminary validation which consists of representing the knowledge, authoring graphically the subject-matter domain, modelling the students' believes and offering to each learner a personalised suitable feedback**.**

Introduction

An important technological concept is being considered by an increasing number of universities and revolves about the idea of virtual learning. Nevertheless, several related key issues should be addressed, such as (1) the necessity to accurately represent the knowledge of the taught domain and the one handled and used by learners when interacting with the teaching material; and (2) the need to have tools which ease representing and modeling that knowledge and which are used by professors without the obligation of high capabilities in computer science at their disposal. These crucial points emerge the importance to exploit a representational model which offers structures that are closer to those recognised by psychology and cognitive science regarding the human learning processes. Especially, if one wishes to develop educational systems capable to adapt contents to the student profile and its needs [6] and to provide tailored aid to learners according to their cognitive states [8].

To approach the mentioned issues, the broader aim of the research discussed here is (i) to suggest a formal model of knowledge representation that is inspired from psychology cognitive theories, (ii) to facilitate modelling the domain knowledge via user-centred graphical authoring tools which are "*life-complicated free*" and (iii) to propose appropriate remediation and suitable suggestion mechanisms applied to help students engaged in learning activities through virtual learning environments. The following sections give a thorough account of our proposal. Section 1 describes the proposed theoretical model of knowledge representation and puts one's finger on some of its originalities. Section 2, presents an authoring tool prototype which offers the opportunity to model the knowledge according to the proposed model. Section 3 introduces a learning environment prototype designed in order to exemplify educational systems which use teaching material specified via the authoring tool. Preliminary experiments are depicted in section 4, followed by current developments in section 5.

1. Theoretical Model

If one has the ambition to endow an artificial system with competence in teaching, then it is not possible to be unaware of all that concerns the human cognition and the related knowledge structures in the human memory. Different approaches in cognitive psychology propose various sets of knowledge representation structures [5,9]. Nevertheless, these sets are not necessary compatible [4,10]. Although there is neither consensus on the number of the subsystems nor on their organisation, the majority of the authors in psychology mentions (in some form or in another) three main subsystems presenting, each one, a particular type of knowledge: (i) semantic knowledge [13], (ii) procedural knowledge [14] and (iii) episodic knowledge [15].

The proposed model regards semantic knowledge as concepts taken in a broad sense. Thus, they can be any category of objects and/or their relations. Moreover, these concepts are subdivided in two categories: primitive concepts and described concepts. The first are defined as syntactically non-split representations; i.e., primitive concept representation can not be divided into parts. For example, in propositional calculus, symbols "*a*" and "*b*" of the expression "*(a & b)*" are non-split representations of the corresponding proposals. On the other hand, described concepts are seen as syntactically decomposable representations. For example, the previous expression "*(a & b)*" is a decomposable representation that represents a conjunction between proposal "*a*" and proposal "*b*", two primitive concepts. The symbol "*&*" represents the conjunction logic operator (AND), and is a primitive concept. In this way, the semantic of a described concept is given by the semantics of its components and their associations which take those components as arguments to create the described concept (the reader can find in [12] more theoretical details and descriptive examples).

In opposition to semantic knowledge, which can be expressed explicitly, procedural knowledge becomes apparent by a succession of actions achieved automatically – following internal and/or external stimuli perception – to reach desirable states. In this sense, a procedure is a mean of satisfying needs without using the attention resources. The automation via the use of procedures reduces the cognitive complexity of problems solving [14]. Nevertheless, a procedure can also be transformed into semantic knowledge by means of reification [2]. The model subdivides procedures in two main categories: primitive procedures and complex procedures. Executions of the first are seen as atomic actions. Those of the last can be done by sequences of actions which satisfy scripts of goals. Each one of those actions results from a primitive or complex procedure execution; and each one of those goals is perceived as an intention of the learner cognitive system.

The episode representation is based on instantiation of goals. These are seen as a generic statements retrieved from semantic memory. In other words, the episodic knowledge is organised according to goals. Each episode specifies a goal that translates a learner interest and gives a sense to the underlying events and actions. If the goal realisation requires the execution of a complex procedure, formed by a set of "n" actions, then this goal will be composed of "n" subgoals whose realisation will be stored in "n" sub-episodes. Thus, executions of procedures are encoded in episodic memory where each goal achievement is encoded in an episode. In this way, the learner episodic knowledge reflects its experiences details during the training activities and the related temporal relations allowing the reconstruction of previously lived events as well as the time and context in which they took place.

1.1 Originalities

The model's distinction between semantic and procedural knowledge is mainly based on the criteria of the ACT-R theory [2]. However, in the approach proposed here, it is suggested to take into account an additional component of the declarative memory: the episodic memory, a structure which is characterised by the capacity to encode information about lived facts [13,15]. Humphreys [11], for instance, affirms that cognitive models which do not make a distinction between *declarative* and *episodic* cannot distinguish various occurrences of the same element of knowledge.[1]

Moreover, ELM-ART [16], a tutoring system conceived to initiate students at the LISP programming, models the learner knowledge respect to (1) the subject-matter domain and (2) to a student history, represented by a set of episodes whose each one described a lived specific activity during the learning process. The episodic knowledge structuring suggested here is distinguished from that of ELM-ART: it places any episode in a novel hierarchical context. The proposed structures connect concrete episodes in a hierarchy which is not of the type *generalisation/specialisation* as in ELM-ART, but rather of the type *event/sub-events* where *event* is represented by an ancestry episode and *sub-events* are represented by a line of descent episodes. Thus, for an adequate strategic reasoning, it is possible – for example – for an intelligent agent to scan and scrutinise the episodic history in order to extract relevant indices directly from concrete episodes.[2]

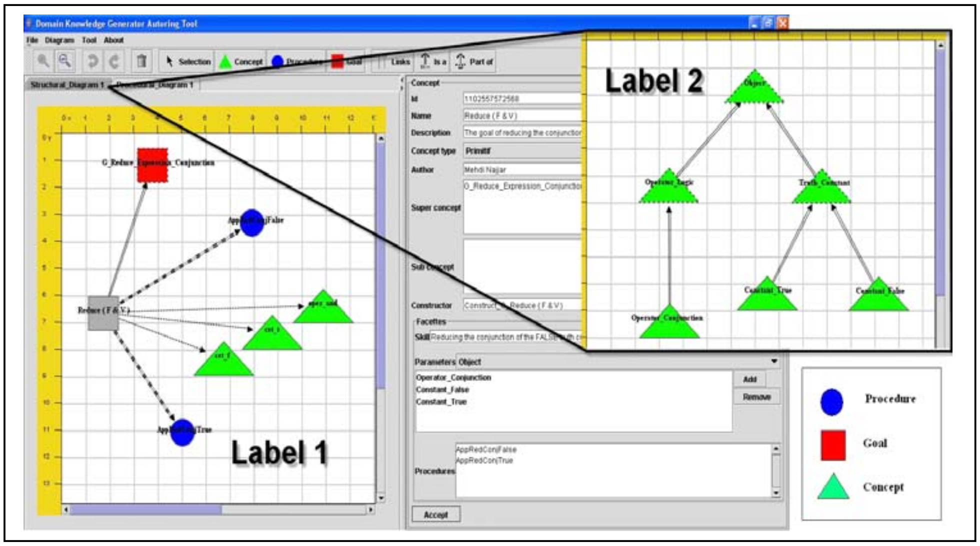

Figure 1: An example of knowledge modelling and specification via the authoring tool.

2. Authoring the Virtual Course Knowledge

An authoring tool prototype was designed in attempt to offer an environment that permits (1) to model graphically the subject-matter domain knowledge and (2) to transpose it automatically into a related XML file, generated to serve as a knowledge support for a tutor reasoning purpose. The left-hand side of the environment (see figure 1) consists of a drawing pane where the various types of knowledge can be represented by means of specific symbols. Our structural model offers two types of diagrams: conceptual diagrams and procedural diagrams. The former specifies *hierarchical links* ("*is-a*") and *aggregation links* ("*part-of*") between primitive and/or described concepts of the knowledge domain. The latter contains (1) *specification links* connecting a complex procedure and all the subgoals which it specifies, (2) *satisfaction links* joining a goal and all the procedures which attempt to achieve it, and (3) *handling links* involving a goal and its handled cognitions. These are concrete instances of concepts and are taken as parameters by goals which pass them to procedures. The right-hand side of the environment permits the author to specify detailed information about the knowledge entities (see figure 1). This information is organised in slots. Those of a concept are either metadata that provide general information (e.g., the concept's name, its description and its author's name) or specific data of the concept (e.g., its concept type, a list of goals which use it, etc). Other than the metadata slots, each procedure is mainly characterised by its arguments specification, a script that indicates a sequence of actions to achieve, a set of constraints on the use of the procedure and pointers to some resources to teach it. Goals have four specific slots (in addition to all the concept's slots). "*Skill*" describes the necessary skill to accomplish the goal, "*Parameters*" indicates the types of its parameters, "*Procedures*" contains a set of procedures which can be used to attain it and "*Didactic-Strategies*" suggests strategies to teach how to realise that goal.

Figure 1 illustrates an example of a procedural diagram (label 1) which defines that the goal "*reduce (F & T)*" (a specification of the abstract goal "*reduce_Expression-Conjunction*") can be achieved by means of two procedures: "*AppRedConjTrue*" and "*AppRedConjFalse*". The former is the procedure that applies the reduction rule of a conjunction with the "*True*" truth constant. The latter reduces conjunctions with the "*False*" truth constant. The diagram also defines that the goal "*reduce (F & T)*" handles three cognitions: "*cst_t*", "*cst_f*" and "*oper_and*". The first is a concrete instance of the concept "*Constant_True*", the second is of the concept type "*Constant_False*" and the third is an instance of the concept "*Operator_Conjunction*". Figure 1 also shows the related structural diagram (label 2) which defines hierarchical links between these concepts. The two former are a specification of the primitive concept "*Truth_ Constant*" which inherits from the abstract concept "*Object*" and the latter is a specification of the primitive concept "*Logical_ Operator*", also a sub-concept of "*Object*".

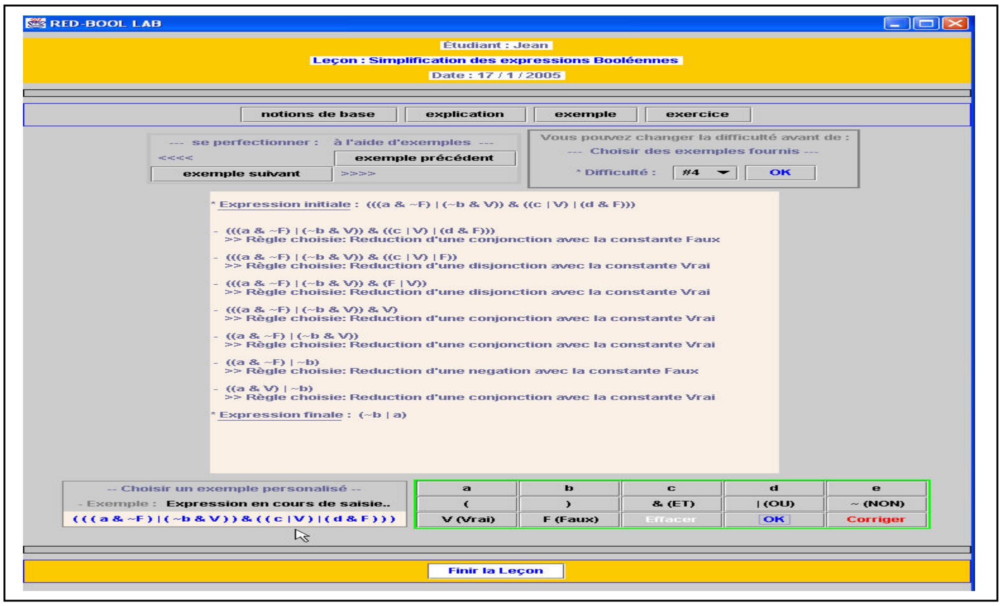

Figure 2: The resolution made by the system for a complexity level 4 example proposed by a user.

3. The Learning Environment Prototype

The subject-matter domain of the learning environment prototype (LEP) is the algebraic boolean expressions and their simplification by means of reduction rules, generally taught to undergraduate students. Within the LEP, preliminary notions, definitions and explanations constitute a necessary knowledge background (available through sections exploration via clicking buttons) to approach the boolean reduction problem. In order to show optimal solutions to simplify expressions and to enlighten learners, examples (whose each one is generated randomly respect to a variable degree of difficulty chosen by the learner) are given. In addition, learners can also enter, by means of a visual keyboard, any boolean expression they want and ask the system to solve it. In this case, the problem solving steps and the applied rules are shown on a blackboard. For example, figure 2 illustrates a complexity level 4 example proposed by a learner. In another section of the LEP, exercises (also with variable complexity levels) give opportunities to learners to practice the boolean expressions reduction problem solving. Via the visual keyboard, learners reduce initial boolean expressions by choosing suitable simplification rules to apply in the order they want. Although various tutorial strategies are to be considered, actually, the prototype applies the *Cognitive Tutor* strategy [3], implemented within several intelligent tutoring systems and which its effectiveness has been largely proven [1,7]. Consequently, in the case of erroneous rule choice (or application) on any of the sub-expressions (forming the initial given expression) the system notifies the learner and shows her/him (i) the selected sub-expression, (ii) a correct rule to reduce it, (iii) the resulted simplified sub-expression and (iv) the current state of the global expression.

4. Preliminary Experiments

For implementing the approach, a first practical validation was (1) to model by means of the authoring tool prototype (section 2) the necessary knowledge for the boolean expressions reduction rules usage and (2) to build the LEP related to that activity (section 3). In a second practical validation, and during early pilot-tests of the model, students in computer science and in mathematics, whose attend courses dedicated to logic calculus, have been asked to practice the reduction of boolean expressions by using the LEP. By this experiment, the interest was the computational modelling of each learner's resolution processes during a problem solving task in a real learning situation. In these processes (and according to the proposed model), each step corresponds to a transition realisable by means of primitive or complex procedure applied to satisfy a goal or a subgoal. This procedure handles primitive and/or described concepts such as rules, proposals, logical operators and truth constants. Traces of the resolution, adopted by each learner, have been stored. For each learner and each made exercise, the system notes the procedures used as well as the cognitions created and handled. Since a procedure is generally called to achieve a goal, for each test the collected data allow deducing goals (and their subgoals) formulated during the reduction process. Parameters of this experiment are reported in Table 1.

Table 1: Main parameters of the experiment

Complexity level	1	2	3	4	5
Number of exercises	4	4	5	6	6
Number of students	10	10	10	10	10

Pilot-tests allowed evaluating successfully the dynamic aspect of the representation offered by the model. This was noted (during the learners' resolutions) in the non-predefined combinations between occurrences of concepts and the procedures handling them when achieving goals. Primitive units of semantic and procedural knowledge, chosen with a small level of granularity, are used to build complex knowledge entities which are dynamically combined – to create a new knowledge – in order to represent the learner cognitive activity. The stored traces of this activity represent a content formed by an episodic knowledge specific to each learner.

5. Current Developments

Learners' behaviours careful observations allowed confirming that if the task is relatively complex, there can be various correct manners to do it. This engenders different behaviours in achieving the same task. The broader aim of the current work is to validate the idea that since there are multiple correct ways to solve a complex problem, it would be more effective to tailor a tutorial strategy – for each learner – which is based on the particular manner chosen by that learner and stored within his/her episodic history. This specific strategy will be based on retrieving and recovering the knowledge that s/he handled when attempting unsuccessfully to achieve the learning task. More precisely, in the proposed model, when a learner makes an error, satisfying the goal that s/he wished to accomplish was realised by means of a non-valid procedure. This error results from bad interpretation of the situation, causing a choice of procedure which (i) can be correct but whose application cannot be done in the current context or (ii) is invented and false. In this case, the procedure will be labelled (within an episode in which the erroneous result is stored) as a "procedure-error" and will lead to formulate a set of valid procedures that the learner should have used to achieve the goal. At this stage, learning and mastering these correct procedures (or at least one of them) will be one of the immediate objectives of the tutorial strategy. More specifically, as the episode containing the 'procedure-error' comprises an instance of the goal, the set of valid procedures which satisfy it will be deduced starting from the goal prototype. This last also contains the necessary didactic resources to teach these procedures which, if they are complex, specify subgoals whose each one contains its own didactic resources. In this way, a tutor can easily conceive an ordered sequence of valid procedures allowing accomplishing correctly any goal. Particularly, those for which the learner has failed. Conceiving an elaborate version of the tutor that permits to provide a personalised feedback to fill each learner knowledge lack is actually under development. Verifying the effectiveness of such tutoring strategy is also planned. These last points – once entirely completed – will be probably detailed in futures papers.

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1. To fill this gap, ACT-R permits to create several instances of the same chunk type in order to indirectly simulate the existence of an episodic memory. However, this form of memory does not have an explicit structure.
2. ELM-ART makes abstraction on the context of each episode. To predict the student behaviour, it only examines a static structure, an abstract generalisation of all similar concrete episodes.

References

[1] Aleven, V. & Koedinger, K. (2002). An Effective Metacognitive Strategy : Learning by doing and explaining with computer-based Cognitive Tutors. Cognitive Science. 26 – 147-179.

[2] Anderson, J. R. (1993). Rules of the mind. Lawrence Erlbaum, Hillsdale, New Jersey.

[3] Anderson, J. R., Corbett, A.T., Koedinger, K.R. & Pelletier, R. (1995). Cognitive Tutors: Lessons learned. *The Journal of the Learning Sciences.* 4 (2), 167-207.

[4] Anderson, J. R., & Ross, B. H. (1980). Evidence against a semantic-episodic distinction. Journal of Experimental Psychology: Human Learning and Memory, 6, 441-466.

[5] Baddeley, A. (1990). Human Memory : theory and practice. Hove (UK): Lawrence Erlbaum.

[6] Brusilovsky, P. & Peylo, C. (2003). Adaptive and intelligent Web-based educational systems. IJAIED 13 (2) : 159-172.

[7] Corbett, A., Mclaughlin, M. & Scarpinatto, K. C. (2000). Modeling Learner Knowledge : Cognitive Tutors in High School and College. User Modeling and User-Adapted Interaction (10) : 81-108.

[8] de Rosis, F. (2001). Towards adaptation of interaction to affective factors. Journal of User Modeling and User-Adapted Interaction. 11(4).

[9] Gagné, R.M, Briggs, L. & Wager, W. (1992). Principles of Instructional Design. (4th edition), NY: Holt & Winston.

[10] Hermann, D. & Harwood, J. (1980). More evidence for the existence of separate semantic and episodic stores in long-term memory. Journal of Experimental Psychology, 6 (5), 467-478.

[11] Humphreys, M. S., Bain, J. D. & Pike, R. (1989). Different ways to cue a coherent memory system: A theory for episodic, semantic and procedural tasks. *Psychological Review*, 96, 208-233.

[12] Najjar, M. & Mayers, A. (2003). A Computational Cognitive-Based Approach to Represent Knowledge within Intelligent Tutoring Systems. Proceedings of *The 3rd IEEE International Conference on Advanced Learning Technologies*. pp:66-71.

[13] Neely, J. H. (1989). Experimental dissociation and the episodic/semantic memory distinction. Experimental Psychology: Human Learning and Memory, Vol. 6, 441-466.

[14] Sweller, J. (1988) Cognitive load during problem solving: effects on learning. *Cognitive Science*,12, 257-285.

[15] Tulving, E. (1983). Elements of Episodic Memory. Oxford University Press, New York.

[16] Weber, G. & Brusilovsky, P. (2001). ELM-ART: An adaptive versatile system for Web-based instruction. International Journal of AI in Education. 12 (4): 351-384.

Authoring Ideas for Developing Structural Communication Exercises

Robinson V. Noronha*
Technological Institute of Aeronautics - ITA, SP, Brazil
rvida@cefetpr.br; rvida@ita.br

Abstract. The process of creating instructional activities based on ill-structured problems exercises is an enterprise that may spend a long period and author's skills. Some of the authors has not the necessary skills to create this type of instructional activities such as novice teachers. There is a high degree of uncertainty about this authoring process and it still remain a very costly and hard task. However, there are some pedagogical techniques such as Structural Communication (SC) that could be used to structure and organize the domain knowledge and aid to produce this type of instructional activities. This paper discusses some ideas of computer tools and process to help the authoring activities of a SC unit. The purpose of these ideas is to partially reduce some of the authoring difficulties. One of these main difficulties is how to foresee possible solutions to ill-structured problems. The authoring ideas described in this paper aim to reduce this specific difficulty.

Keywords: foresee ill-structured problem solutions, authoring tools, Structural Communication.

Introduction

Most educators agree that problem solving is among the most meaningful and important kinds of learning and thinking [1]. Some of instructional activities do not guide the learner to get the right problem's answer, since their main purpose is to enact an argumentation and discussion process likely occurring between teachers and learners. They discuss how, why and which parts of subject could be used to provide or no a possible solution. Two examples of this type of problem are the following: "What kind of marketing approach is appropriate for this new product?" and "What binary operations can be used on all three number systems Q, R e C?".

Structural Communication [2] is a pedagogical technique used to guide the instructional dialogue between learner and teacher while they are conducting a deep analysis of how to solve an ill-structured problem. Despite of SC's sections are well defined and structured, the authoring process is a very costly and hard task. The process of creating instructional activities using the SC technique is a time-consuming activity.

Some techniques from the Artificial Intelligence field could be used to help authors to create SC exercises. The aim of computer resource's ideas described in this paper is to reduce the authoring difficulties of SC exercises.

The paper is organized as follows. Section 2 briefly describes the Structural Communication technique. Section 3 describes the authoring difficulties within this pedagogical technique. Section 4 discusses some of authoring ideas to aid teachers to develop SC instructional activities. Finally, Section 5 presents the conclusions and future

*on leave from CEFET-PR, Brazil.

works.

2. Structural Communication

Structural Communication [2] is an instructional technique that individualizes learning, provides controls for the process by which the learner moves through the lessons, faces him with challenges to construct his own multifaceted responses to complex open-ended problems and ill-structured problems, analyses these responses and firmly provides complex, multifaceted, feedback on all relevant issues revealed by his answer.

The Structural Communication technique involves the development of special units of study of the domain. Each learning unit should be structured in such a way that the learner spends approximately an hour of study to complete the activities foreseen by the author. However, the work of the learner is somewhat analogous to the research of the content and planning of the structure of an essay or term-paper type of response - a task that typically takes many (sometimes many dozens) of hours. Thus, the learner has the opportunity to engage in a much larger number of creative knowledge-construction exercises during the time available for study on a given course. A SC learning unit usually contains the following sections:

- **Intention** - This section defines what should be learned and to what level or intensity. It supplies a general vision of the objectives and context for the unit of study.
- **Presentation** - this section supplies descriptive information on the subject, possibly practical exercises or case studies. It can be composed of text materials, videos, simulations, computer-based training systems, hypermedia courses, adaptive hypermedia systems, intelligent tutoring systems, electronic games, and site visits, among other forms.
- **Investigation** - this section presents a group of usually 3 or 4 interrelated, challenging and generally open-ended questions on the subject of the Presentation. They constitute the challenge for the learner, who responds by selecting elements from the Response Matrix, presented next.
- **Response Matrix** - It is a response-generating instrument formed of a large number of elements, typically between 20 to 40, from the domain under study; they can be sentences that summarize an idea, key words, concepts or principles contained in the Presentation. The learner constructs a response by selecting those elements that are considered part of a complete response to the complex question that is being addressed.
- **Discussion** - This section is composed of two parts: a group of " if - then - else " rules and a series of feedback comments elaborated by the author, each one associated with one of the rules. The comments have constructive purpose and they discuss in depth the reasoning used by the learner when selecting or omitting certain items or subsets of items from the Response Matrix. They seldom classify a response as incorrect and never supply a "correct" response, but rather encourage the learner to think again and to think deeper and wider around the issues being addressed.
- **Points of View** - this last section is used to present other interpretations or conflicting point of views and to revise some aspects presented earlier. This finishes the interaction between the learner and author, which mimics a virtual dialogue between them.

One may ask why the potential of researched methodologies such as Structural Communication has not been realized in large-scale applications in real-world educational systems. One possible reason for this lack of practical application of a theoretically "good idea" is that the design and development of SC units is seen as complex and difficult task by most educators who have attempted it [4]. Therefore, a logical next step is to develop intelligent authoring tools that may simplify the human author's task for developing SC exercises.

3. Authoring difficulties

The author, when creating the Investigation, Response Matrix and Discussion sections, needs to be able to not only interpret new situations in terms of principles, but also simulate and predict results as well as elaborate solutions for questions. This technique therefore demands creative thinking on the part of the teacher-author because it values deep and highly structured understanding of the domain in question and not just simple memorization of information or mastery of simple concepts [2, 4].

From the analysis of the authoring process to create and instructional activities with SC technique shows following aspects:

a. There are no consensual methodologies of how to adapt a specific domain and instructional objective (IG) to be used by SC. This is still an open question.
b. The author need possess abilities of how to identify and articulate which relevant concepts and appropriate principles of the domain may compose a Response Matrix. An expert can easily solve a complex problem but he/she has difficulty to explain how he/she identifies these principles and concepts [5].
c. The authors must be able to identify and foresee the solution's strategies that the learners could use when they face a challenge. How to identify this solution's strategies has many uncertainties about which principles, rules and concepts are necessary to compose problem solutions and how to organize them. A typical Response Matrix has 20 elements. These Response Matrix's elements could be organized in 2^{20} possible strategies of problem's solutions.
d. It must have consistency between Response Matrix and Presentation section. Fyfe and Woodrow [6] and Egan [2] show many examples of SC learning units. In some of these examples is possible to identify elements in the Response Matrix that did not appear in the Presentation section.

4. Authoring Ideas

This section shows some ideas to reduce the authoring difficulties and author's skills. The ideas are being implemented and they will be used as an aid tool in a specific authoring environment to produce SC instructional activities through Internet. The main purpose of the current research project is identifying Intelligent Tutoring System techniques to help teachers to create SC instructional activities.

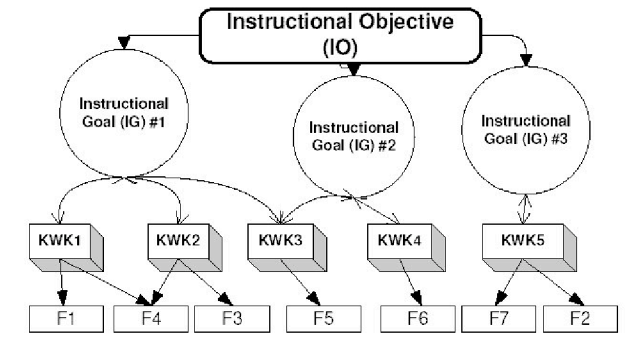
The Section 4.1 describes how to represent a specific domain or skill to authoring process. The sections 4.2 and 4.3 describe two ideas of resources to aid the authoring process. These resources are: i) Extractor of Keywords and Phrases (EKP) and ii) the Discussion Guide Generator (DGG).

4.1 Representing skills and domain knowledge

The process of discovering problem's solutions during the instructional activities should be associate with pre-defined instructional goals (IG) [7, 8]. The instructional objective (IO) is achieved when all IGs are successful reached by the learner [8]. In this research project the following statement are considered:

i) Instructional activities must have a well-defined IO, ie: "The objective of these SC instructional activities is: exercise critical reading in text documents".
ii) An IO has a set of IG. If the learner achieve all IG then he/she complete the IO.
iii) A challenge or problem in the Investigation Section is connected to a unique IG,
iv) Each Response Matrix's Elements (Fn) is connected to at least one IG, Each Fn contains domain relevant principles or concepts.
v) An IG is connected with a set of keywords (KWK). These keywords represent the relevant concepts, rules or principles.

The Figure 1 shows and exemplifies the structure of relationship between IO, IGs and KWKs. Both process EKP and DGG, described in next two sections, use this structure. The subject of instructional activities, in this example, is about "drugs consumption and urban violence". The document text used in this example was extracted from a Brazilian Magazine.



where:
IO : "Developing critical reading skills"
IG1 : ""What is the main problem ?"
IG2 : "Which are the aspects of problem ?"
IG3 : "What are the author's solutions ?"

KWK1: Traffic, Drugs
KWK2 : shantytown
KWK3: drug consumer, addict, fiend
KWK4 : doctors' opinion
KWK5 : legalization

F1: The liberation brings the disappearence of the trafficking.
F2: The most evident medicine should be that the traffickers have more fear: the legalization.
F3: The last week conflict occurred on Rocinha outline a personage that rarely have deserved attention, when discuss the shantytown war.
F4: The drug would not continue to kill more innocent people such as the shantytown populace that are hostage of one-armed bandit.
F5: How to accuse the fiend, if he is ill and doesn't have knowing of his attitudes.
F6: The marijuana could be considered least harmful, despite it is not a consensual doctor's oppinion.
F7: A hard approach that many people don't agree is the disappearance of traffickers resulting from legalization.

Figure 1 - Structure used to represent the pedagogical information of SC instructional activities.

4.2 Extractor of Keywords and Phrases - EKP

The occurrence of keywords determines the sentence's relevance to a specific IG. EKP tries to identify relevant phrases inside of text document of Presentation section. These phrases are selected and sorted following the count of occurrence of keywords found in the phrase. Figure 1 illustrates the current example, the set of phrases {F1 and F4} could be linked with IG1 through KWK1, {F5} could be linked with both IG2 and IG1 through KWK3, {F6}could be linked with IG1 through KWK4 and {F7 and F2} could be linked with IG3 through KWK5.

4.3 Discussion Guide Generator - DGG

The selected phrases are connected at least one IG. This connection occurs because the phrase has the IG's keywords. The Figure 1 illustrates this structure of connection and it must be used to help the following description of meta-strategies. The following three meta-strategies of problem's solutions are defined in function of KWK-IG relationship. These meta-strategies are used to define a set of Discussion Guide rules during the authoring process:

- **Unknowledgeable Strategies (UKS) -** When the learner is solving a specific problem linked with IG1, for instance, the author must select the elements of Matrix Response connected with IG1 (elements F1, F4, F3 and F5 of Figure 1) because these elements are the most relevant phrases of the subject. If the student did not select all expected elements, the feedback message of the Discussion section would contain didactical or dialectical explanation of why the student should have being selected the missing elements.
- **Neighbors knowledge strategies (NKS) -** When the learner are facing a problem associated with IG1, for example, it expected that he/she should select phrases F1, F4, F3 and F5. It is possible that learner's solution could contain the phrase F6, for example. Figure 1 shows F6 is relevant to IG2, but it is not relevant to IG1. F6 represents a learner misconception. Why did the learner select this element to compose his/her problem's solution? A possible answer to this question is that phrase F5 is a common element between IG1 and IG2. It is possible that learner was not able to discriminate the context meaning of keywords common to IG1 and IG2 (KWK3 and KWK4). F5 has function of "conceptual bridge" between IG1 and IG2. The feedback messages of Discussion section should discriminate the concepts, principles and process represented by keywords inside of F5, the bridge element between IG1 and IG2, and F6, the stranger element to IG1.
- **Random knowledge strategies (RKS) -** This strategy occur when learner selects, for example, F2 to compose his/her solution to the problem associated with IG1. F2 is a relevant piece of knowledge to IG3 and it is not relevant to IG1. F2 represents a learner mistake. This case does not have any common keyword between IG1 and IG3. The feedback message of Discussion Section should explore the reasons of why the concepts, principles and process represented by keywords inside of phrase F2 are not relevant to problem associated with IG1.

Table 1. Discussion Guide Rules for problem associated with IG1

Discussion Guide Rules	MS	Suggested objective of feedback message
If included {F1, F3, F4 and F5}	UKS	Reinforce the relevancy of phrases solution of problem associated with IG1.
If not included {F1, F3, F4 or F5}	UKS	Explain why these phrases and concepts are relevant elements to solution of problem associated with IG1.
If included {F6}	NKS	Discriminate F5 and F6
If included {F2} and not included {F7}	RKS	Explain why F2 is not relevant to solution of problem associated with IG1.
If included {F2 and F7}	RKS	Explain why F2 and F7 are not relevant to solution of problem associated with IG1.
If included {F7} and not included {F2}	RKS	Explain why F7 is not relevant to solution of problem associated with IG1.

This section explained some strategies to automatically produce the rules of Discussion section. The set of static meta-strategies produces a set of rules based on key concepts of the domain, instructional goals and objective. Table 1 illustrates the Discussion Guide Rules automatically generated by three meta-strategies. Table 1 shows only the strategies to problem associate with IG1, the problems associated with IG2 and IG3 will have other specific rules.

5. Conclusions and Future Works

Some of authoring difficulties to produce instructional activities with SC claim resources or helpful ideas. The ideas presented in this paper could help inexpert author during the authoring process. The inexpert author only needs to be able to select elements to compose the Response Matrix Section and Discussion Guide rules. The author's skill to foresee the possible learner's solutions is not anymore essential during authoring process. DGG can "foresee" or help author to “foresee” them. These ideas could constraints a creative author, or not? No, they cannot, because the creative author could refine the created rules or change them. The author exercises his/her abilities when he/she agrees or not agrees or changes the set of Matrix Response elements and set of Discussion Guide rules. Three meta-strategies also guide the author to create the Discussion Guide feedback message.

Future work of this research project is comprises the introduction of these ideas into an authoring tool. This authoring tool will help authors to develop instructional activities based on SC technique. Could SC be used like assessment tool in e-learning? Is it possible representing any type of problems within SC? Is it a valid technique to produce ill-structured based learning? These questions among others could be searched with these promising authoring tools.

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References

[1] Jonassen, D. H. (1997). *Instructional Design Models for Well-Structured and Ill-Structured Problem-Solving Learning Outcomes*. ETR&D, 45 v. , no. 1, p. 65-94.
[2] Egan, K. (1976). *Structural Communication*. Fearon Publishers, Inc.
[3] Hong, N. S. (1998). *The Relationship between well-structured and ill-structured problem solving in multimedia simulation*. Doctoral Thesis. College of Education. The Pensylvania State University.
[4] Romiszowski, A. J. (2000). *A methodology for Case-Study in Virtual Groups*, Proceedings of the ABED International Conference, 2000. Available online as www.abed.org.br
[5] Schank, R., Neaman, A., (2000). *Motivation and Failure in Educational Simulation Design*. Smart Machines in Education: the coming revolution in education technology, editado por Kenneth D. Forbus and Paul J. Feltovich, The MIT Press, p. 37-70.
[6] Fyfe, R. M., Woodrow, D., (1969). *Study Unit 1 - Sets. Basic Ideas of Abstract Mathematics*. The Centre of Structural Communication. University of London Press Ltd, P. 9-15.
[7] Bloom, B., S., Hastings, J., T., Madaus, G., F., (1971). Handbook on Formative and Summative Evaluation of Student Learning. McGraw-Hill, Inc.
[8] Mager, R., F., (1997). Measuring Instructional Results, Third Edition. CEP Press.

An Orientation towards Social Interaction: Implications for Active Support

Maarten OVERDIJK and Wouter van DIGGELEN
Department of Educational Sciences, Utrecht University

Abstract: Small group discussions are a common practice in the classroom. Several collaborative technologies based on networked computing have been developed to support these discussions. Computer-mediated communication offers opportunities to develop systems that provide users with 'on the spot' information about their performance. Such a system can reflect information that heretofore could only be provided by a human facilitator of a group discussion. We focus on one particular kind of collaborative technology: a shared workspace system for "graphical" discussion. The active system should be able to transform data to useful information, and moreover, it has to deal with *change* in the way that rules and resources govern users' actions and interactions. In order to further develop such a system, we need to adress conceptual issues regarding the analysis of technology-mediated interaction. This paper presents an exploratory orientation towards interaction from a social perspective, and discusses some implications for active support.

Keywords: Active support, Technology-mediated interaction and Structuration theory.

1. Introduction

Small group discussions are a common practice in the classroom. Several collaborative technologies have been developed to support these discussions. These technologies – based on networked technology – mediate the interactions of participants of the discussion. Because interaction data is stored, it can be used for further analysis. This implies that collaborative technologies can be extended with systems that analyse interaction data and provide participants with 'on the spot' information about their performance. These systems are based on some formal analytical framework that aggregates interaction data into meaningful information. They are considered to be 'intelligent' because they have the potential to take over – parts of – the role of the human facilitator. However, we state that these formal frameworks may not fully address the dynamics of social interaction. Rules of interaction are not stable entities but arise and evolve during interaction. To develop an 'intelligent' system we need to address the interplay between human actors, the technology and the rules that emerge during interaction. In this paper we present an alternative perspective – structuration theory - that stresses the relationship between the human actor, (technological) resources and rules as mutual constitutive. This perspective has implications for the analysis of interactions.

2. From collaborative technologies to 'intelligent' support

In this paper we focus on one particular kind of collaborative technology: a shared worskspace system for graphical discussion. Tools for graphical discussion enhance learning discourse by providing learners with the means to 'express knowledge in a persistent medium where the knowledge then becomes part of a shared context" [20].

Shared workspace systems
The Digalo[1] tool offers the user a shared workspace with a graphical user interface and a notation system that supports specific kinds of communicative acts, *i.e.* users can put forward a textual message in a contribution box, and relate associated contributions through the use of links. The Digalo is designed as a tool for "graphical" discussion, and can be utilized to support collaborative activity like problem-solving discussion. In our studies we used the Digalo to support small-group problem-solving discussions in the classroom where each group member was located behind a workstation, within physical distance from each other and with the ability to interact (non)verbally or electronically.

Pre-structured support
In its present form, a system like Digalo does not actively provide any 'intelligent' support to its users. However, a system that mediates users' communication always provides some kind of support. The system shapes the discussion because it enables the occurrence of certain actions while it constrains others. This so-called *pre-structured support* concerns *e.g.* the organisation of participation in the activity (turn-taking, simultaneous access), communicative acts (notation system), accessibility of information sources (anonymity of users) or modality of expression (textual, diagrammatic). The type of pre-structured support offered by Digalo – from here on referred to as the *structuring properties* of the tool – is designed to support problem-solving discussions.

Active support
Active, 'on the spot' support may provide users with current information about their – individual or group – performance which they may use to adjust their subsequent actions. This kind of support is based on a system that collects interaction data and transforms the data into models of interaction that are presented to the learner, directly or after a comparison with a desired state of interaction [10][13].

3. Problem statement: from data to information

A collaborative technology like Digalo enhances students' discourse with additional resources, such as e.g. a shared workspace and a notation system. However, it is not so much the resources provided by a medium *persé* that determine the nature of its use, but rather the rules and conventions that result from ongoing discursive application. Moreover, research findings *e.g.* [4] indicate that the rules that govern users' actions and interactions in a shared workspace system are by no means *stable*, but rather subject to a process of *change*. More precisely, these rules have an *emergent* character. So, rather than focusing on the ´fixed´ material characteristics - or resources - provided by a collaborative technology, one should take into account the way in which these resources are focused in practice through the use of rules.

In the shared workspace of Digalo, users can perform communicative actions in a textual and in a graphical modality of expression. Moreover, their interaction can proceed in a temporal sequence, spatially, or along both these dimensions. A system that uses interaction data to construct models of interaction requires an analytical framework that accounts for how the electronic discussion proceeds according to the interaction rules, and also for how these rules evolve and change during interaction. Moreover, such a framework should also account for the interplay between the two modalities of expression and the spatial-temporal

[1] Digalo has been developed by the Fraunhofer Gesellschaft within the EC funded Dunes project (IST-FP6-2001-34153).

representation. It is hypothesized that the two modalities of expression and the spatial-temporal representation of interactions *mutually* contribute to the interaction rules.

To our knowledge there exists no framework that meets these requirements. This paper raises some issues of a conceptual nature with respect to the development of such a framework. It adopts a thematical focus on the concepts of *change* and *mutual constitution* in theories of (social) interaction. Furthermore, we will illustrate our approach with some preliminary results that we gained from analyzing Digalo-mediated discussions.

4. The search for stable rules that constitute (social) interaction: a critical account

Conversation analysis (CA) can serve as a valuable approach for studying computer-mediated communication. Conversation analysis studies the structure of talk-in-interaction, and offers concepts to analyse/interpret these interactions. CA research focuses on talk-in-interaction in real life settings. CA is particularly valuable because the analytical frameworks to interpret these interactions are often grounded in a theory *and* data-driven approach.

A basic assumption in conversation analysis is that ‘conversational interaction in all its’ forms is accomplished as the accountable product of common sets of rules and procedures’ [6]. Moreover, these sets of rules and procedures are believed to be subjectable to formal description [16]. However, a group discussion does not always follow such formal rules, nor does it appear to be an organized activity in which participants talk and listen in orderly turns. Sacks, Schegloff & Jefferson [15] recognize that conversational interaction is always situated, nevertheless, they argue, “there must be some formal apparatus that is itself context-free” and exhibits sensitivity to “various of the parameters of social reality in a local context” [15].

Stability and change

What is echoed in the above, and made very explicit by some authors, like Harvey Sacks and his colleagues, is the search for invariant behaviour in conversational interaction across time and space. Analysts in this tradition display an orientation towards describing *mechanisms* that reflect formal, context-free properties. They conceptualize certain reoccurring phenomena based on rules that reflect *stability*, rather than *change*. In the study of social phenomena, it is often stability that is assumed. Even the criterion for change is the state of stability. Questions posed in relation to change concern the stable causes for disturbances of stability [12].

The tendency to search for ‘context-free and stable’ entities is a common practice in scholarly social thought. This preoccupation to stable rules that go beyond the here and now can be traced back to a mechanical view. The common conception in social psychology is based on independent entities that become (mutually) dependent and “start” effecting eachother in a causal relation, *e.g.* [14]. Invariance is explained through appointing entities a stable and independent character. This mechanistic view on the relation assumes that entities influence each other, but never exceeds a change in the essence of the entities. They only effect the “outside” of things. This conception has some strong implications for the analysis of interactions: human beings and the rules that govern their interaction can be considered as being in a dichotomous relation. *Dualism* - *i.e.* the tension perceived in dichotomous relations - can be found in social theory in a broad range of relations that are firmly grounded in scholarly discourse, *e.g.* object vs. subject, individual vs. society, micro vs. macro, internal vs. external and stability vs. change. This dualist relation results in ontological and epistemological problems. First, the concept of independent entities cannot account for the emergent qualities within a system (nonsummativity). Second, the concept presupposes that these social entities reflect a stable character *outside* action. It is questionable whether a social entity could ever be outside action. More viable is to conceptualize entities in a continuous stream of events. In order to resolve these problems, we have to reconsider the relation between the elements of what we see as a *social system*.

5. An alternative perspective

Recent theoretical approaches [1, 8] in sociology seek to escape conceptual dualism. The debate in sociology between dualistic and alternative approaches has its counterparts in social psychology [21] and computer science [5]. In these approaches, entities in the system - like subject and object, are viewed as interdependent at ontological level, rather than independent. This implies that subject and object are mutually constitutive, and that they come into being in the condition of their mutual relation. This co-constitutive view has also proven to be influential to theories in developmental psychology, *e.g.* in situated action [11], socioculturalism [22], and distributed cognition [17, 9]. These *situated* approaches stress that the structuring of activity 'is not something that precedes the activity, but can only grow directly out of the immediacy of the situation' [19, 11].

Structuration theory: an alternative view

Peoples' discourse is not driven by objects in the world – such as the surface properties of a medium - but by underlying structures like e.g. internal systems of meaning, modes of production, and inherent linguistic tendencies [7]. These underlying structures are made available through deeper, structuring properties that are carried in the interfaces of the tools that mediate peoples' action. The concept of 'structure' is subject to different interpretations. Traditionally, structure is seen as a stable and rigid construct that determines action in a constraining way. Structure is here seen as a property of objects in the world, and as external to human action. Recently, scholars have emphasized the dynamic, discursive construction of structure. In this view, structures come into being when agents engage in activity. Structure is seen as a property of social systems, rather than of material objects in the world. Moreover, it is seen as constraining *and* enabling.

Structuration theory (ST) attempts to explain how action in groups becomes structured through interaction. It recognizes a *social system* of interacting human agents and *structure*, in order to explain how practices develop and persist over time and space. In ST, structure is conceived as a property of social systems, 'carried' in reproduced practices embedded in time and space [8]. Structure is not a stable entity or property of a material object; rather it is constantly being (re)produced in a continuous flow of action, and exists only virtually. Structures come into being through peoples' use of rules and resources that are available in the social system. People are seen as "knowledgeable agents" that reflexively interact with the rules and resources in the environment. The upgrade of agency in ST draws attention to the ways in which agents actively shape their discourse and their use of tools.

Structuration is the process by which systems are produced and reproduced through members' use of rules and resources. Structure is seen as both the medium and outcome of the conduct it – recursively, organizes. Structuring properties in a social system allow the binding of time-space in the system; these properties "make it possible for discernibly similar social practices to exist across varying spans of time and space and lend them systemic form" [8].

Although ST focuses on the relation between agency and structure on the macro-level, it seems a promising explanatory framework to account for change and stability in the relation between agency/structure on the micro-level. The focus is then on the practice of the small-group as a part of a larger social system.

6. Implications of discussing Digalo-mediated: towards a framework for analysis

When a collaborative technology is introduced in the classroom, students encounter an unknown situation that changes their communication in a fundamental way. The students have to manage their collaboration, and meet task-requirements, while working with a tool that brings new possibilities and restrictions to their discourse. When students' communication becomes mediated by technology, they cannot always rely on the interaction rules they would normally draw from in face-to-face communication. A graphical discussion environment, designed to support communication and the exchange of ideas and arguments between students, is based on a model of a face-to-face problem-solving discussion. It reflects certain rules and resources of the "ordinary" practice that users are familiar with, but it neglects others. These resources refer to e.g. control over the shared workspace and the notation system; the rules can refer to the constitution of meaning (signification), and to the sanctioning (legitimation) of modes of social conduct. Rules governing signification enable meaningful communication, they allow the coding and decoding of a symbolic order and modes of discourse.

Appropriation during a Digalo-mediated discussion
In order to gain insight in the process of appropriation, we focus on the interaction process of a Digalo-mediated discussion. We propose a descriptive account of the interaction process, *i.e.* a detailed description of the actions and interactions during the discussion. The replay function in Digalo captures a frame-by-frame representation of the discussion as it took place in temporal order. The sequence of consecutive actions reveals an observable pattern of relations in the shared workspace. We build on concepts from CA and (A)ST to analyse/interpret the interactions in the shared workspace. It does not seem feasible to view the organization, content and style of the interaction as independent. Still, we can adopt a *thematical focus* in analysing the interaction [3]. We adopt a thematical focus on the *organization of the interaction* in the shared workspace in order to examine the process of appropriation. In previous research [4], we identified three organising principles that students applied to create an observable pattern of relations when engaged in graphical discussion. We used these principles to distil interaction sequences within the Digalo. A sequence consists of at least 3 related contributions where two successive contributions are made by *two different* students. The diagrams that the students constructed are very diverse. Some groups came up with a more rigid, structured representation while others constructed a more unstructured, complex diagram that may even be judged as chaotic by outsiders. Examination of the interaction process shows that the rules for organizing the interaction change during the discussion, and influence subsequent interaction. The process of appropriation seems to be the outcome of implicit negotiation, and occurs on the group level.

Implications for active support
When students interact in the shared workspace of Digalo they perform actions that can be described according to the 1) two modalities of expression and 2) the spatial-temporal representation. A "Digalo-like" system that reflects information during a group discussion has to collect all actions in the shared workspace, and needs a model that can account for the interplay between *specific combinations* of these actions. The two modalities of expression and the spatial-temporal representation *mutually* contribute to the emergence of interaction rules, and thus to the constitution of interaction.

The theoretical exploration presented in this paper indicates that appropriation of rules and resources that govern users' actions and interactions is a *dynamic* process. The model should be able to deal with *changes* in the appropriation of rules and resources. In other words, it should not assume stable structure. It should be able to deal with stability from a concept that foregrounds change. Application of ideas from structuration theory to the study of interaction can offer a tentative approach to such a dynamic view.

References

[1] Archer, M. S. (1995). *Realist social theory: The morphogenetic approach.* NewYork: Cambridge University Press.

[2] Barros, B. and Verdejo, M.F. (2000). Analysing student interaction processes in order to improve collaboration: The DEGREE approach. *International Journal of Artificial Intelligence in Education, 11: 221-241.*

[3] Bull, P. (2002). *Communication under the microscope: theory and practice of microanalysis.* Routledge, New York.

[4] Diggelen, van, W., Overdijk, M. and Andriessen, J. (2004), Constructing an argumentative map together: Organizing principles and their application. *Paper presented at the Dutch Educational Research Conference (ORD), Utrecht,* http://edu.fss.uu.nl/ord/homepage.htm.

[5] DeSanctis, G. and Poole, M.S. (1994). Capturing the complexity in advanced technology use: Adaptive Structuration Theory. *Organizational Science, 5(2),* 121-147.

[6] Garfinkel, H. (1967). *Studies in Ethnomethodology.* Englewood Cliffs, N.J.: Prentice Hall.

[7] Gergen, K. (1994). *Realities and Relationships: Soundings in Social Construction*. Cambridge, Massachusetts, Harvard University Press.

[8] Giddens, A. (1986). *The Constitution of Society: Outline of the Theory of Structuration.* Polity Press, Cambridge.

[9] Hutchins, E. (1995). *Cognition in the wild*. Cambridge: MIT Press.

[10] Jermann, P., Soller, A. and Muehlenbrock, M. (2001). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *Proceedings of the first European Conference on Computer-Supported Collaborative Learning,* Maastricht, The Netherlands.

[11] Lave, J. (1988). *Cognition in Practice.* Cambridge University Press.

[12] Marková, I. (2003). *Dialogicality and Social Representations: The Dynamics of Mind.* Cambridge University Press.

[13] Reimann, P. (2003). How to support groups in learning: More than problem solving. *Proceedings of Artificial Intelligence in Education 2003,* Sydney, Australia.

[14] Rommetveit, R. (1974). *On Message Structure: A Framework for the study of Language and Communication.* London: Wiley.

[15] Sacks, H., Schegloff, E.A. and Jefferson, G. (1974). *A simplest systematics for the organisation of turn-taking for conversation. Language, 50,* 696-735.

[16] Sacks, H. (1984). Notes on Methodology. In Atkinson, J.M. & J. Heritage (Eds.), *Structures of Social Action: Studies in Conversational Analysis* (pp. 21-27). Cambridge, England: Cambridge University Press.

[17] Salomon, G. (1993). *Distributed cognitions: Psychological and educational considerations.* NY: Cambridge University Press.

[18] Sawyer, R. K. (2001). Emergence in sociology: Contemporary philosophy of mind and some implications for sociological theory. *American Journal of Sociology, 107(3),* 551-585.

[19] Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication.* New York: Cambridge University Press.

[20] Suthers, D.D. (1999). Representational and Advisory Guidance for Learning: Alternate Roles for AI. *Proceedings of the IASTED International Conference Artificial Intelligence and Soft Computing.*

[21] Weick, C.A. (1979). *The Social Psychology of Organizing.* Random House, New York.

[22] Wertsch, J. V. (1995). The need for action in sociocultural research. In J. V. Wertsch, P. d. Rio, & A. Alvarez (Eds.), *Sociocultural studies of mind* (pp. 56-74). New York: Cambridge.

Designing Culturally Authentic Pedagogical Agents

Yolanda RANKIN
Northwestern University, Evanston, Illinois, USA

Abstract: Research has shown that shared ethnicity between a pedagogical agent and a user results in a positive perception of the agent's capabilities and provides motivation for learning tasks for students of color. However, ethnicity has previously has been defined primarily by the physical appearance of pedagogical agents, and it's unclear what kinds of implementations of pedagogical agents are the most authentic representations. I argue that ethnicity includes more than physical appearance but encompasses verbal and nonverbal behaviors as well. I observe verbal and nonverbal behaviors of African American preschool children as they participate in storytelling. I have adapted Cassell's (2000) methodology to the construction of ethnically authentic pedagogical agents. My research goal is to design culturally authentic agents that bridge the gap between language skills practiced outside the classroom setting and those language skills required in the classroom.

Keywords. Pedagogical agents, culturally authentic agents, ethnicity in pedagogical agents

Introduction

Past research has shown that shared ethnicity between an agent and a user results in a positive perception of the agent's capabilities and provides motivation for learning tasks for students of color [1, 2]. However, research has failed to examine what kinds of implementations of pedagogical agents are the most authentic. I argue that ethnicity includes more than physical appearance but encompasses verbal and nonverbal behaviors as well. I have adapted Cassell's [3, 4] methodology to the construction of ethnically authentic pedagogical agents. I observe verbal and nonverbal behaviors of African American preschool children as they participate in storytelling. Based upon these observations, I am designing and implementing a pedagogical agent that portrays culturally authentic verbal and nonverbal behaviors of African American children. I have selected storytelling as the learning activity for reasons described below.

2. Storytelling as a learning activity

Storytelling allows children to navigate between their imaginary world, on-going social world and the real world of people, places and things [5]. While playing with their peers, children navigate back and forth between these three worlds and develop increasingly complex stories as they attempt to describe events that happen within them [6, 7, 8]. Research suggests that children improve their literacy skills as a result of co-narrating stories with their peers. Their peers serve as critics as well as collaborators, questioning the choice of words (e.g. metalinguistic skills), correcting the order of events and suggesting what details should be included in the stories [6, 7]. Vygotsky's theory of the "zone of proximal development" says that children perform better and accomplish more with the help of a partner who is more cognitively advanced than they are [9]. I extend an existing Story Listening System (SLS) to provide cultural modeling through an African American pedagogical agent whose ethnic identity is not defined by appearance but relies more on authentic African American discourse [10]. The culturally authentic ECA I am developing serves as the interface for a SLS that uses speech to reflect African American socio-cultural norms while telling stories.

3. Justifying ethnicity in pedagogical agents

Embodied conversational agents (ECAs) are computer interfaces that have bodies and utilize their bodies as a function of conversational behavior [3, 4]. ECAs can serve as pedagogical agents while simultaneously portraying the role of virtual peer [10, 11, 12, 13]. Previous research indicates that interactive ECAs can be used for creating traditional and nontraditional learning environments [10, 11, 12, 13]. However, in the past, the appearance and behavior of pedagogical agents has represented the cultural biases of mainstream culture. This raises the question of whether ethnicity affects the success of ECA technology. Nass et al. [2] argue that consistent personality traits and shared ethnicity between user and agent results in the user relating more easily to the ECA, and resulting in the user perceiving the ECA as being trustworthy.

An ECA's identity becomes particularly important when the goal is to affirm cultural practices and construct bridges from those same cultural practices to mainstream literacy skills presented in the classroom setting. Lee [14] proposes that rather than requiring students to divorce themselves from cultural practices in order to acquire mainstream literacy skills, we should provide a "cultural modeling framework" that leverages cultural practices as stepping stones for building and honing students' literacy skills. Cultural modeling enables students to learn academic subject matter by forming a link between knowledge that students have constructed from their home and community experiences and learning objectives presented in the classroom environment [14]. It is critical that we create effective learning environments inclusive of tools that leverage diversity. The question is what methodology is best used to capture as well as reflect social and cultural norms of non-majority groups in the design of pedagogical agents? Answering this question requires an understanding of how cultural practices support individual learning and development, and how to create educational technology that models social norms of non-mainstream cultures. To better understand how to address these issues, we survey existing pedagogical ECAs designed to appeal to particular ethnic groups.

4. Ethnicity in previously designed ECAs

Previous research has provided examples of ECAs who were purposefully designed to be a member of a particular ethnic group. Nass et al. [2] conducted studies with two agents; one agent resembled a Caucasian male while the other agent resembled a Korean male. College students belonged to either ethnic group. The authors found that users who shared the same ethnicity as the agent believed the agent to be more socially attractive, trustworthy and competent. In this experiment, then,, college students determined ethnicity based upon the agent's physical appearance.

Baylor [1] designed pedagogical agents using the same facial image but differing in skin tones, hair color, hairstyles, gender, realism and facial expressions representing Caucasians and African Americans, respectively [1]. Baylor's studies indicated that when college students have a choice in selecting tutors, students tend to select agents of the same ethnicity. Furthermore, African American students rated their African American agent as more facilitating of learning, more credible, more human like and more engaging than Caucasian students rated their Caucasian agent [1]. In a similar study evaluating agent's functionality in relationship to gender and ethnicity, one agent portrayed the role of expert while another agent portrayed the role of motivator [1]. Both Caucasian and African American students found the African American Expert more facilitating of learning and more enjoyable than the Caucasian Expert. The design of the pedagogical agents relied on the premise that physical appearance is an adequate indicator of ethnicity, rather than verbal behavior or background information about the agent.

In contrast, Maldonado & Hayes-Roth [15] designed three pedagogical agents that represent three cultural identities (e.g. Brazilian) based on physical appearance, in addition to verbal and nonverbal behaviors. Kirita is a Venezuelan Art History tutor, dances the Merengue and loves the Venezuelan arepa sandwich. Kira is a Brazilian teenager who performs capoeira dance, has admiration for soccer star Pele and loves Brazilian Baroque art. American Kyra sports hair streaked with red highlights, speaks English and loves Jackson Pollock's work [15]. Though these three pedagogical agents were designed to target particular ethnic groups, their ethnic identities are not based on physical appearance alone but are a combination of verbal behaviors, background information about each agent and individual preferences based upon cultural influences. Maldonado & Hayes-Roth [15] suggests that authentic portrayal of ethnicity relies on more than just physical appearance. However, it is unclear from where Maldonado & Hayes-Roth drew their ethnic portrayal.

Similarily, Pinkard [16] developed *Rappin' Reader* and *Say Say Oh Playmate* for the purpose of assisting African American children's early language acquisition skills. The post-test showed 65% word gain after 90 minutes of interaction with *Say Say Oh Playmate* [16]. There was a statistically significant increase in word gain as a result using Say Say Oh Playmate. Pinkard attributes familiarity with rap music and clap routines as the motivating factors for African American children improving their literacy skills [16]. These agents' ethnic identities were based upon physical appearance and participation in cultural activities.

I propose that authenticity is best accomplished by observing ethnic group members participating in culturally defined activities and modeling those same behaviors in pedagogical agents that are designed to interact with a targeted ethnic group. I expand the definition of ethnicity to include verbal and nonverbal behaviors to establish rapport with members of the African American community. African American children may be alienated using traditional modes of instruction and may not recognize the relevance in acquiring the desired learning objectives presented in the classroom. If I can design a culturally believable African American agent that speaks AAVE in one social context (e.g. spending times with friends or family members) and speaks SE in other social contexts (e.g. giving a speech in class), then we can leverage cultural modeling as a framework for acquiring mainstream literacy skills for all children.

5. Designing a culturally authentic agent

Maldonado & Hayes-Roth [15] discuss the importance of creating agents that provide a "suspension of belief" rather than a "suspension of disbelief." Maldonado & Hayes-Roth [15] identify key qualities for creating embodied conversational agents that are culturally believable. I directed my attention to a subset of design criteria that would define the ethnicity of the agent based upon verbal and nonverbal behaviors. Content of speech refers to the matching of language and dialect to culture of the character [15]. What the character says and how the character says it can promote or demote believability. Manner of speech is how and when something is said [15]. Manner of gesturing indicates emotions, actions, and reactions to information that is being transmitted [15]. Nonverbal communication includes gestures, facial expressions and body movements that can be categorized according to cultural group [15]. Each criterion serves as a category for observed behavior as we carefully examine the children's interaction with one another.

I examined the behavior of seven African American children between the ages of 5 and 7 years old telling stories while playing with toys in a wooden castle. The investigator was absent from the room as the children told stories for fifteen to twenty minutes. One child requested permission to tell stories alone while the other children were arranged in dyads. The storytelling sessions were videotaped and transcribed. To analyze the content of speech, the collected stories were evaluated for presence of AAVE features [17, 18]. I found three categories of AAVE present in the children's utterances. (See Table 1.) AAVE encompasses a specific style or manner of delivery [17, 18]. One specific mannerism of conversational behavior is mimicry. Mimicry is defined as deliberate imitation of speech and mannerisms for the purpose of establishing authenticity and refers to manner of speech [17]. During the taped sessions, children would demonstrate mimicry by changing the pitch of their voices to portray different characters in the story. Style of delivery also includes nonverbal communication such as facial expressions and body movements. Green [18] defines ethnic nonverbal communication as gestures, including rolling eyes, rocking head and neck movements and body positions. Collected story data shows both males and females nodding their heads for emphasis, females rocking head and necks for emphasis and both males and females directing eye gaze to partner when attempting to gain creative control of the story. It was difficult to identify eye rolling since the children moved behind the castle, making it difficult to view facial expressions. In the following example, the child's gesture provides additional information about the child's ideas about watching someone take a shower:

Child1: Watch out. She's finna take a shower.
Child2: I don't want to see this so I cover my face. [A doesn't want to watch P undress the female doll, but he doesn't cover his face. He looks down towards the floor.]

Based upon the observations, I selected a subset of head (e.g. *emphatic nods*) and neck gestures (e.g. *sassing neck gesture*) to be implemented in ***Alex***, an authentic African-American pedagogical agent.

6. Implementation

We chose a set of stories told by our subjects, and reduced them to more manageable two-minute lengths. The stories were then recorded using a human voice pitched to portray a child's voice. Gestures were first created and implemented using previous Flash implementations of our virtual peer [10]. Using a scripting language, I integrated verbal and nonverbal behaviors.

Alex is controlled with a Wizard of Oz interface (WOZ) that enables the researcher to control Alex's interaction with the child. The WOZ provides real-time speech and gestures in response to what the child says while playing with Alex. Alex tells a story featuring AAVE discourse and then prompts the child to tell a story, using eye gaze and speech. Alex indicates interest by eye gaze, backchannel (e.g. "For real") and gestures (e.g. *ListenandDisagree*). Thus, I have attempted to implement an interactive storytelling system that features an authentic representation of an African American virtual child named Alex.

7. Conclusion and future work

In conclusion, I have attempted to create a prototype of an authentic virtual representation of an African American child. Current research efforts focus on the following question: Will children perceive Alex as a African American based upon verbal and nonverbal behaviors? In addition, further research is planned to evaluate the affects of culturally authentic pedagogical agents on African American children's early language acquisition skills. This brings us one step closer to designing and implementing culturally authentic pedagogical agents that can bridge the gap between language skills practiced outside the classroom setting and those language skills required in the classroom.

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References

[1] Baylor, A.L. Paper presented at the Workshop on "Affective Interactions: Computers in the Affective Loop" held at the International Conference on Intelligent User Interfaces, San Diego, CA, 2005.

[2] Nass, C., Isbister, K., & Eun-Ju, L. (2000). Truth is beauty: Researching embodied conversational agents. In J. Cassell, J. Sullivan, S. Prevost, and E. Churchill (Eds.) *Embodied Conversational Agents*. Boston: MIT Press: 95–122.

[3] Cassell, J., Bickmore, T. (2003). Negotiated Collusion: Modeling Social Language and its Interpersonal Effects in Intelligent Agents. *User-Modeling and Adaptive Interfaces 13(1-2)*: 89-132.

[4] Cassell, J., Bickmore, T., Vilhjalmsson, H., Yan, H. (2001). More Than Just a Pretty Face: Conversational Protocols and the Affordances of Embodiment. *Knowledge-Based Systems 14*: 55-64.

[5] Dyson, A. H. (1991). The roots of literacy development: Play, pictures, and peers. In B. Scales, A. Almy, M. Almy, A. Nicolopoulou & S. M. Ervin-Tripp (Eds.), *Play and the social context of development in early care and education*.New York: Columbia Teachers College, 98-116.

[6] Bokus, B. (1992). Peer co-narration: Changes in structure of preschoolers' participation. *Journal of Narrative and Life History*, 2(3), 252- 275.

[7] Preece, A. (1992). Collaborators and critics: The nature and effects of peer interaction on children's conversational narratives. *Journal of Narrative and Life History*, 2(3), 277 – 292.

[8] Auwarter, M. (1986). Development of communicative skills: The construction of fictional reality in children's play. In J. Cook-Gumperz (Ed.) *Children's worlds and children's languages*, 205 – 230. Berlin, Germany: Mouton de Gruyter.

[9] Vygotsky, L.S. (1978). Mind in society: the development of higher psychological processes. Cambridge, MA: Harvard University Press.

[10] Cassell, J. (2004). Towards a model of technology and literacy development: Story listening systems. *Applied Developmental Psychology* 25, 75 – 105.

[11] Ryokai, K., Vaucelle, C. & Cassell, J. (2003). Literacy learning by storytelling with a virtual peer. *Journal of Computer Assisted Learning 19(2)*: 195-208.

[12] Rickel, J. & Johnson, W.L. (2000). Task-oriented collaboration with embodied agents in virtual worlds. In J. Cassell, J. Sullivan, S. Prevost, and E. Churchill (Eds.) *Embodied Conversational Agents*. Boston: MIT Press: 95–122.

[13] Lester, J.C., Towns, S.G., Callaway, C.B., Voerman, J.L. & Fitzgerald, P.J. (2000). Deictic and emotive communication in animated pedagogical agents. In J. Cassell, J. Sullivan, S. Prevost, and E. Churchill (Eds.) *Embodied Conversational Agents*. Boston: MIT Press: 95–122.

[14] Lee, C.D. (1997). Bridging home and school literacies: Models for culturally responsive teaching, a case for African American English. In James Flood, Shirley Brice Heath, & Diane Lapp (Eds.), *A Handbook for Literacy Educators: Research on Teaching the Communicative and Visual Arts.* New York: Macmillan Publishing Co.

[15] Maldonado, H. & Hayes-Roth, B. (2004). Toward Cross-Cultural Believability in Character Design. In S. Payr & R. Trappl (Eds.) Agent Culture: Human-Agent Interaction in a Multicultural World. New Jersey: Lawrence Erlbaum Associates, 143-176.

[16] Pinkard, N. (1999). Lyric reader: An architecture for intrinsically motivating and culturally relevant reading environments. *Interactive Learning Environment*, 7(1), 1-30.

[17] Smitherman, G. (1977). *Talkin and testifyin: The language of black America*. Boston, MA: Houghton, Mifflin & Co.

[18] Green, L.J. (2002). African American English: a Linguistic Introduction. Cambridge Press.

Verbal Behaviors	**Features of AAVE**	**Example**
Phonology	Deletion of *r* after a vowel	"Sleep on the **flo**."
	Realization of final *ng* as *n*	"Yeah we weren't **doin' nothin'"**
	Voiceless th as *t* of *f*	"Gonna move upstairs cuz they messin' **wit** me too much."
	Realization of *th* as *d*	"Where **da** food?"
Syntax	Absence of copula/auxiliary *is* and *are* for present tense	"She big."
	Multiple negation or negative concord	"Well I hope ya'll **weren't** doing **nothin'** son."
	Use of ain't as a general preverbal negator	"You **ain't** supposed to put your hands on a girl."
	Absence of third-person verbal -s	"She **take** up the whole bathroom."
	Absence of possessive	"**Jaylen** house."
	Use of invariant *be* for future tense	"Who gonna **be** da momma?"
Narrative style of delivery	Sing song intonation while narrating story.	Good **nigh---ty** [in a sing song voice with high intonation on first syllable].
	Change in voice pitch to impersonate a character in the story.	**"Good night, kids. "** [impersonating the mother] **"Good night, Mommy!"** [impersonating a little child's voice]

Table 1

Incorporation of Learning Objects and Learning Style - Metadata Support for Adaptive Pedagogical Agent Systems

Shanghua Sun
Department of Computer Science
University of Warwick, Coventry CV4 7AL, United Kingdom

Abstract. Learning objects have been increasingly used in pedagogical systems, but effective pedagogic strategies to support adaptive learning are still lacking. We report an investigation into incorporating learning styles into learning object metadata used in a pedagogical agent system. At the conceptual level, adaptivity is achieved by the use of learning styles in metadata to tailor the presentation of learning objects to individual students. Conversely, at the practical level, the adaptivity is achieved by providing a set of agents that uses a combination of pre-built and acquired knowledge to determine the learning styles and learning objects that are appropriate for individual students.

Introduction

The concept of learning objects has been proposed to address the issue of reuse in learning materials, from the perspective both of educators and learners. For educators, learning objects reduce the repetition of building same or similar learning materials [1]; for learners, learning objects increase personalization, interoperability, and flexibility [2]. In practice, learning objects are tagged with metadata so that their identity and content are available to software systems. Along with the use of learning objects in recent years, several metadata standards have been proposed to describe the content and structure of learning objects such as IEEE LOM [3], SCORM [4], and IMS [5].

People have their own preferences of how they can learn effectively, and to support a personalized learning strategy the differences between learners must be recognized [6]. The differences have been described as "learning styles" by educationalists. It has been suggested that learning objects can form individual learning paths for students, to achieve a student-centred adaptive learning environment [7]. Customizing learning materials as learning objects can support students with different learning styles. Although this idea has been proposed elsewhere [8], the incorporation of learning objects and learning style theories to support adaptivity is still a research problem. There are many metadata strategies for learning object design and categorization, but research about incorporating real learning objects with learning style schemes into education systems is rare.

We have developed a pedagogical agent-based system [9], in which agent technology provides a dynamic adaptation not only of domain knowledge but also of the behaviour of individual learners. The system is student-centred, adaptive and dynamic, and our approach takes a multi-disciplinary approach, combining learning theory with agent-based systems. In contrast to other agent-based pedagogic architectures, the incorporation of learning objects and learning style schemes form the pedagogic foundation for adaptivity, and the investigation of suitable granularity of learning object classification is also one of the subjects of our research.

1. Brief Introduction to Related Technologies

Our proposed pedagogic agent system architecture represents the integration of three key technologies and concepts: learning objects, learning style theories, and agent technology, and here we give a brief overview of these foundational aspects of our system.

1.1 Learning Objects

The idea of learning objects originates from breaking educational materials down into modular objects, which is analogous to the decomposition of an object-oriented program into objects and classes, and permits an individual learning object to be used in a variety of educational contexts. Each object can then have its defining properties tagged using metadata constructs, facilitating its use in an e-learning context [7]. In our pedagogical agent system, the decomposition of learning materials into learning objects guarantees that knowledge can be organized as a variety of learning paths to present to different students.

1.2 Learning Style Theories

People never learn in the same way. The concept of *learning style* has been introduced by educationalists as a "description of the attitudes and behaviours that determine our preferred way of learning" [10]. Learning styles depend on a variety of factors, and are individual to different people. An individual's learning style can change over time, and learning styles may differ between men and women, and between children and adults [11]. In this paper, we restrict our view of learning styles to those applicable for students in higher education.

Learning style theory is the pedagogic foundation of the multi-agent system, however there are several different ways of categorising people learning style preference. Kolb's Learning Style Inventory describes learning styles on a continuum running from concrete experience, through reflective observation, to abstract conceptualization, and finally active experimentation [12]. Gardener's Multiple Intelligences divides learning styles as dealing with words, questions, pictures, music, moving, socializing, and alone [13].

The Felder-Silverman Learning Style Model, which we have chosen to adopt, situates a student's learning style within a four-dimensional space, with the following four independent descriptors: *sensing learners* or *intuitive learners*; *visual learners* or *verbal learners*; *active learners* or *reflective learners*; *sequential learners* or *global learners* [14].

1.3 Agent Technology

An agent is an entity that is capable of carrying out flexible autonomous activities in an intelligent manner to accomplish tasks that meet its design objectives, without direct and constant intervention and guidance of humans. Agents should also know users' preferences and tailor their interactions to reflect these [15].

Multi-agent systems contain many agents that communicate with each other. Each agent has control over certain parts of the environment, so they are designed and implemented as a collection of individual interacting agents. Luck *et al*. remark that, "Multi-agent systems provide a natural basis for training decision makers in complex decision making domains [in education and training]" [16]. Furthermore, multi-agent systems can substantially contain the "spread of uncertainty", since agents typically process information locally [17]. In the context of our education system architecture, agents provide a means to manage the complexity and uncertainty of the domain.

1.4 The Incorporation of Learning Styles and Learning Objects within Pedagogical Systems

Some pedagogical systems have adopted learning style theories, and explored the delivery of learning materials adapted to students' learning styles. The system developed by Carver *et al.* presents a list of links to each student based on their learning style, leaving the individual student to select the material to use [18]. Paredes and Rodriguez use two dimensions of the Felder-Silverman Learning Style theory [19], and progress has been made on the mechanism elsewhere [20, 21, 22]. They have incorporated the learning style theory into their system and learning material design; however, the pedagogies and technologies are not suited to dynamic adjustment to students' learning styles. Knowledge is still delivered in a static way and the learning materials are more or less preset for a certain type of learning style or preference, and will not be changed or adjusted according to a change of learning style of the user over time. Few of the systems organize learning materials as learning objects. The incorporation of learning objects with learning style in our system allows us to dynamically organise and deliver learning materials to satisfy individual learning requirements, and agent technology gives dynamic support.

2. Incorporating Learning Style into Learning Object Metadata

In our pedagogical agent system, a single agent, the Learning Object Agent, is responsible for incorporating the learning style scheme and the learning objects. We refer the reader elsewhere for a more extensive technical discussion [9]. A repository provides the learning objects, which is under the charge of the Learning Objects Management Layer (one of the three layers) in the Learning Object Agent. In order to deliver the learning objects according to different learning styles, the implementation has been divided into three parts: accommodating students into the learning style scheme, categorizing learning objects according to the learning style scheme, and delivering learning objects. From a highly abstract level, the method can be laid out as in Figure 1.

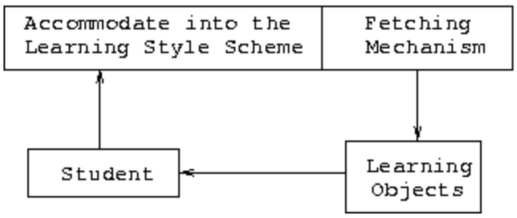


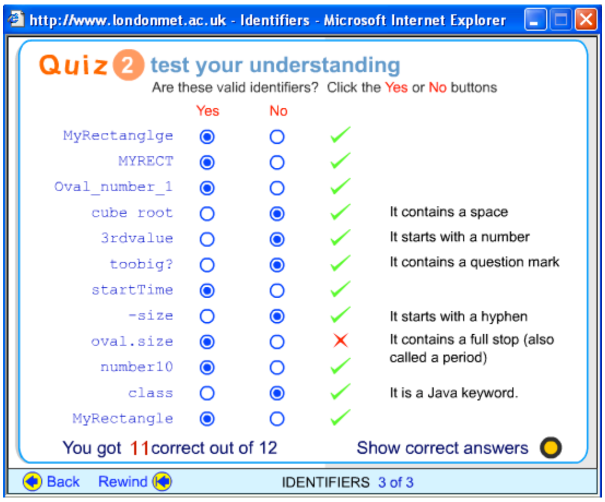
Figure 1. The Abstract Method

The learning style theory we have adopted in the system is the Felder-Silverman Learning Style Model. The reasons we has chosen the Felder-Silverman Learning Style Model are that it has been validated by pedagogy research [14, 23], and the number of dimensions of the model is constrained, improving the feasibility of its implementation.

2.1 Categorizing Learning Objects according to the Learning Style Scheme

The learning objects we use are also organized into the four-dimension learning style space, and include learning objects for Introductory Programming [24], as well as some suitable learning objects from the other open sources.

In addition to the descriptions in the existing metadata standards, the learning object metadata incorporates a *dimension description*, suggesting for each of the four learning style dimensions the extent of each object's suitability on a five-point scale. For instance, the visual/verbal dimension contains the following descriptors: strongly visual, weakly visual, neutral, weakly verbal, and strongly verbal.



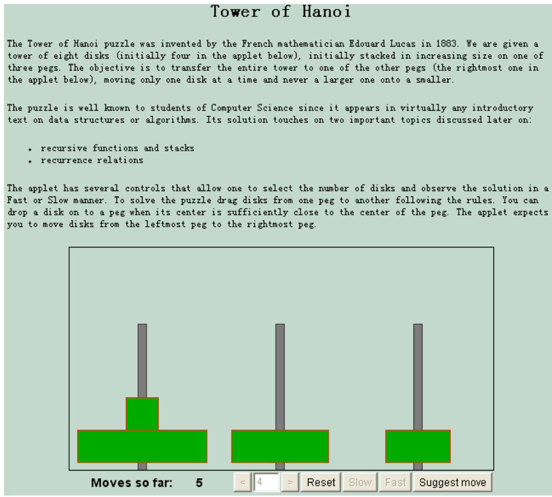


Figure 2. Identifiers – Learning Object from [24]   **Figure 3.** Tower of Hanoi – Learning Object from [25]

As an example, consider the learning object in Figure 2 [24], which uses a game like format to help to distinguish valid identifiers in Java. The learning object is composed of three interactive pages. The values of the five-point scale of this learning object are weakly intuitive, neutral of visual and verbal, strongly active, and weakly global, and this is also the value of *dimension description* in the metadata of this learning object. Consider the learning object in Figure 3 [25], which is an animation of the Towers of Hanoi. The user sets the number of towers and the speed of movement, and substantial user interaction is required. In the *dimension description* of this learning object's metadata, the value is weakly sensing and visual, strongly active, and neutral on sequential or global. Preliminary experiments suggest that it is feasible to categorise learning objects in the learning style space.

2.2 Accommodating Students into the Learning Style Space

A simple algorithm that approximates the positioning of a student's learning style in the four-dimensional space is constructed by using a reduced set of appropriate questions from [26]. A statistical analysis has been performed on the results for a sample of students with those generated by Felder and Silverman's original questionnaire, and indicated a strong correlation between the two data sets. This suggests that the reduced set of questions is sufficient to categorize a student's learning style.

The intelligent pedagogical agent system we have developed stores each student's current learning style (which may change over time), and in the metadata the style dimension description of each learning object as co-ordinates in the four-dimensional space. The algorithm used to deliver learning objects to students involves matching the style attributes of (appropriate) learning objects to the current style preferences of the individual student. The system then searches the repository of learning objects to fetch appropriate learning objects with similar (but not necessarily identical) dimensional descriptions. These are supported by agent technology to realize the algorithm and implement the process. The objects are then presented to the student, and subsequent interactions between the student and the learning objects may be used to modify the student's learning style attributes.

3. The Pedagogical Agent System

Agent technology has been used in education systems to facilitate autonomy and adaptivity, decoupled from the pedagogic foundations of the system [27, 28, 29]. Each such system emphasizes a particular aspect, such as training, group work, or human resources requirement. Each has its individual ways of organizing the learning materials, but few have considered the effect of different learning styles or the adoption of learning objects.

Our proposed multi-agent based pedagogic system is functionally constructed by five agents, as shown in Figure 4, and comprises the Student Agent, the Record Agent, the Modelling Agent, the Learning Object Agent, and the Evaluation Agent. Each agent is designed to satisfy a certain functional requirement to actualize the service purpose of the education system, namely to provide dynamic and adaptive learning materials to individual users. For more technical detail about the agent architecture, we refer readers to [9].

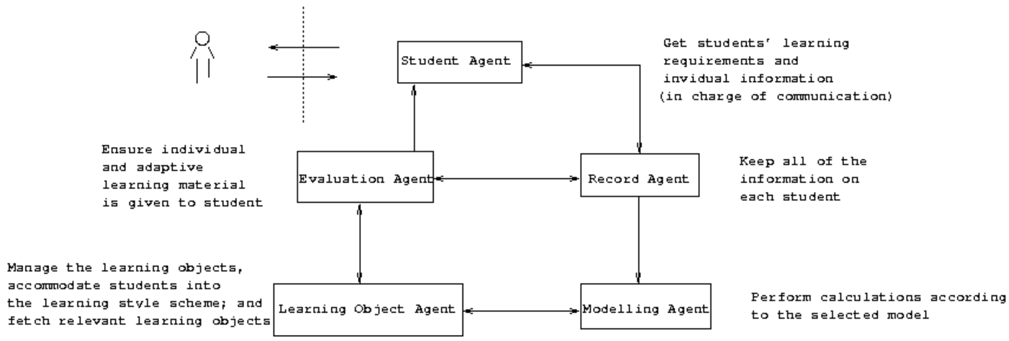


Figure 4. The Pedagogical Agent System

4. Conclusions and Future Work

We have reported an investigation of incorporating learning style into learning objects' metadata to support adaptivity in a pedagogical agent system. The evaluation suggests that the approach is appropriate for the pedagogical agent system. Current and future work includes further investigation of the granularity of the learning object category, and optimising the system architecture to enhance its effectiveness and efficiency.

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References

[1] D. A. Wiley, Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. *The Instructional Use of Learning Objects: Online Version*, (2000), http://reusability.org/read/chapters/wiley.doc. Accessed Jan 2003.
[2] W. Longmire, A Primer on Learning Objects, *Learning Circuits, ASTD's Source for E*-Learning, (2000), http://www.learningcircuits.org/mar2000/primer.html. Accessed Mar 2003.
[3] IEEE LTSC, IEEE Standard for Learning Object Metadata, *IEEE (2002).*
[4] ADL, Sharable Content Object Reference Model (2004), http://www.adlnet.org/. Accessed Mar 2004.
[5] IMS Global Learning Consortium, IMS Enterprise Best Practice and Implementation Guide V.1.01, *(1999).*
[6] T. Jenkins, On the Difficulty of Learning to Program, *Proceedings of the 3rd Annual Conference of the LTSN Centre for Information and Computer Sciences,* (2002), 53-58.
[7] P. Semmens, The Potential for Learning Objects to Support Flexible Learning in Higher Education, *Technology newsletter, IEEE Computer Soc. Technical Committee on Learning Technology,* (2004), 23-27.
[8] R. Smith, Guidelines for Authors of Learning Objects, *NMC: The New Media Consortium*, (2004), http://www.nmc.org/guidelines/. Accessed July 2004.
[9] S.Sun, M. Joy, N. Griffiths, An Agent-Based Approach to Dynamic Adaptive Learning, *Proceedings of Agent Based Systems for Human Learning (ABSHL) Workshop, the Fourth International Joint Conference on Autonomous Agents and Multi Agent Systems - AAMAS,* (2005).
[10] P. Honey, Honey and Mumford Learning Styles Questionnaire, *PeterHoney Learning,* (2001), http://www.peterhoney.com/product/learningstyles. Accessed Apr 2004.
[11] J. Blackmore, Learning Styles, *Telecommunications for Remote Work and Learning,* (1996), http://www.cyg.net/~jblackmo/diglib/styl-a.html. Accessed May 2004.
[12] D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development,* Englewood Cliffs, NJ, Prentice-Hall, 1984.
[13] H. Gardner, *Multiple Intelligences: The Theory in Practice,* Basic Books, 1993.
[14] R. M. Felder and J.E. Spurlin, Applications, Reliability, and Validity of the Index of Learning Styles, *Int. Journal of Engineering Education*, 21(1), (2005), 103-112.
[15] N. R. Jennings and M. Wooldridge, Applications of Intelligent Agents, *Agent Technology Foundations, Applications and Markets*, Springer-Verlag, 1998.
[16] M. Luck, P. McBurney, and C. Preist, *Agent Technology: Enabling Next Generation Computing A Roadmap for Agent Based Computing*, AgentLink, 2003.
[17] M. Georgeff, B. Pell, M. Pollack, M. Tambe, and M. Wooldridge, The Belief-desire-intention Model of Agency, *Proceedings of the 5th Int. Workshop on Intelligent Agents V: Agent Theories, Architectures, and Languages*, (1999), 1–10.
[18] C. A. Carver, R. A. Howard, and W. D. Lane, Enhancing Student Learning Through Hypermedia Courseware and Incorporation of Student Learning Styles, *IEEE Trans. on Education,* 42(1) (1999), 33-38.
[19] P. Paredes and P. Rodriguez, Considering Learning Styles in Adaptive Web-based Education, *Proceedings of the 6th World Multiconference on Systemics, Cybernetics and Informatics,* (2002), 481-485.
[20] M. Specht and R. Oppermann, ACE – Adaptive Courseware Environment, *The New Review of Hypermedia and Multimedia* 4 (1998), 141-161.
[21] J. E. Gilbert and C. Y. Han, Arthur: A Personalized Instructional System, *Journal of Computing in Higher Education*, 14(1) (2002).
[22] H. Hong and Kinshuk, Adaptation to Student Learning Styles in Web Based Educational Systems, *ED-MEDIA* (2004), 491-496.
[23] M. S. Zywno, A Contribution to Validation of Score Meaning for Felder-Soloman's Index of Learning Styles, *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition,* session 2351.
[24] T. Boyle, *et al.* Learning objects for Introductory Programming, http://www.londonmet.ac.uk/ltri/javaobjects/. Accessed Feb 2004.
[25] CTK Software, Inc., Tower of Hanoi, *Interactive Mathematic Miscellany and Puzzles, CTK Software, Inc.,* http://www.cut-the-knot.org/recurrence/hanoi.shtml. Accessed Oct 2004.
[26] B. A. Soloman and R. M. Felder, Index of Learning Styles Questionnaire, http://www.ncsu.edu/felder-public/ILSpage.html. Accessed Apr 2004.
[27] M. A. Razek, C. Frasson, and M. Kaltenbach, Toward More Cooperative Intelligent Distance Learning Environments, *Software Agents Cooperation Human Activity*, (2002), http://www-perso.iro.umontreal.ca/~abdelram/. Accessed Feb 2003.
[28] T. J. Norman and N. R. Jennings, Constructing a Virtual Training Laboratory using Intelligent Agents, *Int. Journal of Continuous Engineering Education and Life-Long Learning,* 12(1-4) (2002), 201-213.
[29] Y. Shang, H. Shi, and S. Chen, An Intelligent Distributed Environment for Active Learning, *Proceedings of the tenth Int. Conference on World Wide Web,* (2001), 308-315.

Enhancing Collaborative Learning through the use of a Group Model based on the Zone of Proximal Development

Nilubon TONGCHAI[1]
The SCRE Centre, Faculty of Education,
University of Glasgow, 11 Eldon Street, Glasgow, G3 6NH

Abstract: Collaborative Learning is seen as a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling can help learners to improve their performance and their understanding using high-level indicators to monitor, and represent, the state of their learning. In this work we aim to develop a learning environment that encourages students to obtain an advantage from both Collaborative Learning and open learner modelling. We then seek to determine the benefits of Collaborative Learning with a scrutable Group Learner Model[1] by examining the learning gains when compared with the case in which no Group Learner Model is available.

Introduction

Collaborative Learning is seen as a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling can help learners to improve their performance and their understanding using high-level indicators to monitor, and represent, the state of their learning. This research seeks to apply both concepts of Collaborative Learning and open learner modelling.

We consider Collaborative Learning in term of Vygotsky's Zone of Proximal Development which is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" [2, p.86]. The ZPD concept emphasises a learning process which involves the mastering some skill or idea through a series of interactions including both individual and Collaborative Learning activities - i.e. eventually the learner can do it on their own.

When someone learns something, whether on their own or with a friend, they may need to know how well they performed in that particular task. In the classroom, the teacher may give some information such as a score or some suggestion about your performance on the task. An Open Learner Model is considered to be an aid to reflection. Bull defines an Open Learner Model (OLM) as a student model which is designed to help learners understand what they have learned more effectively[3]. This kind of model allows the learner to inspect, and sometimes challenge, beliefs recorded in the user model in order to change them.

Less has been done with Group Open Learner Models (GOLMs) though there is some work with them. Zapata-Rivera and Greer [4] found that students could be very confused when seeking to understand their GOLM. However, this GOLM was developed by a group of students working together with a single instance of ViSMod. The issue of the GOLM is taken up again later.

[1] The PhD student is under the supervision of Dr.Paul Brna.

1. Research Problems

For the past decades, many tools and methodologies have been designed to support Collaborative Learning interaction. The focus of this research topic is shifted from 'studying group characteristics and product', which contain many unpredictable factors, to 'studying group process' in the nineties. Jermann, Soller et al [5] introduced the idea of the 'Collaboration Management Cycle', which consists of four phases: Collect interaction data, Construct a model of interaction, Compare the current state of interaction to the desired state and Advise/Guide the interaction. This cycle provides a conceptual framework for managing collaborative interaction. In their view, all the four phases above are covered by three computer-based support options: Mirroring tools, Metacognitive tools and Guiding Systems.

Collaborative Learning is interpreted here in two distinct ways - the way that learners help each other in a group and the way that a teacher or a learning system helps the student to gain a better understanding. Teaching collaboratively helps learners to learn skills and ideas initially in their ZPD which is why "collaborative teaching" is important. Murray and Arroyo [6] implemented a learner model to support the concept of ZPD – their work illustrated that the student who masters material collaboratively today can master it individually tomorrow.

Related to the idea of ZPD is that everyone may be in a different state of learning in a group. Hence with a user model, either a personal or a group model, it is possible to individualise the level of knowledge to provide a suitable degree of reflection. However for more efficacies for Collaborative Learning, empirical studies have changed the focus from 'establishing parameters' to trying to understand the role which such variables play in mediating interaction [7].

There are many systems that are used for Collaborative Learning, some of which refer to the concept of ZPD, some reflect back the learner model to an individual student and a very few use a GOLM but how many of them contain both concepts of reflecting back group knowledge and explicit use of the notion of the ZPD? Six systems have been selected as representative of the state of the art; these are compared.

Table 1: The comparison of systems to represent concept of ZPD, individual and group leaner model

System's name	References	Did they use the ZPD concept explicitly [2]?	Did they reflect back to individual learner?	Did they reflect back the Group Learner Model?
ViSMod[3]	[4]	No	Yes	No
ECOLAB	[9]	Yes	Yes	No
ICLS	[10]	No	Yes	Yes
PairSM	[11]	Yes	Yes	No
STyLE-OLM	[12]	No	Yes	No
Mr.Collins	[13]	No	Yes	No

[2] I mean that internally there is a model of the learner which represents ZPD in some direct ways.
[3] Another version of ViSMod [8] describes some works with a Group Model but not the kind that we are interested in.

According to the table, ViSMod, STyLE-OLM and Mr.Collins are systems that reflect back only to individual learners whereas PairSM and Ecolab use both the concept of ZPD and reflect back the model to each learner while ICLS reflect back both individual and Group Learner Models. However none of the systems above uses all of the concepts - namely, ZPD, reflecting back the individual and group models. In this paper, the ideas of the system that utilises both the concept of ZPD and reflecting back the Group Learner Model. The first question is why the Group Model and the second is how are we going to generate a Group Model?

1.1 How are we going to generate a Group Model?

Most people see the Group Model as some kind of addition of individual models. Hoppe (1995) combined multiple individual learner models with the aim of forming more effective peer groups though Paiva(1997) looked for something better by combining the concept of a group model with an individual learner model to construct a basic framework for models in collaborative situations. However PairSM, a model that applied a simple picture and equation to illustrate the Group Learner Model, seems to be interesting because it considers a Group Learner Model together with the notion of the ZPD even though the group model comes from a simple combination of the individual learner models.

The explanation above expresses a Group Model as an equation SM-S1S2 = SM1 $\cup$ SM2 $\cup$ SM S1&S2 ,which SM represents the knowledge of an individual learner, and SM S1&S2 represents knowledge that the two can display only when working together. The group model in this work borrows ideas from both Paiva and PairSM to generate the group model for Collaborative Learning taking the ZPD concept into account.

In this work, there are two types of group models: GLM (Group Learner Model) and Ideal GLM (Ideal Group Learner Model). See Figure1

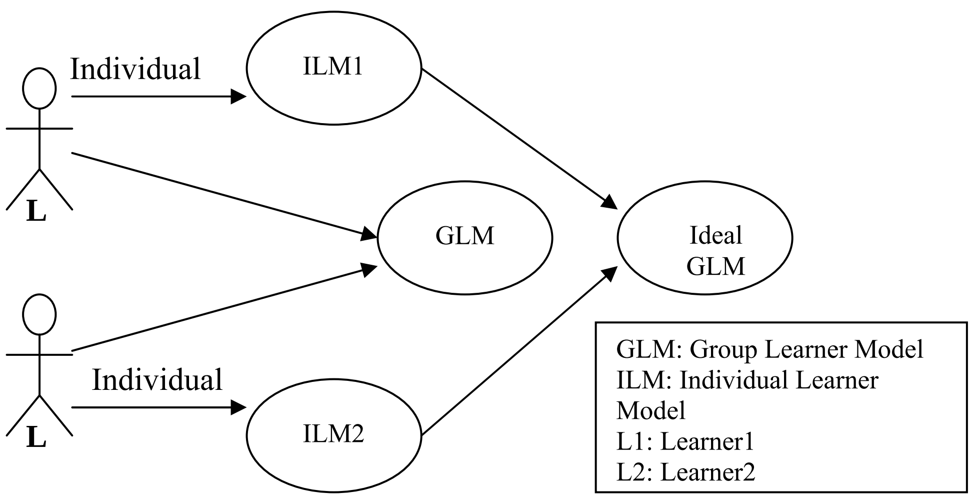

Figure 1: A Group Model diagram

- *GLM*: the group model that reflect quantity of knowledge for each concept when learner1 (L1) and learner2 (L2) collaboratively solve the group task. (This group model was formed after peer learned together)

- *Ideal GLM*: the group model which is generated from merging knowledge of individual models (ILM1 and ILM2) into a model that system expects peers to achieve when they learn together. This model merges individual models by taking their intersection as the group model (assuming no learning takes place).

1.2 How are we going to represent the model?

There are many possible ways such as text and graphical form that we could represent the learner model. STyLE-OLM uses a diagrammatic form of conceptual graph to represent the learner model and the text form for an interaction model. Moreover users can swap between learning mode and interaction mode to see what they have done in the past. ViSMod uses different colour and size of link and node to indicate the level of knowledge for particular learners on each concept. This should help learners quickly distinguish how well they perform for each concept. In our work, we will use a text form to represent the interaction model, while a graphical form will be used to indicate the level of knowledge for both group and individual learners.

1.3 How are we going to manage the interaction?

STyLE-OLM, and ICLS use different means of tagging individual moves in the interaction. STyLE-OLM uses the notion of a dialogue game for interactive communication between a learner and the system, while the open learner model concept allows student to inspect and negotiate their own model.

Mr.Collins aims at improving learning through promoting reflection by giving a chance to both students and a system to defend their beliefs using the difference of beliefs' confident between learner's and system. Whether learners can challenge and negotiate models through menus, changing models ultimately depends on the rules programmed into the system.

ICLS (Intelligent Collaborative Learning System) provides a good example of the use of sentence openers. This emphasises the role of communicative interaction. The ICLS system classifies groups of sentence openers, helping the group know how well they perform. In our work, we borrow the idea of dialogue game and sentence opener for the communication interaction and the level of confidence for their beliefs to generate the learner model.

In our research we focus on a Group Open Learner Model for Collaborative Learning. The group model will borrow ideas from Paiva and Bull's PairSM to generate the group model while taking the notion of the ZPD into account. Dialogue game and sentence openers will be used for communication interaction whereas it is planned to use a pie-chart and text as mirroring tools to represent the learner's beliefs and knowledge.

2. Evaluation

It is currently envisaged that two conditions for learning with a peer are compared: *can see* the group model and *cannot see* the group model using the pie-chart to represent as a group model. The hypothesis is that learning with a peer and seeing the group model will help the learner get a higher score than not seeing the group model.

In a group model, if learners see the pie-chart which represents the skills of the group using the GLM and the ZPD, the value calculated from the difference between the

Ideal GLM and GLM, and perform better than learners who cannot see the group model, we may be able to conclude that a group model is effective for collaborative learning.

To fulfil that aim, we have decided to use two students as a group learning together. Each student can choose their peer as they wish from the list that the system provides. Before starting to learn with a peer, the learner registers with the system and takes a pre-test. The learner's information is kept individually for use in the future. The experimental situation is shown in Figure2.

After learners choose their peer, they do the task individually and then go for the communication session. During the session, learners can communicate by using dialogue moves provided by the system that might help the system to understand what learners try to say to each other. This will be used to determine what learners understand of that particular task. Each dialogue move that learners use will contribute a score which affects the assessment for each concept of the group model as 'known', 'ZPD' or 'unknown'. The approach will rely technically on the use of fuzzy logic.

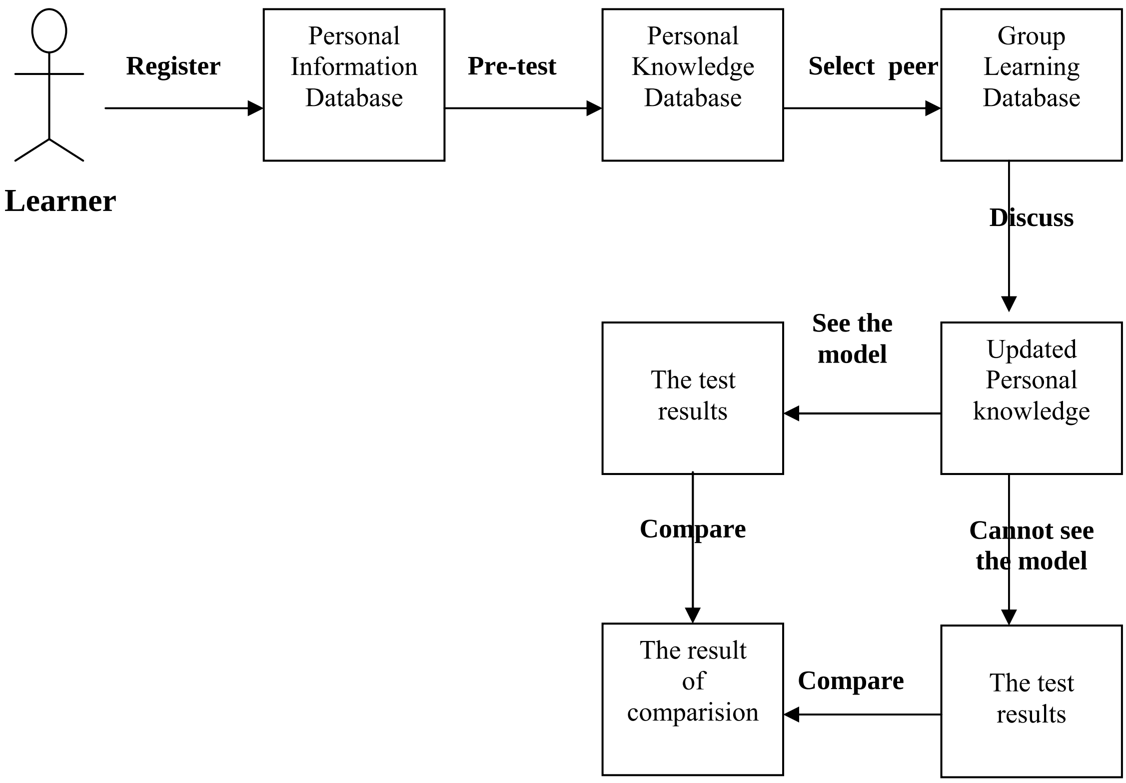

Figure 2: The experimental situation diagram

A prototype will be built to demonstrate the working of the model and it is expected to use fuzzy logic for dealing with the uncertainty in such a model. After the model has been developed further, the approach above will be implemented, tested and revised prior to developing the model used for the final study with learners. A repeated measure design within subject will be used to compare the result of learning to show that collaborative learning with the Group Open Learner Model is better than without the Group Open Learner Model.

3. Conclusion

Collaborative learning is a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling gives learners an opportunity to inspect or sometimes challenge[4] their user model to make it more accurate and to learn from this process.

The work in this thesis aims to encourage students to obtain an advantage from both collaborative learning and the use of an Open Learner Model to try to prove that the result of collaborative learning with a group model capitalise Open Learner Model allows the learner to get a higher score than when unable to inspect the group model. Now we are in the process of simplifying the group model taking the ZPD into account and using fuzzy logic as a technique to generate values representing group knowledge After the hypothesis described above is tested, the next question for this work is 'In what ways is a Group Learner Model better than an Individual Learner Model?'

References

1. Kay, J. Stereotypes, Student Models and Scrutability. *In Proceedings of ITS 2000*. 2000. Berlin: Springer-Verlag.
2. Vygotsky, L., *Mind in Society: The Development of Higher Psychological Processes*. 1978: Cambridge, MA: Harvard University Press.
3. Bull, S. and T. Nghiem. Helping Learners to Understand Themselves with a Learner Model Open to Students, Peers and Instructors. in Proceedings of Workshop on Individual and Group Modelling Methods that help Learners Understand Themselves. In *Proceedings ITS 2002*. 2002. Berlin: Springer-Verlag.
4. Zapata-Rivera, J.-D. and J. Greer. Externalising Learner Modelling Representations. In Proceedings of Workshop on External Representations: Multiple Forms and Multiple Roles at AIED 2001. 2001. San Antonio, Texas.
5. Jermann, P., A. Soller, and M. Muehlenbrock. From Mirroring to Guiding: A Review of State of the Art Technology for Supporting Collaborative Learning. In *Proceedings of the First European Conference on Computer-Supported Collaborative Learning*. 2001. Maastricht, The Netherlands.
6. Murray, T. and I. Arroyo. Toward Measuring and Maintaining the Zone of Proximal Development in Adaptive Instructional Systems. In *Proceedings of ITS 2002*. 2002. Berlin: Springer-Verlag.
7. Dillenbourg, P., et al. The evolution of research on collaborative learning. In *Learning in Humans and Machine: Towards an interdisciplinary learning science*. 1996: Oxford: Elsevier.
8. Zapata-Rivera, J.-D. and J.E. Greer. Interacting with Inspectable Bayesian Student Models. *International Journal of Artificial Intelligence in Education*. 2004. 14, 1-37.
9. Luckin, R. and B. du Boulay, Ecolab: The Development and Evaluation of a Vygotskian Design Framework. *International Journal of Artificial Intelligence in Education*. 1999. 10, 198-220.
10. Soller, A., et al. What Makes Peer Interaction Effective? Modeling Effective Communication in an Intelligent CSCL. In Proceedings of the AAAI Fall Symposium: Psychological Models of Communication in Collaborative Systems. 1999. Cape Cod, MA.
11. Bull, S. and M. Smith. A Pair of Student Models to Encourage Collaboration. In Proceedings of the Sixth International Conference on User Modeling UM97. 1997. Berlin: Springer.
12. Dimitrova, V., STyLE-OLM Interactive Open Learner Modelling. *International Journal of Artificial Intelligence in Education*, 2003, 13.
13. Bull, S., H. Pain, and P. Brna, Mr. Collins: A Collaboratively Constructed, Inspectable Student Model for Intelligent. Computer Assisted Language Learning. *Instructional Science*, 1995. 23, 65 - 87.

[4] Currently, we are planning to allow students to inspect but not change their GOLM.

Tutorial Planning: Adapting Course Generation to Today's Needs [1]

Carsten Ullrich
German Research Center for Artificial Intelligence, DFKI GmbH

Abstract. Most of today's course generation does not allow an in-depth, generic representation of pedagogical knowledge. However, supporting individual learners with different goals requires an elaborate representation of pedagogical expertise. In this paper, I describe a framework that adapts existing approaches for representing and using pedagogical knowledge to meet today's needs. Furthermore, I will show how in this framework several of today's problems are solved, such as the integration of distributed content, dynamic adaptivity of a generated course, new forms of interaction, and offering course generation as a service.

Keywords. Course generation, pedagogical knowledge, learning objects, adaptivity, Web services

1. Introduction

Course generation (CG) automatically assembles learning objects (LOs) to a greater unit that supports the learner to reach a given learning goal. Today's CG uses rather simplified pedagogical knowledge, e.g., the typical learning time of a LO [11]. However, to generate a course adapted to the individual learner's goals and needs requires more elaborate expertise. Representing pedagogical expertise is not a new idea [14,20], but it seems to have been neglected in the last years. In this paper, I argue to look back and adapt these ideas to suit today's needs. I will show how the introduction of *pedagogical tasks* and *methods* provides a framework that solves several of today's challenges. These challenges include: the integration of distributed content, dynamic adaptivity of a generated course, new forms of interaction, and offering course generation as a service.

Section 2 starts by summarizing the advantages of declarative pedagogical knowledge and provides the basics of my approach. Section 3 then describes in detail what is new in my approach and how existing challenges are solved. The paper closes with a comparison to related work and a description of the current state of the implementation (Section 4).

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```
(:method (teachConcept ?c)
         ((problem ?p (for ?c))) ;; this is the precondition
         (;; the following are the sub-tasks:
          (!startSection bookTitle) (provideSituation ?p)
          (teachSubConcepts ?p) (provideResult ?p) (!endSection)))
```

Figure 1. A method for a problem-based pedagogical strategy

2. Representing and Applying Pedagogical Knowledge

A *declarative*, *generic* representation of knowledge about *tasks and methods* offers several well-known advantages [18]. *Declarativity* eases authoring and change; being *generic* allows reusability; and to distinguish between *task and methods*, i.e., between what to achieve and how to achieve it, clearly separates different kinds of knowledge. Using partly different collections of tasks and methods, various problem solving *strategies* can be realized.

Declarative knowledge can be executed in a number of ways. In my work, I decided to use hierarchical task network planning [6] (HTN), among others because it is a very efficient planning technique and offers a relatively straight-forward way for representing human expert knowledge. It incorporates heuristic knowledge in the form of the decomposition rules: A planning problem is represented by sets of tasks (*task networks*); *methods* decompose non-primitive tasks into sub-tasks until a level of primitive tasks is reached, which can be solved by *operators*.

Together with the University of Augsburg, we are developing a problem-based pedagogical strategy that relies on the "Programme for International Student Assessment" (PISA) framework, [15]. Figure 1 contains an example of one of our methods. This method is applicable in case there exists a LO that represents a "problem" for concept c. Then, the complex task of teaching concept c is decomposed into three non-primitive sub-tasks: The first one describes the context the problem; the second one teaches the sub-concepts necessary for solving p, and the last one discusses the results of solving the problem using c (e.g., possible shortcomings). One by one, these tasks are further decomposed. "!startSection" and "!endSection" are primitive tasks, which insert and close a section.

Figure 2 provides an example of a method that encodes the pedagogical knowledge of selecting an exercise that is just within the current capabilities of the learner. Even this simplified method shows that even such a very basic task can require sophisticated knowledge: If the learner has low knowledge and additionally is unmotivated, then an appropriate exercise needs to be easier than in case he is highly motivated.

The result of the planning is a sequence of LOs called *course structure*. Similar to the "organization" element of an IMS Content Package [9], it consists of nested sections with the leaves being pointers to LOs. Additionally, leaves can consists of tasks (see Section 3.2). Because in my approach tasks represent a vast range of pedagogical issues, the size of the generated courses ranges from a single element to a complete curriculum.

```
(:method (insertAppropriateExercise ?c)
         ;;preconditon
         ((learnerProperty competencyLevel ?c low)
          (learnerProperty motivation low))
         ;;sub-task
         ((insertExercise ?c easy))
         ;;preconditon
         ((learnerProperty competencyLevel ?c low)
          (learnerProperty motivation high))
         ;;sub-task
         ((insertExercise ?c medium))
         ;;more
         ...)
```

Figure 2. A method for selecting an exercise

3. Tutorial Planning

In this section, I describe my contributions to CG and how several of today's challenges are solved. Because the resulting framework offers a broader approach to the sequencing of LOs as CG, I will refer to it as *tutorial planning.*

3.1. Integration of Distributed Content by Tutorial Planning

Today, content is distributed over the Internet and made available via Web-servers or LO repositories. Integrating this content by CG involves several difficulties.

First, traditional AI planning requires that a method's preconditions are evaluated against the planner's world state. However, in a distributed environment this would require to mirror all the metadata of the content stored in the repositories. This is simply infeasible. Second, despite standardization efforts content is described in various knowledge representations and metadata formats. Third, LOs can be constructed on the fly using generators [7]. How can the tutorial planner integrate these LOs without a practically impossible explicit modeling of the generators?

To solve these problems, I applied techniques for information integration from different knowledge sources [13]. There, an additional component acts as a *mediator* between the knowledge processing and knowledge storing components. It uses a reformulation engine to transform the incoming queries into queries in the formats of the repositories and sends back the collected results. Based on this approach, I extended the HTN-planning architecture so that queries about LOs in a method's preconditions result in a call to a mediator. The "lingua franca" of the mediator uses the vocabulary of an ontology of instructional objects [19] that defines about 30 different types of learning resources. Currently, however, mappings between the ontology and the knowledge representations of the repository need to be provided by hand.

Additionally, I extended the mediator approach to handle LO generators similar to repositories: the generators check whether they can generate an LO corresponding to the query, and, if so, send back identifiers from which the LO can be reconstructed later when it is presented to the learner. In this way, the tutorial planner abstracts from the LO repositories and generators and can focus on pedagogical knowledge.

3.2. Dynamic Adaptivity of a Generated Course

CG faces the dilemma that early course generation cannot take into account how capabilities of the learner actually change. Still, generating a course as early as possible supports orientation and self-organisation of the learning process. Plan repair [21] is a possible solution, I will present another one, lazy task execution.

I extended the planner such that planning may stop at the level of specially marked tasks (lazy tasks). These tasks are inserted in the content structure like a LO. When the learner first visits a page that contains a lazy task, the task in the content structure is passed to the tutorial planner. The resulting LOs replace the task in the course structure for good (hence, when the page is revisited, the elements do not change, which avoids confusion of the learner reported in [1]). This means a course is partly static, partly dynamic.

Lazy task execution offers new possibilities for authors, too. An author can define a course structure, where parts of her course are predefined, and others dynamically computed taking the learner model into account. In this way, an author can profit from the best of both worlds: she can compose parts of the course by hand and at the same time profit from the adaptive features of the tutorial planner.

The method in Figure 2 is an example of a method that can serve as a lazy task. Because the motivation of the learner may change while working through a course, the lazy execution of the task *insertAppropriateExercise* can take the current state into account.

3.3. New Forms of Interaction between Learner and Content

The explicit representation of tasks and the abstract layer they introduce offers to the learner new ways to access the pedagogical knowledge of the tutorial planner. If the learner requires support while navigating through a course, she can trigger the execution of a tutorial task (e.g., *insertAppropriateExercise*), for instance by selecting them from a drop-down list. Then, the task is processed by the tutorial planner and the resulting LOs are presented to her.

This approach has the advantage that content is retrieved in a more sophisticated manner than search, sparing the learner the exact knowledge of the LO metadata. Hence, she can easily and actively request additional content, and thus, a course less resembles a traditional text book but a dynamic and extensible workbook.

3.4. Tutorial Planning as a Service

Currently, several research groups investigate the integration of e-learning (Web) services and sharing of functionalities (see, e.g., [5]). In my approach, tasks can be interpreted as a description of the functionality that the tutorial planner offers. They can therefore serve as a basis for making the functionality of a tutorial planner accessible as a service to other systems. More specifically, the tutorial planner makes itself accessible as a service by offering a set of public tasks. The tasks range from the generation of a complete course to selecting a not too difficult exercise. Other components can start the tutorial planner on these tasks and receive a content structure as a result.

Again, the method *insertAppropriateExercise* can serve as an example. Several services could make use of this task, e.g., an Open Learner Model (OLM, [4]) that while interacting with the learner diagnoses that the learner has a erroneous belief about his knowledge state. One possible remedy is to offer him an exercise he should be able to solve. Instead of encoding the pedagogical knowledge of selecting an appropriate exercise in the OLM, it can make use of the services provided by the tutorial planner.

4. Related Work and Conclusion

CG has a long history, e.g., [16,14,20,21]. Despite continued research (e.g., [17,12, 11]), to my knowledge no system paralleled the extent of explicit representation of pedagogical knowledge as done by van Marcke. My work extends van Marcke's approach and adapts it to meet today's needs.

A related strain of research is Adaptive Hypermedia (for an overview, see [3]). One of its techniques, Adaptive Presentation, allows to conditionally include text fragments. In systems like AHA [2], conditional rules are included into the hypertext document. Using a technique like lazy task execution allows moving the rules from the document to a dedicated component like the tutorial planner with the advantages described above.

Open corpus hypermedia as described in [8] allows to integrate HTML pages from different sources. Using information about the concepts a page covers (provided by the author), the system generates a trail (course) leading the learner to her learning goal. The generation takes into account the learner's knowledge and the dependency relations between the concepts, but no other explicitly represented pedagogical knowledge.

An alternative to IMS CP [9] as the output of the course generation is IMS Learning Design (LD, [10]). IMS LD describes ordered activities in learning and the roles of the involved parties. However, in our context of web-based elearning, the simpler IMS CP proved to be adequate.

To summarize, in this paper I described tutorial planning, an approach to course generation that is based on a declarative representation of pedagogical knowledge. This knowledge level provides a framework which solves several of today's problems. These include the integration of distributed content and learning supporting tools within a course, dynamic adaptivity of a generated course, new forms of interaction, and offering course generation as a service.

The implementation is currently underway. The HTN-planner JSHOP was extended and connected to a metadata mediator. Parts of the problem-based pedagogical strategy are formalized. After the implementation, several pedagogical scenarios will be formalized and tested. An evaluation will assess and help to improve the system. It is an essential goal of my research not only to theoretically but also practically advance technology supported learning.

References

[1] P. D. Bra. Pros and cons of adaptive hypermedia in web-based education. *Journal on CyberPsychology and Behavior*, 3(1):71–77, 2000.

[2] P. D. Bra, A. Aerts, D. Smits, and N. Stash. AHA! Version 2.0 – more adaptation flexibility for authors. In *Proceedings of the AACE ELearn'2002 conference*, 2002.

[3] P. Brusilovsky. Adaptive hypermedia. *User Modeling and User Adapted Interaction*, 11(1/2):87–110, 2001.

[4] V. Dimitrova. STyLE-OLM: Interactive open learner modelling. *International Journal of Artificial Intelligence in Education*, 13:35–78, 2002.

[5] P. Dolog, N. Henze, W. Nejdl, and M. Sintek. Personalization in distributed elearning environments. In *Proc. of WWW2004*, 2004.

[6] K. Erol, J. Hendler, and D. S. Nau. HTN planning: Complexity and expressivity. In *Proceedings of the 12th National Conference on Artificial Intelligence (AAAI-94)*, volume 2, pages 1123–1128. AAAI Press/MIT Press.

[7] S. Fischer and R. Steinmetz. Automatic creation of exercises in adaptive hypermedia learning systems. In *Proceedings of the eleventh ACM on Hypertext and hypermedia*, pages 49–55. ACM Press, 2000.

[8] N. Henze and W. Nejdl. Adaptation in open corpus hypermedia. *International Journal of Artificial Intelligence in Education*, 12:325–350, 2001.

[9] IMS Global Learning Consortium. IMS content packaging information model, 2003.

[10] IMS Global Learning Consortium. IMS learning design specification, February 2003.

[11] P. Karampiperis and D. Sampson. Adaptive instructional planning using ontologies. In *Proc. of the 4th IEEE International Conference on Advanced Learning Technologies, ICALT 2004*, pages 126–130, 2004.

[12] K. Keenoy, A. Poulovassilis, V. Christophides, P. Rigaux, G. Papamarkos, A. Magkanaraki, M. Stratakis, N. Spyratos, and P. Wood. Personalisation services for self e-learning networks. In N. Koch, P. Fraternali, and M. Wirsing, editors, *Proc. of 4th International Conference on Web Engineering*, volume 3140 of *Lecture Notes in Computer Science*, pages 215–219. Springer, 2004.

[13] C. Knoblock and S. Kambhampati. Tutorial on information integration on the web at the 18th National Conference on Artificial Intelligence. July 2002.

[14] W. R. Murray. Control for intelligent tutoring systems: A blackboard-based dynamic instructional planner. In D. Bierman, J. Breuker, and J. Sandberg, editors, *Proc. 4th International Conference of AI and Education*, pages 150–168, Amsterdam, Springfield VA, Tokyo, 1989. IOS.

[15] Organisation for Economic Co-operation and Development (OECD), editor. *Measuring Student Knowledge and Skills – A New Framework for Assessment*. 1999.

[16] D. R. Peachy and G. I. McCalla. Using planning techniques in intelligent tutoring systems. *International Journal of Man-Machine Studies*, 24:77–98, 1986.

[17] M. Specht and R. Oppermann. ACE - adaptive courseware environment. *The New Review of Hypermedia and Multimedia*, 4:141–162, 1998.

[18] L. Steels. Components of expertise. *AI Magazine*, 11(2):30–49, 1990.

[19] C. Ullrich. The learning-resource-type is dead, long live the learning- resource-type! *Learning Objects and Learning Designs*, 1(1):7–15, 2005.

[20] K. van Marcke. Instructional expertise. In C. Frasson, G. Gauthier, and G. McCalla, editors, *Proceedings of the 2nd International Conference on Intelligent Tutoring Systems*, number 608 in LNCS, pages 234–243. Springer, 1992.

[21] J. Vassileva. Dynamic courseware generation: at the cross point of CAL, ITS and authoring. In *Proceedings of ICCE'95, Singapore*, pages 290–297, December 1995.

Mutual Peer Tutoring: A Collaborative Addition to the Cognitive Tutor: Algebra-1

Erin WALKER
Carnegie Mellon University, Pittsburgh, PA, USA
erinwalk@andrew.cmu.edu

Abstract. Although the Cognitive Tutor: Algebra-1 is effective at increasing individual learning, it lacks support for collaboration between students. We intend to explore the potential benefits of integrating a mutual peer tutoring script with the cognitive tutors, such that students take turns tutoring each other on problem-solving tasks, rather than being tutored directly by the computer. The script is based on current Algebra-1 curriculum goals and situated within the cognitive tutor environment, but requires collaborative additions to the interface and cognitive model. We expect that the script, in conjunction with the cognitive tutors, will improve domain learning and knowledge of problem-solving skills.

Introduction

A cognitive tutor is an intelligent tutor that compares student action during problem-solving to a model of correct action, and provides context-sensitive hints, error feedback, and problem selection. These tutors are effective at increasing student learning; use of the Cognitive Tutor: Algebra-1 (CT) has been shown to improve algebra understanding by about one standard deviation over traditional classroom instruction [1]. Because students would show further learning gains if their use of the cognitive tutors was balanced with collaborative activities, the CT is intended to be deployed in classrooms where students work together in groups and teachers act as facilitators, not lecturers. Unfortunately, this collaborative vision is not always realized in practice [2].

Collaboration can increase student mastery of domain knowledge and reasoning strategies, but is only effective when designed to encourage particular behaviours, such as providing group members with useful help, resources, and feedback [3]. To this end, many researchers develop collaboration scripts, or structured interactions with designated roles and activities for participating students. These scripts engage students in elaborate cognitive activities that promote domain learning [4], and might be a way of introducing collaboration into the CT environment.

One type of collaboration script is a mutual peer tutoring script. In mutual peer tutoring, a student first tutors a partner and then is tutored by the same partner. To be most effective, tutoring sessions need to be structured and incorporate rewards for good performance [5]. Tutors must prepare ahead of time [6] and, during the tutoring session, provide elaborated explanations [7] that the tutee can constructively use to solve the problem [8]. Making individual students aware of and accountable for the skills that they are acquiring has been shown to increase learning in peer tutoring settings [9]. In general, incorporating these elements into a peer tutoring script tends to increase student learning.

We propose to integrate collaboration into the existing cognitive tutor framework using a peer tutoring script (PTS) that is consistent with the curriculum goals of the CT [10]. The script will be easy for students to use, because it will be built upon the existing CT interface. Students will already be aware of tutoring concepts, because they will have internalized information about the tutoring process due to their previous exposure to cognitive tutors [11]. Finally, this integration will leverage the modeling capabilities of the CT to build a cognitive model of the student collaboration that can further support a positive interaction.

In this paper, I review the structure of the current CT. Next, I describe the script, and detail additions to the CT in terms of the interface and cognitive model. We expect that the integration of the peer tutoring script and CT will increase student algebra achievement.

1. Cognitive Tutor: Algebra-1

The CT focuses on "the mathematical analysis of real world situations and the use of computational tools" [1]. Students read a word problem and related mathematical questions in the Scenario Window (Figure 1). To solve the problem, students can use the Worksheet, Grapher, and/or Solver Windows. In the Worksheet, students identify quantities and units, answer Scenario questions, and enter algebraic expressions. The Grapher is for labelling axes, setting axes bounds, and plotting lines and intersection points. Students use the Solver to solve equations in a step-by-step fashion. Once students have completed all problem steps, they select "Done" from a menu, and proceed to the next problem.

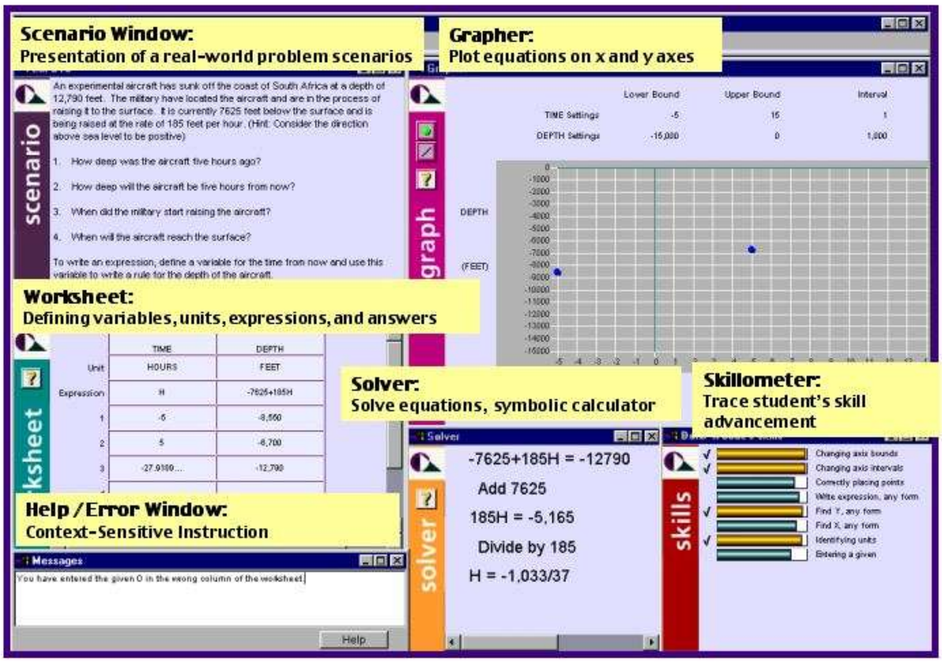

Figure 1. A screenshot of the Algebra Cognitive Tutor

As the student works on the problem, the cognitive tutor performs model tracing, monitoring the student's progress based on a model of correct and buggy (incorrect) student performance. When the student makes an error, the cognitive tutor will immediately "flag" it (i.e., turn input text red) and, for common errors, output a message in the Help/Error Window that explains the student's misconception. At any time, the student can request help, and the cognitive tutor will provide hint messages in the Help/Error Window. For each desirable action in the cognitive model, there are hint messages at multiple levels, so if students cannot solve a problem using the first hint, they can request the next hint. Model tracing insures that students get immediate and useful feedback on their progress.

The tutor also performs knowledge tracing [12] by keeping a running estimate of student mastery of skills and areas of difficulty. Skill levels are displayed in the Skillometer window, shown in the lower right of Figure 1, so that students are aware of their progress. Once a skill bar crosses a particular threshold, it is marked as a known skill. Cognitive tutors choose problems in a unit based on the skills the student has not yet mastered.

2. Expanding the Cognitive Tutor Curriculum using the Peer Tutoring Script

The PTS builds on the existing algebra problems and tools in the CT curriculum. Students are placed in homogeneous dyads with respect to age and gender and take turns being the peer tutor (the person doing the tutoring) and the peer tutee (the person being tutored). In the first phase of the script (or *preparation phase*) peer tutors perform exercises related to each problem they will be helping the peer tutees solve in the second phase (the *collaboration phase*). During the final phase (the *meta-evaluation phase*), the students have a structured discussion of the skills they used. Students should show learning gains after using this script because of its peer tutoring and monitoring requirements.

In the *preparation phase,* the peer tutor prepares to teach the peer tutee. Peer tutors read through an example solution for the current problem and solve an analogous problem. They then reflect on their role as a tutor by matching the skills required to solve the problem with the steps taken, rating the difficulty of the skills, and thinking about how they would explain the problem steps. For example, the peer tutor might be given the scenario and solution to this rate-of-change story problem found in the CT curriculum: “A huge mirror with a telescope is being moved by truck from Pittsburgh, PA to Charleston, South Carolina, a distance of 523 miles. The truck averages 12 miles per hour and has already traveled 70 miles.” After reading through the example solution, involving the use of the Worksheet and Grapher, students would be asked to solve a similar problem with different surface features (i.e., 12 miles per hour might become 17 miles per hour). Students would then explictly match problem-solving skill questions, such as “Can you find an expression for the problem?” to steps they have taken in solving the problem, such as typing “y = 12x + 70” in the appropriate textfield in the Worksheet. Students might rate finding the expression as a difficult skill, and, to further prepare for the tutoring, explain to themselves the steps they took in finding the expression. Throughout this process, the students will be aided by the CT, which will offer hints and bug messages as necessary.

In the *collaboration phase*, the peer tutor helps the peer tutee solve the problems that the tutor completed in the preparation phase. As in the individual use of the CT, the peer tutee is given the problem in the Scenario window, and solves it using the relevant tools (in the above example, the Worksheet and the Grapher). However, it is the peer tutor who is responsible both for providing explanations to the tutee and for rating the tutee’s mastery of the skill questions. For example, the first step in solving the problem might be identifying the quantities involved. As the peer tutee correctly completes this step by filling in the quantity names in the worksheet, the peer tutor would increase the values of the skill bar in the Skillometer beside the skill question “Can you identify the quantities involved in the problem?” The next step might be identifying the units involved in the problem. If the peer tutee gets this step wrong, the peer tutor is expected to recognize that the tutee needs help, explain what to do, and then confirm that the tutee understands the explanation. The peer tutor will be encouraged to formulate good explanations by first asking a leading question, then providing a hint, and then providing a more detailed description of how to solve the problem. This rating and hinting process continues until the problem is complete. The CT will also be used during this phase to monitor and tutor the collaboration between the students, ensuring that the dyads solve the problem correctly and provide each other with good explanations and feedback.

In the *meta-evaluation phase*, the students have a structured discussion about the skills involved in the problems. The peer tutee asks the peer tutor each skill question, the peer tutor explains how to complete the skill, and the two students discuss the merits of the peer tutor's answer. Next, the peer tutee looks at his or her rating on that skill, explains the mistakes made, and discusses whether the rating is justified. The students also examine the preparation to teach that skill, reflecting on simple questions such as, "Did the peer tutor think it would be difficult?" Eventually, the students will come to an agreement on how to answer the skill question, the peer tutee will input the answer, and the students will move on to the next skill. The purpose of this phase is to have the students reflect very specifically on the steps they took and skills they employed in solving the problems.

Learning gains due to this approach are expected to come from student engagement in positive collaborative behaviors and skill-monitoring. The preparation phase should allow the peer tutor to master a given set of problems, even if the student has been previously unsuccessful at math. The skill reflection exercise should lead peer tutors to think in elaborated ways about the problem, encouraging them to link concrete problem-solving steps to abstract skills and describe how they would explain those steps. During the collaboration phase, the tutor's explanations should benefit both students. Because the tutor's explanations have been prepared, even weaker students should serve as effective tutors, and tutees of all abilities should be able to use the explanations constructively. The process of rating the tutee should help both peer tutors, who will become more aware of the skills involved in solving the problem, and peer tutees, who will become more aware of their progress. The meta-evaluation phase is expected to be useful because students will discuss the problem steps and skills employed in the previous two phases in further depth. If the problem is challenging enough, these benefits should appear in dyads of all abilities.

3. Integrating the Peer Tutoring Script with the Cognitive Tutor: Algebra-1

To implement the PTS, collaborative additions need to be made to the CT. Because it is important that the PTS is situated within the CT environment, the script uses preexisting elements of the CT, such as the Worksheet, Grapher, and Solver tools. Some changes involve adding additional tasks to the interface and model, such as the skill reflection task in the preparation phase. These changes are relatively simple to implement. However, the collaborative extensions are more complex and require more description.

3.1 Interface Changes for Collaboration

The primary change to the structure of the CT occurs during the collaboration phase, because collaboration is not supported in the current interface. In the collaboration phase, students are located at different computer terminals. Students share windows so that an action performed by one student is seen by the other student. Some shared windows allow some actions from one student and different actions from another student. Table 1 contains a list of the windows that will be available in the collaboration phase, their visibility to each student, the actions they allow, and their use.

Despite these necessary changes, the use of the interface in the collaborative phase will be similar to students' experiences during the individual use of the cognitive tutors. The only new window is a Chat Window, which allows the students to discuss the problem. Further, the actions that the peer tutor can perform in this phase parallel the cognitive tutor actions in the individual use of the tutor: flagging errors, updating the Skillometer, and providing feedback in the Chat Window. Student familiarity with the individual tutors should generalize to their use of the collaborative tutors.

Table 1. Interface Windows in the Collaboration Phase

Interface Tool	Shared	Allowed Actions	Use
Scenario Window	Yes	None	Problem description
Completed Tools from Preparation Phase	No - visible only to the peer tutor	None	Answers to the problem
Active Tools	Yes	Peer Tutor – flag actions Peer Tutee – input actions	Tools the peer tutor must use to solve the problem
Chat Window	Yes	Text input	Place for Peer Tutor to give hints and feedback
Skillometer	Yes	Peer Tutor – changing the values of the skill bars	Facilitates student monitoring of skills
Hint/Error Window	No - each student has a separate window	None	Place for Cognitive Tutor to give hints and feedback

3.2 Developing a Cognitive Model for Collaboration

Adding collaboration to the cognitive model is another change to the CT. Because the two students are at different computer terminals, the CT can "model trace" *each* student's collaborative actions and provide feedback as necessary. By improving the interaction between the students, the CT will increase learning gains. To achieve this difficult goal, a model will be developed for peer tutoring, using empirical data from student collaboration.

In an early step toward developing the cognitive model, we conducted a pen-and-paper pretest of the PTS with two dyads of middle-school students. As we expected, the process of the tutoring needs to be supported. Peer tutors went through a process of watching the tutee solve each problem step, comparing the solution to their answers, and then rating the student on that particular skill. When they had to provide explanations to the tutee, they went through three steps: recognizing that the student needed help, providing explanations, and then confirming that the student understood. Should future studies support these observations, a cognitive model can be developed that emphasizes these tutoring stages.

Surprisingly, tutors made specific errors that suggest that the content of the tutoring sessions also needs to be modeled. There were skills for which the peer tutors wanted to provide explanations, such as writing an algebraic expression, but were unsure of how to proceed. They would fail to explain problem steps in a manner that their tutee could understand, or would provide the tutee with too much information. On a parallel note, peer tutees did not always use the tutor's explanations constructively, copying down the answer without ensuring that they understood the material. Using this and further pretest data, it is possible to gather information about common student errors within the context of the PTS that can form the basis for definitions of buggy student actions. Although the development of a cognitive model for tutoring is difficult, we think the initial step of creating a model for the tutoring process in the PTS is achievable. Once that is accomplished, a model for the tutoring content can be considered.

4. Future Work

Although the CT has been effective at increasing student learning, it lacks support for collaboration, which has also been shown to be beneficial. We have proposed to add collaborative features to the existing CT curriculum, expanding the interface and cognitive model, by incorporating a mutual peer tutoring script. This script builds on students' experience with the CT by putting students in the role of the computer, asking them to "model trace" their tutee's steps, provide feedback as necessary, and update their estimates of the tutee's mastery of the skills. We anticipate that these additions will improve students' domain-content understanding and knowledge of desired domain skills, by increasing their ability to provide useful explanations and to monitor their own and others' performance.

The addition of the PTS to the CT involves design and implementation phases, followed by an experimental phase to evaluate the suitability of the script for deployment. We will be pretesting the PTS using dyads of middle school students to refine the script and aid in the design of the collaborative interface and cognitive model. Simultaneously, we will be implementing the changes to the CT and developing appropriate algebra problems to complement the script. In the fall, we will be conducting classroom studies with the modified CT and evaluating the effectiveness of the PTS. The combination of collaboration and cognitive tutor methodology should combine the benefits of both approaches.

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References

[1] Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8*, 30-43.

[2] Ritter, S., Blessing, S. B., & Hadley, W. S. (2002). SBIR Phase I Final Report 2002. Department of Education. Department of Education RFP ED: 84-305S.

[3] Johnson, D. W. and Johnson, R. T. (1990). Cooperative learning and achievement. In S. Sharan (Ed.), *Cooperative learning: Theory and research* (pp. 23-37). New York: Praeger.

[4] Kollar, I., Fischer, F., & Hesse, F. W. (2003). Cooperation scripts for computer-supported collaborative learning. In *Proceedings of the International Conference on Computer Support for Collaborative Learning (CSCL) 2003,* 59-61.

[5] Fantuzzo, J. W., King, J. A., & Heller, L. R. (1992). Effects of reciprocal peer tutoring on mathematics and school adjustment: A component analysis. *Journal of Educational Psychology, 84*(3), 331-339.

[6] Fantuzzo, J. W.; Riggio, R. E.; Connely, S.; and Dimeff, L. A. (1989). Effects of reciprocal peer tutoring on academic achievement and psychological adjustment: A component analysis. *Journal Of Educational Psychology, 81*(2), 173-177.

[7] King, A., Staffieri, A., & Adelgais, A. (1998). Mutual peer tutoring: Effects of structuring tutorial interaction to scaffold peer learning. *Journal of Educational Psychology, 90*, 134-152.

[8] Webb, N.M., Troper, J.D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87,* 406-423.

[9] Fuchs, L.S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C.L., Owen, R., & Schroeter, K. (2003). Enhancing third-grade students' mathematical problem solving with self-regulated learning strategies. *Journal of Educational Psychology, 95*(2), 306-315.

[10] Carnegie Learning (2003). Cognitive Tutor® Algebra I, Teacher's Guide.

[11] Kollar, I., & Fischer, F. (2004, July). Internal and external cooperation scripts in web-based collaborative inquiry learning. Special Interest Meeting of EARLI SIG 6 and SIG 7. Tübingen.

[12] Corbett, A. T. & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction, 4,* 253-278.

Enhancing Learning through a Model of Affect

Amali WEERASINGHE
Intelligent Computer Tutoring Group
Department of Computer Science, University of Canterbury
Private Bag 4800, Christchurch, New Zealand
acw51@student.canterbury.ac.nz

Abstract: The effectiveness of human one-to-one tutoring is largely due to the tutor's ability to adapt the tutorial strategy to the students' emotional and cognitive states. Even though the tutoring systems were developed with the aim of providing the experience of human one-to-one tutoring to masses of students in an economical way, using learners' emotional states to adapt tutorial strategies have been ignored until very recently. This paper proposes an initial study to understand how human tutors adapt their teaching strategies based on the affective needs of the students. The findings of the study will be used to investigate how these strategies could be incorporated into an existing tutoring system which can then adapt the tutoring environment based on the learner's affect and cognitive models.

1. Introduction

Intelligent tutoring systems (ITS) are computer-based educational programs that help students to learn by providing adaptive pedagogical assistance. A number of empirical studies [8, 11] have shown that the performance of students who interact with an ITS improved significantly compared to those who learn in a traditional classroom setting. The effectiveness of ITSs is mainly due to their ability to adapt the learning instruction to the learners' knowledge and belief state. However, systems that strictly focus on these aspects often miss critical components of user mental state and behaviour. Users' emotional state was shown to strongly influence both reasoning and communication which in turn affect the learning process [14]. This paper outlines a study to investigate how a model of affect can be used to improve the objective performance of learners interacting with an ITS. Related work is presented in section 2. Next section presents the proposed work.

2. Background

There have been various research attempts to incorporate models of affect into an ITS. These attempts can be categorised based on the methods used to assess the quality and the intensity of the affective states of the learners [5]: (i) self-report (ii) behavioral and cognitive indices (iii) psycho-physiological indices.

Self-report: If we assume that emotional states are conscious, the primary way to assess their presence is self-report. Self-report provides an opportunity for students to externelise their feelings or attitudes during learning. This makes it easier for the tutors to adapt their pedagogical actions to suit the individual learners. Self-report methods include questionnaires and interviews that might be conducted briefly during a help session. Reporting can also be facilitated using scales, buttons, menus etc.

de Vicente and Pain (1999) conducted an empirical study to explore the feasibility of self-report in diagnosing motivation. They investigated whether self-report was acceptable to students and whether the information obtained was reliable. It was concluded that self-report was generally well-received by students, and is a valid approach to diagnose motivation. However, it was also recommended that relying exclusively on self-report was not advisable, as sometimes students did not update the self-report facilities as frequently as the motivational states changed.

Behavioral and Cognitive indices: Another means of measuring emotional states is to detect behavioral and cognitive patterns that are associated with them [5]. de Vincete and Pain (2002) conducted an empirical study to investigate whether the feasibility of detecting a student's motivational state based on her interactions with an ITS. The participants (10 post graduate students with previous teaching experience) were asked to watch the recorded interactions of a student with MOODS (a prototype ITS for learning Japanese numbers with an added motivation self-report facility), and infer and comment on the motivational state of the student during the interaction. The inferences were based on the way a student performed the exercises such as the order in which she did the exercises, whether she gave up or not, mouse movements during an interaction etc. These inferences were then used to produce a set of motivation diagnosis rules and their validity is yet to be evaluated. The results suggest that it is feasible to infer motivation diagnosis knowledge based only on the information provided by the computer interactions in an intelligent tutoring system.

Conati and Zhou (2002) have developed a probabilistic model that assesses student emotional reaction during interaction with Prime Climb, an educational game designed to assist students learn number factorization. This model is based on the OCC cognitive theory of emotions. This model records how game events relate to the students' goals, as well as how these goals probabilistically depend on the students' traits and playing behaviour. This model is developed to assess student's affective states during the interaction with the climbing instructor, an intelligent agent used to improve the pedagogical effectiveness of Prime Climb. The function of this agent is to provide hints that help the student to reason about number factorization, without compromising her level of engagement. Evaluations were carried out to validate the accuracy of the model and is yet to be incorporated into the pedagogical activities of the agent.

A model proposed by Beck (2004) determines the probability that a student is actively engaged when trying to answer a question. This model is based on item response theory and uses as input the difficulty of the question, how long the student took to respond, and whether the response was correct. The model was validated using students' interactions with the 2002-2003 version of the Reading Tutor. Students were asked to select the missing word (from a list of four responses) for a given sentence. The analysis revealed that disengagement is better modelled by simultaneously estimating student proficiency and disengagement than just estimating disengagement alone. Moreover, disengaged students had smaller learning gains while students with a positive attitude towards reading had higher gains. Even though this study allows to validate the affective model using data normally collected by an ITS, it has been applied only for closed questions.

Psycho-physiological indices: It has been shown that that an emotional state modulates many physical changes in tandem: provoke specific facial actions, increase or decrease tension in muscle groups etc.[14]. A variety of psycho-physiological indices such as heart rate, blood pressure, skin conductance, finger temperature, respiration can be used to detect emotions via sensors such as microphones, cameras, strain gauges applied to mouse buttons, special wearable devices etc. Use of such psycho-physiological data may provide the most dynamic and objective approach for assessing changes in a person's affective state.

An empirical study was conducted to assess the performance of biometric signals in detecting students' affective states interacting with Prime Climb (mentioned above) [3]. The biometric signals focused on are skin-conductivity (SC), electromyography (EMG) of the muscles involved in frowning and corrugating eyebrows, blood-volume pressure (BVP), and respiration (RESP). The study was carried in an uncontrolled environment in which students interacted freely with Prime Climb. The objective of the study was to ascertain whether the four sensors could identify the six specific emotions currently modelled in the dynamic decision network (joy, distress, admiration, reproach, pride and shame). The level of noise in all the signals was high and all the sensors are sensitive to motion. Consequently the researchers had to focus on less noisy SC and EMG signals as it was difficult to detect meaningful patterns for RESP and BVP during the preliminary analysis. Results indicated that a sudden arousal can cause a startle response in the SC signal and that the relative amplitude of this pattern is directly related to the user's arousal level.

Haag and colleagues (2004) used data gathered from a set of biosensors to train a neural network classifier. It was then used to automatically detect the emotional state of a user in terms of arousal and valence values. The data was gathered from a single participant on different days and different times of the day. The standard photo set was used to elicit emotions. The participant's heart rate, BVP heart rate, BVP amplitude, EMG amplitude, skin conductivity, respiration rate were used to train the neural net. Two separate networks for valence and arousal each were trained. The results indicate that the estimation of the valence value is a much harder task than arousal.

3. Proposed Work

The field of affective tutoring systems is very young and researchers still focus on the initial issues such as which emotions are most important for learning, how to assess the emotions of interest etc. Currently researchers focus on generating models and evaluating them. To the best of our knowledge, an affective model is yet to be used to improve the objective performance of the learners.

According to Self (1990), it is more important to focus on using the student model to enhance the effectiveness of the pedagogical process, than building a highly accurate student model that models everything about the student. Therefore, we are interested in investigating how an affective model can be used to improve the objective performance of learners. One of the things that we choose to focus on is to develop an effective problem selection strategy because most ITSs employ adaptive problem selection based only on the cognitive model which may result in problems being too easy or too hard for students. This may occur due to factors like how much guessing was involved in generating the solution, how confident she was about her solution, how difficult/easy she thought the problem was etc., which are not captured in the student's cognitive model. Therefore, using both cognitive and affective models can potentially increase the effectiveness of a problem selection strategy, which in turn can improve the learners' motivation to interact with the system.

One of the main issues in developing a problem selection strategy is to decide on the level of difficulty for each problem. We plan to dynamically compute the difficulty of the problem for a given student at a certain moment during learning which was shown to improve the effectiveness of problem selection compared to that is based on static problem complexities [10]. The approach discussed in [10] is based on the weighted sum of probability of the student having already learned each constraint relevant for the problem. However, this approach does not consider the student's confidence while solving the problem. In other words, if the student struggled to solve the problem, that might lead to shallow learning. In such situations, it is better if the next problem covers the same domain concepts with a lager number of constructs involved. For example, in the domain of Entity Relationship (ER) mapping, students are given an Entity Relationship (ER) diagram and expected to design the relational database mapping following a seven-step procedural algorithm [6]. If a student struggles to solve a problem, which involves only the first three steps, it will be better for the student if the next problem requires applying the first three steps for a larger number of constructs. This way, the student is given an opportunity to reinforce the domain concepts she has just learnt before having to learn new domain concepts.

Even though it may be possible to find a problem which is at the correct level of difficulty using this method, student's perceived level of difficulty will play an important role in deciding whether she is motivated enough to solve the problem. One possibility is to use psycho-physiological indices to estimate the student's perceived level of difficulty of the problem. We have yet to investigate which psycho-physiological indices will best indicate the changes in the student's affective state. The next step is to decide how these changes which may occur between the time period of completing the current problem and reading the next problem, can be linked to perceived level of problem difficulty. If there is an indication of a higher perceived problem difficulty, then we plan to give the student the opportunity to decide whether she wants to attempt the selected problem or an easier one.

If the student wants to attempt the current problem in spite of her perception of it being too difficult, we propose to provide more support to solve the problem. Currently all the constraint-based tutors provide feedback on demand. However, it might be more beneficial to provide immediate feedback, as it avoids the student hitting too many impasses which can frustrate the student. We also propose to use self-explanation to enhance opportunities to engage in deep learning and also to prevent the student depending too much on the immediate feedback to solve the problem. Self-explanation is described as an "*activity of explaining to one-self in an attempt to make sense of new information, either presented in a text or in some other medium*" [2]. Self-explanation has been shown to be an effective teaching and learning meta-cognitive strategy which facilitates the identification and removal of misconceptions promoting reflection. We plan to use the student's affective model to identify instances where students need explicit assistance to engage in deep learning through self-explanation. Therefore, in this research we propose to use the model of affect not only to help students gain domain-specific knowledge, but also meta-cognitive skills such as self-explanation, reflection etc.

When the student solves a problem perceived as being too difficult with the system's additional support, it will be better if the next problem covers the same domain concepts but with a larger number of constructs as discussed earlier. On the other hand, if the student requests an easier problem, then it may be sufficient to provide feedback on demand. If the student is able to solve this problem successfully, it may help her to improve her confidence. Therefore, we believe that it is appropriate to give the student the option of attempting the problem which was earlier perceived as too difficult. This strategy will provide us valuable insights as to whether increased confidence gained by solving easier problems motivates the students to attempt difficult ones.

Several ITSs have been developed by the Intelligent Computer Tutoring Group, at the University of Canterbury [12] based on constraint-based modelling [13], a student modelling technique which is becoming increasingly popular. Some of the tutors developed are SQL-Tutor for database querying, KERMIT for database modelling, NORMIT for database normalization and ERM tutor for database mapping [9]. We chose to use ERM tutor as our tutoring environment as ER mapping is a very well-defined task making it relatively easier to incorporate an affective model than an open-ended task such as database modelling. The current version of the ERM tutor does not have a sophisticated problem selection strategy or a strategy to facilitate adaptive self-explanation.

As we want to explore how emotional states of students could be used to adapt the tutoring strategies, we propose to conduct a study to understand how human tutors respond to learners' affective states. The objectives of the study are to understand how human tutors identify the emotional states of students during learning and how human tutors adapt tutoring strategies in each situation. Based on the study we want to explore how this adapting of tutorial strategies can be incorporated into an intelligent tutoring system. Participants will be students who are enrolled in an introductory database course for 2005 at the University of Canterbury. As ERM tutor provides a problem-solving environment and intend to complement classroom instruction, the study will take place only after the students have learnt the relevant learning material in the classroom. Several professional tutors will sit beside the students and observe them while the students interact with the system.

At the beginning of the study, the participants will be asked to sit a pre-test online which can be used to understand their background knowledge. The participants will then be asked to use the current version of the ERM tutor. In addition, the human tutors are expected to provide a one-to-one tutoring environment for each student based on their emotional states i.e. to guide the students towards the correct solutions using appropriate methods like asking questions at appropriate times etc. The problem set in the ERM tutor is arranged according to the complexity by a human expert. However, the students have the freedom to select any problem they want. Participants are expected to use the system for at least an hour. However, deciding when to stop using the system is left to students. At the end of the study, they are asked to sit a post-test online which can be used to gain a measure of their improvement. All the participants will be interviewed at the end of the individual sessions to understand their perceptions about the human tutoring and the system. They will also be asked to comment on the non verbal behaviour they received from the human tutors and how it affected their learning experience. At the end of the study, the human tutors will also be interviewed to understand their views on the tutoring sessions and the system. Students' interactions will be recorded by the ERM tutor and all the sessions will be videotaped.

Initially, the researchers will analyse the video recordings without the human tutors to investigate whether the tutoring strategies used by different tutors and the non verbal behaviour which triggered them could be understood. The researchers will also look for any similarities between the strategies. The extent to which this information can be extracted without the human tutors' assistance will provide a measure of the feasibility of incorporating the tutoring interventions into an ITS. As the second step, the video recordings will be analysed with the human tutors to understand the students' emotions detected by the tutor and how the presence of these emotions helped the tutor to decide what type of intervention is needed. For instance, how does a human tutor recognise that a student is frustrated because the current problem is too difficult for her, or what is the most appropriate question to ask in a situation where the student tries to guess the answer. The first example relates to how an adaptive problem selection strategy can be incorporated into an ITS, whereas the second one relates to how self-explanation can be facilitated in an ITS.

User logs will be analysed to obtain important behavioural data such as response times, number of attempts required to arrive at the correct solution etc. We would then explore how this type of behavioural data can be used to adapt the tutorial strategies.

Students' performance on pre- and post-tests will also be analysed to understand how much they have improved. For each student, we plan to record the domain concepts or the steps of the mapping algorithm the students have problems with before interacting with the system, the tutoring strategy used to help them, and the effectiveness of the used strategy in terms of post-test scores and students' comments. If several students have difficulties with same domain concepts and have been tutored by different human tutors using different strategies, then the effectiveness of each strategy can be compared.

Video recordings, user logs, students' and tutors' comments and pre-and post-test performance will provide valuable insights to which emotions are vital to assess and how to detect their presence. Then we need to decide on how to assess the selected emotions through the available methods such as self-report, behavioural (interaction) patterns (such as response times, mouse movements etc.) and other data collected through bio-sensors. The next step is to develop an affect model which can be incorporated into the ERM tutor. It is crucial to carefully select the effective tutorial strategies to be incorporated into the tutor based on the study. We then need to design and implement the selected tutorial strategies based on the affect and the cognitive models. Finally, comprehensive evaluations studies are required to obtain a measure of the effectiveness of these affective components and the tutorial strategies in the domain of database mapping.

4. References

[1] Beck, J. E., Using response times to model student disengagement, Workshop on Social and Emotional Intelligence in Learning Environments in association with ITS 2004.

[2] Chi, M. T. H. Self-explaining Expository Texts: The dual processes of generating inferences and repairing mental models. *Advances in Instructional Psychology,* 2000, pp. 161-238.

[3] Conati, C., Chabbal, R. and Maclaren, H. A Study on Using Biometric Sensors for Monitoring User Emotions in Educational Games, Third Workshop on Affective and Attitude User Modeling, Assessing and Adapting to User Attitudes and Affect: Why, When and How in conjunction with User Modeling 2003.

[4] Conati, C. and Zhou, X. Modeling Students' Emotions from Cognitive Appraisal in Educational Games In S. A. Cerro, G. Gouarderes and F. Paraguacuv (eds.) Proceedings of the International Conference on Intelligent Tutoring Systems ITS 2002, pp 944-954, Berlin: Springer, 2002.

[5] Dalgleish, T. and Power, M. J. Handbook of Cognition and Emotion John Wiley & Sons Ltd, West Sussex, England, 1999.

[6] Elmasri, R. and Navathe, S.B. *Fundamentals of Database Systems*. Addison Wesley, 3rd edition, 2000.

[7] Haag, A. Goronzy, S., Schaich, P. and Williams, J. Emotion Recognition Using Bio-sensors: First Steps towards an Automatic System In E. André et al. (eds.):Workshop of Affective Dialogue Systems, ADS 2004, Springer-Verlag Berlin Heidelberg pp. 36–48, 2004.

[8] Koedinger, K. R., Anderson, J. R., Hadley, W. H. and Mark, M. A. Intelligent tutoring goes to school in the big city. International Journal of Artificial Intelligence in Education, 8 (1), 1997, pp. 30-43.

[9] Marshall, M. ERM Tutor and ER-to-Relational Mapping Tutor Honours Report, University of Canterbury 2004.

[10] Mitrovic, A., Martin, B. Evaluating adaptive problem selection, In: P. De Bra, W. Nejdl (eds) Proc. 3rd Int. Conf. Adaptive Hypermedia and Adaptive Web-based Systems AH 2004 conference, pp. 185-194, Springer-Verlag, 2004.

[11] Mitrovic, A. and Ohlsson, S. Evaluation of a Constraint-Based Tutor for a Database Language. International Journal on AIED, 10 (3-4), 1999, pp. 238-256.

[12] Mitrovic, A., Suraweera, P., Martin, B. and Weerasinghe, A. (2004) DB-suite: Experiences with Three Intelligent, Web-based Database Tutors . Journal of Interactive Learning Research (JILR), vol. 15, no. 4, pp. 409-432, November 2004.

[13] Ohlsson, S. Constraint-based Student Modeling. In: Greer, J. E. and McCalla, G. (eds.). Proceedings of Student Modeling: The Key to Individualized Knowledge-based Instruction, Berlin 1994, Springer-Verlag, pp. 167-189.

[14] Picard R.W. Affective Computing MIT Press, Cambridge, Massachsusetts, 1997.

[15] Self. J. "Bypassing the intractable problem of student modelling", In Intelligent Tutoring Systems: At the Crossroads of Artificial Intelligence and Education. Frasson, C. and Gauthier, G. (Eds.), Norwood, NJ, Ablex Publishing Corporation**,** pp. 107-123,1990.

[16] de Vicente, A. and Pain, H. Motivation self-report in ITS. In Lajoie S.P. and Vivet, M. (eds.) proceedings of the Ninth World Conference on Artificial Intelligence in Education AIED1999, IOS Press, pp. 648 -650,1999.

[17] de Vicente, A. and Pain, H. Informing the detection of students' motivational state: An empirical study. In S. A. Cerro, G. Gouarderes and F. Paraguacuv (eds.) Proceedings of the International Conference on Intelligent Tutoring Systems ITS2002, pp 933-943, Berlin: Springer, 2002.

Integrating an Affective Framework into Intelligent Tutoring Systems

Mohd Zaliman YUSOFF
IDEAS lab, Department of Informatics, School of Science &Technology, University of Sussex, UK
m.z.yusoff@sussex.ac.uk

Abstract. This paper presents the integration of an affective framework into an Intelligent Tutoring System (ITS). This framework extends current affective learning frameworks by introducing a two layered appraisal and reaction process. The implementations of these layers are undertaken at two learning stages: at the beginning of a lesson and during the lesson. Primary appraisal, which is implemented at the beginning of a lesson, uses the PANAS questionnaire to appraise the student's affective state. The secondary appraisal phase, on the other hand, uses two emotion eliciting factors: the difficulty level of the lesson and the students' control over the lesson. As for the reaction phase, both domain-dependent and domain-independent strategies are used as a means to help students manage their emotional state. Preliminary empirical work supports the hypothesis that students believe that emotions are important to leaning.

1. Introduction

Although emotion plays a central role in human learning, the issue has been largely neglected in most implementations of computer-based and web-based learning environments [18]. However, in the context of Intelligent Tutoring Systems (ITS) emotion is an area gaining increasing attention (e.g [2, 4, 5, 7, 14, 16]). Many findings from researchers in education and psychology have indicated that positive emotions help students to perform their work better (e.g [9, 10]). Bryan & Bryan [3], for instance, have reported that the performance of students with learning disabilities can be improved by inducing positive emotions. Astleinter [1] has made an interesting advance by integrating emotion into instructional design. He proposed 20 instructional strategies for reacting to five emotional states, namely anger, envy, fear, pleasure and sympathy.

There is evidence that positive emotions can enhance a student's performance in learning. The ability to broaden the scope of student cognition in learning is the first advantage of being in a positive emotional state. Isen and colleagues have shown that people experiencing positive emotions show patterns of thought that are notably unusual, flexible, inclusive, creative, integrative, open to information and efficient [12, 13]. In general terms, Isen suggests that positive affect produces a "broad, flexible cognitive organization and ability to integrate diverse material" [13]. Although Isen's work does not directly involve students, it provides strong evidence that positive emotions broaden cognition in solving problems that have a big impact on learning. Positive affect appears to increase learning by engaging higher brain mechanisms that enrich and activate mental schemas, consolidate long-term memories, and enhance learner ability to make diverse associations [9].

Broadening students' scope for action is the second advantage of students being in a positive emotional state. Renninger [17], studied children's reactions when playing with objects that elicited interest. He found that children in a positive emotional state showed a wider range of types of play, more variations of action within play types and longer play episodes. In another experimental study, Yasutake & Byran [20] reported that students in a positive emotional state tend to produce significantly faster mastery of a learning task.

Finally, positive emotions have the ability to correct, restore, and undo the after-effects of negative emotion [8, 15]. Fredrickson & Levenson [8] measured the time elapsed from the start of a randomly assigned film until the cardiovascular reactions induced by the negative emotion provoked by that film returned to baseline levels. The participants in a positive emotional state exhibited faster recovery. This finding suggests that positive emotions have the ability to reduce a negative emotional arousal. Although these experiments are not related to learning environments directly, it seems plausible that positive emotions might have similar impact for students while learning.

2. An Emotionally Sound Affective (ESA) Framework

The ESA framework consists of two phases: 1) the appraisal phase, which attempts to assess the students' emotional state and 2) the reaction phase, which proposes the use of adaptive strategies and activities in order to help students manage their emotions. The implementation of these phases will both be undertaken at each of two learning stages: the beginning of a lesson and during the lesson.

The primary appraisal, which uses the PANAS questionnaire [19] appraises the student's emotional state at the beginning of a lesson. The primary appraisal establishes the student's emotional state with regard to his personal beliefs and goal commitments. However, the primary appraisal is envisaged only if the student feels it is necessary. The secondary appraisal uses the student's reactions to two eliciting factors to appraise emotion. These eliciting factors are: the difficulty level of the lesson which is based on the nature of the lesson and the student's control over the lesson.

The student's Control over the lesson is modelled using student-computer interactions that are based on three methods: 1) by on-line communication with the student during the interaction, 2) by monitoring student's requests for help to complete the lesson, and 3) by the student's self-reporting. The intensity of the Control eliciting factor is determined by its three eliciting variables: Independence, Effort and Competence. These are derived from earlier motivation modelling techniques (e.g [6, 7]). Independence is defined as the degree that students prefer to work without asking others for help. Effort is defined as the degree of engagement that students display in accomplishing a task. Competence is a measure of the students' knowledge and skills when performing a lesson task proficiently.

Just as for the appraisal phase, the ESA framework implements the reaction phase at two learning stages: 1) at the beginning of a lesson and 2) during the lesson. Its main objective is to help students manage their emotions, especially after experiencing negative emotions, by using two underpinning strategies: domain-independent or emotion-focused strategies and domain-dependent or problem-focused strategies. Domain-dependent strategies help students by providing suitable suggestions and tips that are adapted to the students' elicited emotional state and are based on the premise that students in a positive emotional state are more capable of mastering their lesson [9]. Domain-independent strategies include the use of coping statements and relaxation exercises. For example statements such as "I can make things happen" are used to maintain students' happiness while statements such as "I can see this problem from another perspective to make it seem more bearable" are used to reduce students' nervousness. Apart from coping statements, relaxation activities such as muscle and head exercises are employed to help students manage their emotions.

3. Preliminary result

In order to judge how students view the role of emotions in learning, a small questionnaire based study was conducted. The survey involved 18 students at the University of Sussex. This survey consisted of three parts which were meant to determine 1) the importance of emotion with regard to learning, 2) their emotional state while programming and 3) strategies that they believed might help them in learning. The questionnaire was administrated during a lab session associated with their programming course which was three days before the deadline for their programming project.

In the first part of this survey, three questions were asked to determine the student's view of the importance of emotions with regard to learning. 53% of students regarded emotions as important to learning while 41% of the students regarded emotions as very important to learning. The result of this first part that summarised respondents' answers is presented as Table 1.

Table 1: The summary of the importance of emotions with regard to learning

Questions	Not True	Somewhat true	Don't know	True	Very True
Emotions are important in learning.	0.0%	5.8%	0.0%	52.9%	41.2%
Emotions are as important as knowledge in learning.	5.8%	17.6%	11.8%	47.1%	17.6%
Emotions are important, but not in learning.	68.8%	25.0%	0.0%	12.5%	0.0%

In the second part of this survey, the PANAS questionnaire [19] that has 20 questions was used to determine students' belief about their affective state while doing programming. Students were asked to indicate "how you feel at the present moment" and rated each emotion term with a five-item Likert-type response format with 1 being *slightly or not at all* to 5 being extremely. A one-sample t test was then conducted on the students' data to compare with the average student (assumed to be 2.5 on the PANAS scale). The summary of this survey is as Table 2 below.

Table 2: Analysis of students' affective state

	Mean	Std D	t	df	Sig (2 Tailed)	N
Positive Affect	3.0	0.68	3.35	17	p <0.01	18
Negative Affect	2.1	0.64	-2.64	17	p <0.01	18

The results lend some support to the notion that students experience either a positive affective state or a negative effective while learning. With many other findings from researchers in education and psychology indicating that emotion plays an important role in learning [9, 10], it is hypothesised that if the affective state of students can be observed during their lesson, a better strategy can be developed to help them manage their emotions which eventually can lead to better performance.

The third part of this survey was meant to determine which strategies students preferred for managing their emotions. Students indicated that both domain- dependent and domain-independent strategies could be used to help them manage both their positive and their negative emotional states. The outcome of this survey supports the premise that domain-dependent and domain-independent strategies are equally important in order to help student mange their emotional state. The strategies preferred by the students are summarised as Table 3 and Table 4.

Table 3: The strategies preferred by students to manage their negative emotion in learning.

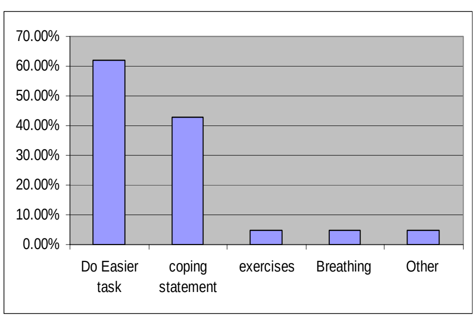
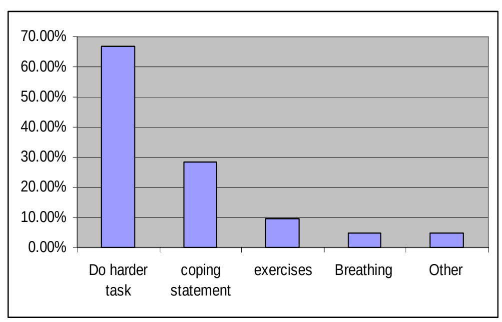


Table 4: The strategies preferred by students to manage their positive emotion in learning.



4. Conclusion and future work

The ESA framework makes two contributions to traditional 'affective learning' frameworks. First, it integrates domain-independent strategies that help students manage their emotions into an 'affective learning' framework. In contrast, traditional 'affective learning' frameworks only consider domain-dependent strategies in helping students cope with their affective states. Emotion regulation involves both domain-dependent and domain-independent strategies (e.g [11,15]). Therefore, the introduction of psychologically grounded domain-independent strategies as an extension to current 'affective learning' frameworks (e.g [5, 7, 14]) should help students learn better.

In its second contribution, the ESA framework integrates primary and secondary appraisal processes at two learning stages into an 'affective learning' framework. According to cognitive emotion regulation theories, (e.g [11, 15]) there are two appraisal processes at two different stages involved in individuals' emotion regulation. The first appraisal takes place before the potentially affective situation has fully activated while the second appraisal takes place after the potentially affective situation has been activated. In a learning environment, it is hypothesised that the first appraisal stage should take place at the beginning of a lesson where the potential emotional situation is not yet fully activated whereas the second appraisal process should take place during the lesson.

The ESA framework is still at its infancy stage. However, a small empirical study has indicated that emotions are important to students in learning. To manage their emotions, both domain- dependent and domain-independent strategies are perceived to be useful. In the near future, a prototype system of ESA framework that combines both strategies will be implemented. Apart from implementing the prototype, research will be conducted on the efficiency of domain-independent strategies in laboratory environments and also on cultural differences between UK and Malaysian students with respect to its utility of different strategies. An initial study has shown that students perceived that both dependent and domain-independent strategies are seen to be equally important in order to help them manage their affective state in learning.

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References

[1] Astleitner H. (2000), Designing emotionally sound instruction: The FEASP-approach. *Instructional Science* 28: 169–198

[2] Burleson, W., & Picard, R. (2004). Affective Agents: Sustaining motivation to learn through failure and a state of "stuck". In Social and emotional intelligence in learning Environments workshop, 7th International Conference on Intelligent Tutoring System, 30 August – 3rd September 2004, Brazil. (pp. 29-36)

[3] Bryan, T., & Bryan, J., (1991). Positive mood and math performance. Journal of Learning Disabilities, 24, 490-494.

[4] Chaffar, S., & Frasson, C. (2004). Using an emotional intelligent agent to improve the learner's performance. In Social and emotional intelligence in learning Environments workshop, 7th International Conference on Intelligent Tutoring System, 30 August – 3rd September 2004, Brazil. (pp. 37-43)

[5] Conati, C. (2002). Probabilistic assessment of user's emotions in education games. Journal of Applied Artificial Intelligence, 16(Special Issue on managing cognition an Affect in HCI), 555-575.

[6] De Vicente, A., & Pain, H. (1999). Motivation self-report in ITS. [Proceeding of the Ninth World Conference on Artificial Intelligence in Education]S. P. Lajoie & M. Vivet (Eds.), (pp. 651-653). Amsterdam: IOS Press.

[7] del Soldato, T., & du Boulay, B. (1995). Implementation of motivational tactics in tutoring system. *Journal of Artificial Intelligence in Education*, 4(6), 337-378.

[8] Fredrickson, B. L., & Levenson, R. W. (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cognition and Emotion, 12,* 191-220.

[9] Fredrickson, L. (1998). What good are positive emotions? *Review of General Psychology*, 2, 300-319.

[10] Goleman, D. (1996). Emotional Intelligence: Why it can matter more than IQ. Bloomsbury Publishing Plc.

[11] Gross, J. J. (1999). Emotion and emotions' regulation. In L. A. Pervin & O. P. John (Eds.), Handbook of Personality: Theory and Research (2nd Edition) (pp. 525-552). Guildford, New York.

[12] Isen, A. M. (2000). Positive affect and decision making. In M. Lewis & Haviland-Jones J. M. (Eds.), Handbook of Emotions 2nd Edition (pp. 417-435). New York: Guilford Press.

[13] Isen, M., A., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilities creative problem solving. *Journal of Personality & Social Psychology*, 52(6), 1122-1131.

[14] Kort, B., & Reilly, R. (2001). An affective model of interplay between emotions and learning: reengineering educational pedagogy- building a learning companion . In Proceedings of International Conference on Advanced Learning Technologies (ICALT 2001), Madison, Wisconsin, August 2001.

[15] Lazarus, S. R. (1991). Emotion and Adaptation. Oxford U. Press.

[16] Nkambou, R., & Heritier,. V. (2004). Facial expression analysis for emotion recognition in ITS. *In Social and emotional intelligence in learning Environments workshop, 7th International Conference on Intelligent Tutoring System,* 30 August – 3rd September 2004, Brazil. (pp. 84-93)

[17] Renninger, K. A. (1992). Individual interest and development: Implications for theory and practise. In K. A. Renninger & A. Krapp (Eds.), The Role of Interest in Learning and Development (pp. 361-395). Hillsdale: Erlbaum.

[18] Thissen, Frank (1999): Inventing A New Way of Learning. Constructive Fundamentals of a Multimedia Teaching Methodology. *Proceedings of the 7th International BOBCATSSS*-Symposium 25th-27th January 1999 Bratislave Slovak Republic. Darmstadt, pp. 459-467.

[19] Watson, D., Clerk, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative Affect: The PANAS scales. *Journal of Personality & Social Psychology* , 54(6), 1063-1070.

[20] Yasutake, D., & Byran, T. (1995). The influence of induced positive affect on middle school children with and without learning disabilities. Learning Disabilities Research and Practice, 10, 38-45.

[21] Yusoff, M.Z (2004). An Emotionally Sound Affective Framework for Intelligent Tutoring System (ITS), CSRP 571, The 17th White House Papers Graduate Research In Informatics at Sussex, University of Sussex, June 2004.

[22] Yusoff, M.Z & du Boulay,B.(2005) Integrating Domain-Independent Strategies into an Emotionally Sound Affective Framework, (to be presented) at Agents that want and like: motivational and emotional roots of cognition and action: Symposium of AISB, 12-14 April 2005, University of Hertfordshire (in press*)*.

Understanding the Locus of Modality Effects and How to Effectively Design Multimedia Instructional Materials

Jesse S. Zolna
Department of Psychology
Georgia Institute of Technology

Abstract

AIED learning systems sometimes employ multimedia instructional materials that leverage technology to replace instructional text with narrations. This can provide cognitive advantages and disadvantages to learners. The goal of this study is to improve principals of information design that cater to human information processing. Prior research in educational psychology has focused on facilitating learning by presenting information in two modalities (auditory and visual) to increase perceptual information flow. It is hypothesized that effects might also occur during cognitive manipulations (e.g., extended storage and fact association). The described study separates perceptual information effects from those of cognitive operations by presenting auditory and visual information separately. Both types of effects can influence learning from multimedia instructional materials. Therefore, effective information design should consider both physical and mental representations. Knowing that multimedia effects are more than the result of perceptual effects raises the questions of what other psychological processes influence the multimedia effect. An understanding of these other causes will help us create a more complete picture of what producers of multimedia learning materials should consider during design.

Introduction

Contemporary technology is increasingly employed to improve the efficiency of educational instruction. To this end, effective artificial intelligence may be used in tandem with multimedia material. If either the artificial intelligence or multimedia materials are designed in a way that impedes learning, the instruction might be rendered ineffective. Educational psychologists have been trying to understand how *multimedia instructional materials*, that is presenting to-be-learned information in more than one modality, can improve learning [1; 2]. Multimedia instruction aims to assist learners by leveraging technology to present information in a more compelling, complete, and engaging manner. Multimedia learning can be efficient, in that the instructional material can potentially provide the same amount of information in a shorter time than traditional instructional materials. The benefits from multimedia instructional design are accomplished by mixing media ingredients (e.g. text, narration, diagrams, animations and sounds) that represent a variety of modal forms (e.g., auditory and visual), to assist in the learning process. Presenting more information faster and more completely improves efficiency of instruction. However, great care has to be taken in the development of multimedia instructional design because multimedia can also have cognitive costs [3], causing instructional inefficiencies. Applying technology might overload learners' cognitive resources, hindering their ability to perceive new information, operate on it, and/or commit it to long-term memory.

The goal of this study is to advance the limited knowledge associated with mixing media ingredients that best cater to the strengths and limitations of human information processing. In the past, researchers developing multimedia systems have noted that guidelines for choosing how to present information within multimodal user interfaces (e.g., multimedia instructional material) should include principals based on human information processing capabilities [4]. It has also been demonstrated that implications for the structure and relationship among elements that comprise multimedia information have been found in the cognitive science research [5]. In addition, it is clear that effective learning can be fostered by instructional design that has been developed with a sufficient understanding of how the human cognitive system interacts with instructional material [6]. Research related to instructional design has proposed that controlling the processing demand needed in multimedia learning environments might be achieved by spreading information among working memory stores [1; 2]. However, the focus of these explanations have been on perceptual level encoding (i.e., transition from the sensory store), creating information design recommendations that center on the presentation of multimodal information. They have deemphasized the importance of how the two streams of information influence the active processing of information once encoded by the learner. The two influences, that is on perceptual encoding and active processing, may be separable, each influential for learning. If so, designing multimedia interfaces with considerations for only perceptual effects, as has been common in the past, may be incomplete.

To increase our understanding of modality effects, the present research program aims to examine the human information processing system in regards to learning, with the explicit intent to gather insight on how it relates to the design of multimedia instructional material. The differences in learning from information presented by visual versus auditory means will be explored. The study discussed herein will compare learning from descriptive material (a verbal description of the way parts of systems function) presented via a visual medium (text) and an auditory medium (narration). This descriptive material will accompany visual diagrammatic material (still diagrams of the system). Later studies intend to extend the knowledge gained to investigations of different kinds of verbal materials (i.e. conceptual, factual, concrete, abstract, narrative, and others), diagrammatic (including animated and still) materials, non-verbal auditory materials, and interleaving combinations of visual and auditory materials. Including factors that research currently posits about perceptual effects, and adding to it new discoveries about cognitive resource effects, we hope to achieve the basis for developing a complete taxonomy of multimedia effects. The vision of this taxonomy is an understanding of human information processing based on the effects of modality for both internal and external representations of information, and consequently to make suggestions to designers of multimedia information.

1 Learning and Information Processing

Multimedia instructional materials are distinct from traditional instructional materials in that they often add auditory or animated information to text, diagrams and illustrations. Complimentary verbal and pictorial information are presented to fully illustrate the subject matter. Diagrammatic instructional materials make relationships between elements explicit, and allow the learner to process more of the instructional material simultaneously; the benefit of descriptive information is that it can express and emphasize precise details [7]. When used carefully, materials presented in tandem can take advantage of the strengths and avoid the weaknesses of both diagrammatic and descriptive material. Empirical evidence supports the contention that student learning is affected positively by presenting descriptions and diagrams together [8]. Multimedia instructional materials have the potential to exploit the human's ability to sense information in two presentation forms simultaneously (e.g., visually and auditory) by presenting two types of information at the same time, and thereby facilitate processing verbal and pictorial information simultaneously [e.g. 1 and 3].

In any learning presentation, the information is presented with the intention that observers will be able to encode, understand and remember it; learning is the analysis and incorporation of sensory information into the long term memory store. Visual and auditory information are both encoded rapidly and can extract and briefly store vast amounts of information [9; 11]. However, this information must be transferred to a limited, more durable form of memory [10], and every detail is not retained. This limited internal representation of both auditory and visual information is eventually used as a basis for further processing [12]. Information is then stored in long-term memory which has unlimited capacity. Information loss is likely to be associated with short term memory because the sensory-perceptual store has been shown to be virtually unlimited, and the long term store has also been found to be unlimited [13]. Therefore, major impedance for learning might be a lack of cognitive resources for two important processes on new information to be committed to long term memory: encoding and active processing.

2 Internal representations

Baddeley's [14] conceptualization of working memory is similar to a mental workbench where the cognitive system temporarily stores information and performs cognitive tasks, such as transfer of information to long term memory. It contains the phonological loop which receives, holds and operates on *auditory* information and the visual-spatial sketchpad which receives, holds and operates on *visual* information. Using this framework of working memory, educators have attempted to identify methods for designing multimedia information that increase learning efficiency by combining auditory and visual streams of information. Wickens' Multiple Resource theory (MRT) is a theory of multiple task performances with practical implications that stem from predictions regarding a human operator's ability to perform in high work-load, multi-task environments [15]. The value of MRT lies in its ability to predict operationally meaningful differences in performance and prompt changes to workload that can be easily coded by the analyst and designer and includes a four dimensional model of multiple resources, one dimension being *processing codes* [16]. Wickens states that an important feature of resources is their structure; an important structural distinction is visual-spatial versus auditory. Interaction among information streams is thought to be influenced by the relationship among internal representations of information. Paivio's Dual Code Theory predicts understanding based on internal representations specifically related to internal cognitive manipulations on information gathered by the sensory system [17]. The theory is based on the general view that cognition consists of the activity of symbolic representational systems that are specialized for dealing with environmental information, such as instructional material. Two classes of phenomena handled by separate subsystems are specialized for the representation and processing of information concerning non-verbal and verbal information.

Non-verbal (or visual-spatial) and verbal (or auditory) internal representations often correspond to diagrammatic and descriptive external representations, respectively. However, visually and auditorily presented information included in multimedia learning environments correspond imperfectly to this division of internal representations. Research investigating multimedia instructional materials in light of Wickens' and Paivio's theories will define internal representations by more than just materials' external representations.

3 Modality

The common definition of information *modality* refers to the physical form of presentation for a specific piece of information. However, after conversion of information from its physical/perceptual form to a representational/processing code form, the modal form of information might not be dependent upon its physical form in the world [6]. Research on modality effects has been performed with the caveat that verbal material can evoke the construction of visual representations, and visual material can evoke the construction of verbal representations [8; 17]. There is also evidence that regardless of physical presentation, there exist circumstances in which a given task may be performed using either a verbal or spatial strategy [16].

Therefore, it is possible that the *physical* modality of information (e.g., visual or auditory presentation style) will be transformed to a different *mental* modality (structure of internal representation) for one reason or another. Such a transformation might be manifested in subvocalizing text or forming a mental image of a verbal description. The external representation of information, its physical modality, is inherent in the presentation mode. Internal representations of information, its mental modality, are inherent to how the information corresponds to processing mechanisms in use by the observer.

Baddeley, Wickens, and Paivio all consider the mental modal form and interaction of these internal representations of information in their attempts to explain human performance and behavior. The three theories of knowledge assimilation propose a dichotomous view of internal representations. Moreover, the dichotomy for each of Baddeley, Wickens and Paivio's conceptualization of internal representations separate auditory/verbal information from visual/spatial information. Empirical studies demonstrating the advantage of multimodal instruction design compared to unimodal instruction design [e.g. 17; 18; 19] have focused on manipulating the modal form of presentation (physical modality) in order to improve learning, but have not converged on the possibility that there are effects on performance that depend upon the modality of internal representations (mental modality). A complete understanding of both presentation and internal modality effects on processing demands will offer a thorough approach to designing information that will eliminate modality effects that impede cognition important to learning and emphasize modality effects that aid learning.

4 Experiment

This study focuses on experimentally controlling the interaction between external modal form (perceptual form) and internal modal form (which may be related to information type). In the current investigation, the external form of verbal-descriptive information was manipulated (visual text versus auditory narration). The accompanying diagrammatic information was held constant, and the information contained in the diagrammatic material was deemphasized in the recall test of learning performance. The different physical-modal representations of the descriptive information (predicted to be internally represented and stored in an auditory-verbal subsystem) will lead to variations in the efficiency of processing, and hence learning. These differences in learning can not be explained simply as multimedia presentation effects, as has been common in the past.

4.1 Participants and Materials

The participants were 108 undergraduate students at Georgia Institute of Technology who volunteered to participate for course credit.

The short lessons used to create experimental multimedia lessons were adapted from David McCaulay's (2003) "The New The Way Things Work." The topics included as lessons in this experiment were Window Shade, Stapler, Air Filter, Refrigerator, Hot Air Balloon, Metal Detector and an Electric Bell. Learning was measured with a paper and pencil test. Participants were given a packet that contained 10 recall questions for each lesson. After each lesson, participants were asked to answer the selected content questions based on the lesson material.

4.2 Design

The experiment had two manipulations: presentation form of the descriptive information, and presentation of the descriptive information with or without diagrammatic information. See Table 1 for a description of each trial type.

Table 1: Types of trials

	Diagram before descriptive (Asynchronous)	**Diagram with descriptive (Synchronous)**	**Diagram after descriptive (Asynchronous)**
Only visual presentation (unimodal)	Diagram then text (D+T)	Text and diagram simultaneously (T&D)	Diagram then narration (D+N)
Visual and auditory presentation (multimodal)	Text then diagram (T+D)	Narration and diagram simultaneously (N&D)	Narration then diagram (N+D)

4.3 Procedure

Each participant received seven lessons, one training lesson and six experimental lessons. Each of the six experimental lessons had a visual diagram accompanied by either text (visual input, hence unimodal) or narration (audio input, hence multimodal). For each combination (i.e., diagram and text vs. diagram and narration), participants received three variations on the presentation order (form of lesson), creating six types of trials.

Each participant received the same order of lesson content (Microscope, Stapler, Air Cleaner, Hot Air Balloon, Electric Bell, Window Shade, and Metal Detector) with the order of the form of lesson varied by Latin Square to eliminate order effects. Each lesson lasted three minutes during which participants could attend any available information they chose. For asynchronous trials, participants are able to view or hear the first set of information for 90 seconds, and the second type of information for 90 seconds immediately following. For synchronous trials, all the information was available for three minutes. Learning was assessed after each lesson with a test of recall. The paper-and-pencil test included 10 fill-in-the-blank questions about information given during the experimental trial.

5 Data analysis

Due to the difference in performance based on the topic of individual lessons, recall rates were converted to individual z-scores. Z-scores were computed on a groupwise (for each lesson) basis and reflect the distance from the mean for each testing event based on how other participants performed on that lesson, including all presentation forms. A 2x2 ANOVA (form of descriptive material x order of presentation) was performed for the asynchronous presentations. A single factor (form of descriptive material) ANOVA was performed for the simultaneous presentations.

6 Results and Discussion

When descriptive information was presented synchronously with diagrammatic information, no effects were found for form of presentation, $F(1, 214) = .08$, $MSE=.96$. The means were .08 for auditory presentation, .04 for visual presentation. This is inconsistent with past multimedia effect findings. For asynchronous presentations, learning was better for the text presentation (M = .03 vs. -.24) $F(1, 430)=8.91$, $p<.05$, MSE=.87. This demonstrates that learning effects are not solely determined by physical mode of presentation, but raises an interesting question about why multimedia learning was not better than unimodal learning in this study. We believe the reason lies in effects that take place during cognitive operations involved in learning.

7 Conclusions

In this experiment, multimedia learning effects were not found. The next steps for this research are to determine the reasons for this surprising finding and to expand the investigation to diagrammatic materials, including animations. Including what research currently posits about physical modality, and adding to it new discoveries about internal modality, we hope to achieve the basis for developing a taxonomy of multimedia effects. The vision of this taxonomy is to understand human information processing based on the effects of modality for both internal and external representations of information, and consequently to make suggestions to designers of multimedia information.

References

[1] Mayer, R. (2001) *Multimedia Learning.* Boston: Cambridge University Press.

[2] Sweller, J. (1999). *Instructional Design.* Melbourne: ACER Press.

[3] Ainsworth, S.E., (1999) A functional taxonomy of multiple representations. *Computers and Education, 33*(2/3), 131-152.

[4] Reeves, L. M., Lai, J., Larson, J. A., Oviatt, S. (2004). Guidelines for multimodal interface design. *Communications of the ACM*, *47*(1): 57-59.

[5] Drommi, A., Ulferts, G. W., Shoemaker, D. Interface Design: A Focus on Cognitive Science. In *The Proceedings of ISECON 2001*, v 18 (Cincinnati).

[6] Schnotz, W. (2002). Towards an Integrated View of Learning from Text and Visual Displays. *Educational Psychology Review, 14*(2), 101-120.

[7] Larkin, J. H., Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science 11*, 65-99.

[8] Mayer, R. E. & Sims, V. K. (1994). For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning. *Journal of Educational Psychology, 86,* 389-401.

[9] Potter, M. C. (1976). Short term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 509 - 522.

[10] Jolicceur, P. (1999). Dual task interference and visual encoding. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(3), 596-616.

[11] Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constrains within the human information processing system. *Psychological Bulletin, 104,* 163-191.

[12] Busey, T. A., and Loftus, G. R. (1994). Sensory and cognitive components of visual information acquisition. *Psychological Review, 101*: 446-469.

[13] Anderson, J. R. (1995). Learning and Memory: An integrated approach. John Wiley & Sons, Inc. New York, NY.

[14] Baddeley, A., & Hitch, G.J. (1994). Developments in the concept of Working Memory. *Neurosychology*, *8*(4), 485-493.

[15] Wickens, C. D. (2002). Multiple resources and performance prediction. Theoretical Issues in Ergonomic Science, 3(2), 159-177.

[16] Wickens, C., & Lui, Y. (1988). Codes and modalities in multiple resources: A success and a qualification. *Human Factors, 30*(5), 599-616.

[17] Paivio, A. (1986). *Mental representations: A dual coding approach.* New York: Oxford University Press

[18] Gellevij, M., van der Meij, H., de Jong, T., Pieters, J. (2002). Mulitmodal versus unimodal instruction in a complex learning context. *The Journal of Experimental Education, 70*(3), 215-239.

[19] Mousavi, S.Y., Low, R, & Sweller, J. (1995). Reducing Cognitive load by Mixing Auditory and Visual Presentation Modes. *Journal of Educational Psychology*, *87*(2) 319-334.