A Study of Teachable Agents for Scientific Reasoning

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Abstract- Teachable agent instantiates Learning- by-Teaching theory through simulating a "naive" learner in order to motivate students to teach it. Teachable Agent (TA) is a special type of pedagogical agent. Soon after its emergence, researches of TA become an active field and encourage students to take the responsibility of learning. Teachable agent enable student to teach the agent and query their agent to monitor their learning and problem solving behavior. This motivates the students to learn more so they can teach their agent to perform better. This paper presents a teachable agent called Betty that combines learning by teaching with self-regulated learning feedback to promote deep learning and understanding in science domains.

Index Terms- Key Learning-by-teaching, Intrinsic motivation, Teachable agent, Goal-oriented approach word,

1. INTRODUCTION

Over the past several decades, technology has continually assumed an essential and transformative role in the teaching and learning process. This can best be seen in recent trends in education: flipped classroom approaches to instruction, 1-to-1 tablet programs, computer-based learning environments (CBLEs) that understand what each individual knows and does not know, and massive open online courses, or MOOCs, which connect as many as hundreds of thousands of learners all studying the same topic within a shared virtual space [3]. With each new technology-oriented trend comes new hope for the future of education; technology is viewed as a means of providing access to information in rich, engaging, interactive spaces where students can experiment, learn, and grow[3].

In many ways, these hopes are well-founded; technology has the potential to offer students an endless supply of personalized, one-on-one attention. In addition to endless attention and perfect execution of tutoring strategies, CBLEs can capture, analyze and report every interaction they have with learners. This abundance of data, if properly analyzed, filtered, and understood, can provide new opportunities for researchers, educators, and policy makers to gain better understandings of how people learn [3]. Moreover, educational data can be analyzed in real-time to personalize instruction for learners in ways that lead to measurable optimizations of the teaching and learning processes.

In computer-based learning by teaching systems partially demonstrated the effectiveness of explicit teaching tasks with shared representations and shared responsibilities in facilitating learning and motivation.

The use of explicit shared representations may provide the social interaction framework that promotes shared responsibility. Students get a chance to observe and analyze how their teachable agents apply the learnt knowledge to solve problems, and, in this process, they may learn to monitor their own knowledge.

The purpose of the present study was to examine the learning benefits of different activities associated with "learning by teaching" in teachable agent environment. This was done by constructing computer-based agents that students could teach domain knowledge [1]. In particular, we created an agent environment called Betty's which can operate in three modes: (i) the TEACH mode, where students impart knowledge to the agent Betty by means of a dynamic concept map interface, and access content materials as needed to learn information for teaching,
(ii) The QUERY mode, where students ask Betty questions (using question templates) which Betty answers by reasoning with information that the student has taught
(iii) The QUIZ mode, where students evaluate how well they have taught Betty by observing performance on a quiz. At times, an expert teacher agent intervenes to make suggestions that may help Betty (and the student) correct her answers.

Betty is a computer-based learning environment that capitalizes on the social aspects of learning. In Betty, students instruct a character called a Teachable Agent (TA) which can reason based on how it is taught [3]. TAs represents knowledge structures rather than the referent domain. This is a departure from traditional simulations, which typically show the behavior of a physical system, for example, how an algae bloom increases fish mortality. Instead, TAs simulates the behavior of a person's thoughts about a system. This is important because the goal of learning is often to simulate an expert's reasoning processes about a domain, not the domain itself. Learning empirical facts is important, but learning to think with the expert theory that organizes those facts is equally important.

2. METHODS DESCRIPTION OF BETTY

Two principles drive the design and implementation of Teachable Agent learning environments. The first one ensures that students activities in the learning environment cover the three distinct phases of the teaching process, i.e., (i) preparing to teach, (ii) teaching and interacting with the teachable agent, and (iii) monitoring and reflecting on what the agent has learned and using this information to make preparations to teach further. The second ensures that interactions between the student and their TA are based on an explicit shared representation and shared responsibility.

Figure 1 illustrates the Betty's interface. The system possesses multimedia capabilities. Students use graphical drag and drop interface to create and modify their concept maps. When queried, Betty can provide explanations for how Betty derives answers, and simultaneously depict the derivation process on the concept map by animation. In the sections below three modes are described: TEACH, QUERY and QUIZ [1].

2.1 TEACH BETTY

Students teach Betty by means of a concept map interface. A concept map is a collection of concepts and relations between these concepts. A relation is a unidirectional link connecting two entities. Concept maps help to categorize groups of objects and express interactions among them. They also provide a mechanism for representing knowledge hierarchies and cause-effect relations. This makes the concept-mapping technique very amenable to applications in scientific domains, in particular, for modeling dynamic systems.

Figure 1 displays an example of a concept map that student created in Betty's - the map represents what the student has taught Betty. Note that this map is not totally accurate or complete. The labeled boxes correspond to concepts (the labels are concept names), and the labeled links correspond to relations. Students can use three kinds of links, (i) causal, (ii) hierarchical, and (iii) descriptive [1]. Students use descriptive links to embed notes or interesting characteristics of an object in their concept map (e.g., "Fish live by Rocks"). Hierarchical links let students establish class structures to organize domain knowledge (e.g., "Fish is a type of Animal").

A causal link specifies an active relationship on how a change in the originating concept affects the destination concept. For example, in the map below, students could ask Betty to explain how cold temperatures affect a person's body temperature. Betty uses the causal map she has been taught to answer the qeustions.

2.2 QUERY BETTY

Students are able to query Betty about what they have taught. The query mode consists of two mechanisms: (i) a reasoning mechanism and (ii) an explanation mechanism. The reasoning mechanism enables Betty to analyze the knowledge that the student has taught so that Betty can answer questions. The explanation mechanism enables Betty to produce a detailed explanation of how Betty generated answer [1].

The explanation mechanism uses a simple process to convert concept-link-concept pairs to a specific text form. The reasoning mechanism is based on a simple chaining procedure to deduce the relationship between a set of connected concepts. If the teachable agent is asked to answer the question about the effects of an addition of Algae on Fish, Betty searches the concept map and deduces that Fish increase when more Algae are added to a river.

The structure of Betty's explanations is closely tied to the reasoning algorithm. To avoid information overload, the explanation is broken down into segments [3]. If users ask for more explanation, Betty works backward, and links the concept back to the closest nodes. When asked "What happens to fish when algae increase?", Betty's initial response is: "I think that when Algae increase, Fish increase." Students can then ask Betty for a more detailed explanation. The following is the sequence of explanation that Betty generates:

1. "You asked me: If Algae increase, what happens to Fish? I think that if Algae increase, Fish increase."
2. . "To find out what happens to Fish when Algae increase, I must first know what happens to Oxygen and Plants. Both directly affect Fish."

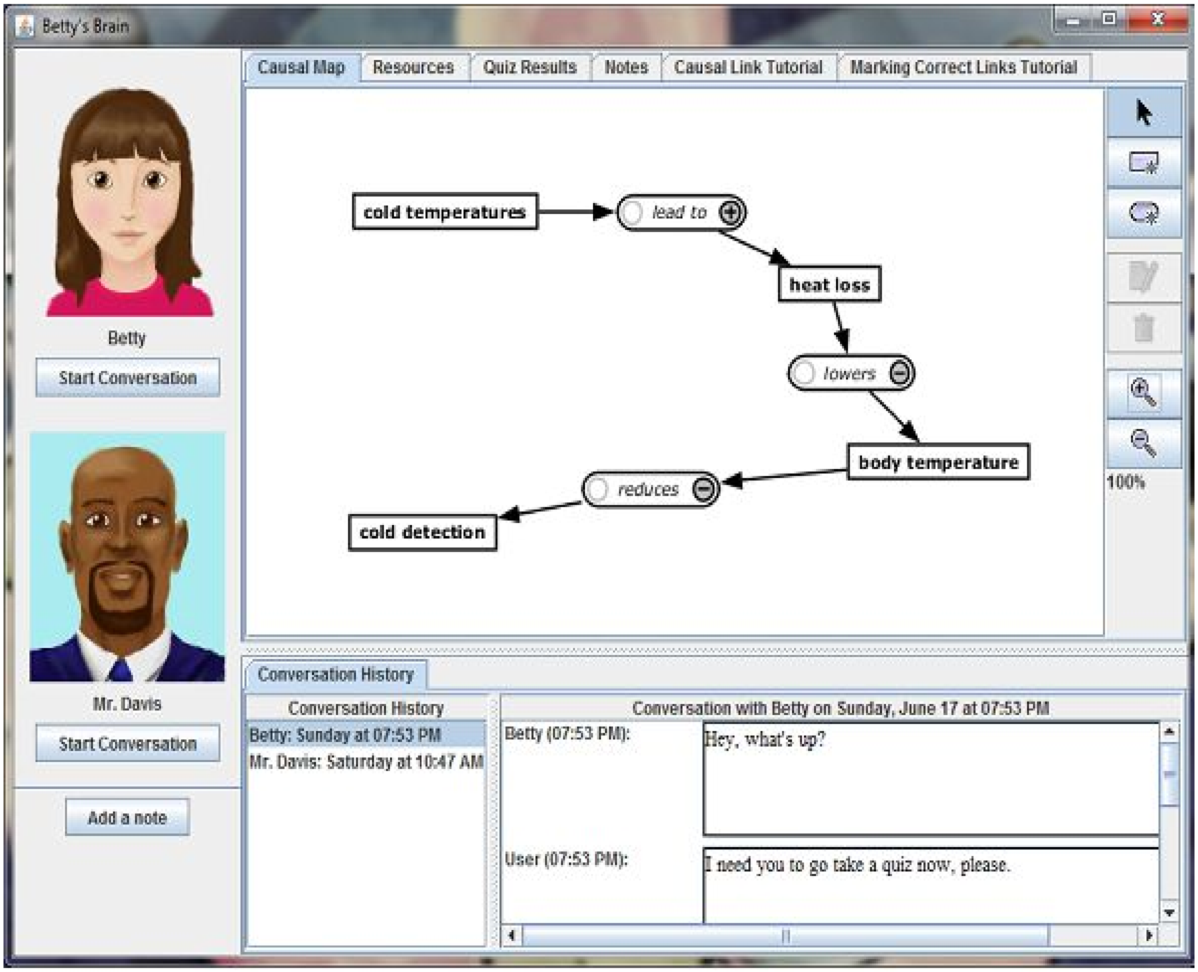

Figure:1 Betty's interface and Example for Concept Map

3. "An increase in Algae causes Plants to increase, which causes Fish to increase."
4. "Now let me explain how Algae affect Fish through Oxygen. An increase in Algae causes Oxygen to remain the same which causes Fish to remain the same."
5. "So, no change in Fish from Oxygen and an increase in Fish from Plants cause an increase in Fish". After each step in the explanation, students have the option to: (i) ask Betty to repeat the explanation or (ii) look at the explanation in text form.

2.3 QUIZ BETTY

During the quiz phase, the student observes Betty's responses to a set of pre-scripted questions. The teaching expert informs Betty (and the student) if Betty's answers are right or wrong. The teaching expert also gives hints to help the student debug the concept map. The teaching expert employs a simple mechanism for generating feedback. The system is provided with an expert concept map (built by a teacher or other expert) in the domain of study. The student's concept map structure is superimposed on the expert's, and the teaching expert searches for a missing concept (first) or relation that is considered essential for the right answer, and uses this to generate a hint for the student. A hint is given, if necessary, for each quiz question. Currently, the system implements three levels of hinting. First, the expert suggests that the student read a section of the resource materials that relates to the concept or link [1]. The second hint for the same question explicitly mentions the name of the missing concept or relation, and asks the student to look for more information on that topic. The third hint tells how to correct the concept or relation in the map.

The aim of this system is to create an effective teaching environment with shared knowledge representation and reasoning mechanism. To aid and motivate learning, formative assessment is also provided in the teaching and quiz modes, whereas overall evaluation or summative assessment is covered in the test mode. The backstage of the system used exhaustive search for the concept map to do reasoning and answer corresponding questions.

With this platform, how can Betty's realize the benefits of learning-by-teaching theory? We examine this from three aspects corresponding to the three advantages of learning-by-teaching. Firstly, Betty helps students develop structured networks of knowledge. A CM helps students avoid doing complex programming by dragging graphical nodes and arcs to construct domain knowledge. It helps students to meaningfully organize knowledge, get better memory, and easily apply knowledge to new situations.
Secondly, it provides opportunities for students to take responsibility for teaching. When sending Betty to do the quiz, students can observe learning results and make changes to the CM on their own. They need to dominate all the teaching process [1].

The third aspect is that teachable agent helps students to develop meta-cognitive skills. When they monitor Betty's learning status, such as asking questions or sending a quiz, it also provides the opportunity for students to monitor their own learning status. The reflection of knowledge can help them to double check what they have done, reorganize their knowledge structure and practice their rethinking habits.

3.META COGNITIVE STRATEGIES AND SELF-REGULATION TO SUPPORT LEARNING

Meta cognition and self-regulation play an important role in developing effective learners. In the learning context, self-regulated learning (SRL) describes a set of comprehensive skills that start with setting goals for learning new materials and applying them to problem solving tasks, deliberating about strategies to enable this learning, monitoring one's learning progress, and then revising one's knowledge, beliefs, and strategies as new materials and strategies are learnt[2].

Betty's persona in the SRL version incorporates meta cognitive knowledge that she conveys to the students at appropriate times to help them develop and apply monitoring and self regulation strategies [4][5]. For example, when the student is building the concept map ,Betty occasionally responds by demonstrating reasoning through chains of events. She may query the user, and sometimes remark (right or wrong) that the answer she is deriving does not seem to make sense. The idea of these spontaneous prompts is to get the student to reflect on what they are teaching, and perhaps, like a good teacher check on their tutee's learning progress. These interactions are directed to help Betty's student teacher understand the importance of monitoring and being aware of one's own abilities[6].

The two interacting factors of TA implementations: (i) the visual shared representation that the students use to teach their agents, and (ii) shared responsibility that targets the positive effects of social interactions to learning are particularly supportive of self-regulation. These manifest as a joint effort between the students and their TA. The student has the responsibility for teaching the TA (the TA knows no more and no less than what the student teaches it), whereas the TA takes on the responsibility for answering questions and taking tests.

The shared representation plus the agent's ability to answer questions independently results in situations where the "self-monitoring" task is shared between the agent, who does the reasoning and problem solving, and the student as teacher, who is responsible for assessment and evaluation of performance[2]. This reduction in cognitive load helps students self-assess their knowledge by "projection," and the combination of this projective assessment plus the motivation to make their agent "succeed" prompts the student to learn more and teach their agent again so student may perform even better.

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4. CONCLUSIONS

Learning-by-teaching provides many learning opportunities for students, but taking advantage of these opportunities places a heavy Meta cognitive demand. The goal is to develop Betty as a generic teachable agent that can be applied to a variety of scientific domains, where reasoning with cause-effect structures helps in learning about the domain.

Providing students with opportunities to quiz their agent decreases the amount of irrelevant information and increases the proportion of causal information in students' maps; whereas having opportunities to query their agent helps students develop an understanding of the interrelationships of things living and non living.

The results point to the importance of various forms of feedback when designing teachable agent environments that promote teach Betty which provides self-regulated learning feedback to cues from the agent clearer and more salient, and support students reflective knowledge-building and learning [2].

From the results of various research [7] it is suggested that when students find the challenges associated with a modeling activity manageable, their computational models generally improve and become better predictors of their prepost learning gains.

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