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INTELLIGENT TUTORING SYSTEMS: HOW WELL CAN THEY GUIDE STUDENTS IN PROBLEM-BASED LEARNING SCENARIOS?

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ABSTRACT

Problem-based learning (PBL) has a strong focus on skills and requires students to use self-regulated learning (SRL). However, SRL puts considerable demands on learners and often leads to students making frequent requests for guidance.

This paper reports the outline design, construction and evaluation of a simple prototype web-based Intelligent Tutoring System (ITS) which was constructed to provide guidance for self-regulated learning activities in a PBL scenario. It was constructed using Chatbot technology which provides extended dialogue with students in order to guide them through the initial stages of developing learning objectives. User testing with undergraduates suggests that the system prompted them to analyse the scenario in more detail (one of the foundational skills needed in a PBL task) and that the technology can be both usable and provide the adaptability required.

INTRODUCTION

PBL is a learning system that has a strong focus on helping students acquire relevant learning skills rather than just knowledge, and one of its aims is to develop Self-Directed Learning (SDL) skills (Barrows and Tamblyn 1980; Norman and Schmidt 1992). There are

many variations of PBL but typically it will involve presenting students with an ill-structured and authentic problem, to which there are no simple solutions or answers. Students work in groups on the problem with the tutor acting as a facilitator. The process requires students to understand and analyse a scenario, identify personal / group learning objectives, locate suitable learning resources, monitor their learning and evaluate and reflect on their achievement at the end of a scenario. These skills correspond exactly with self-regulatory processes that are components of Zimmerman's (2000) model of Self-Regulated Learning (SRL). Furthermore, motivational beliefs, such as self-efficacy, task value and goal-orientation that are part of the model are also important for success within PBL.

While it is widely accepted in the pedagogical literature that the most effective learners are self-regulating (Butler & Winne, 1995; Zimmerman, 2000), SRL puts considerable demands on learners (Loyens *et al,* 2008) and managing the uncertainty in this process often leads to students making frequent requests for guidance and may lead to a high cognitive load which can result in anxiety and frustration (Dyck, 1986). Furthermore, the first author's experience as a facilitator suggests that students have difficulty in constructing well-formed learning objectives in PBL as well as in selecting appropriate resources.

PBL facilitators can provide guidance that is appropriate to a particular student team's needs, but there are two major challenges: firstly the demands on a facilitator can be very high if they are simultaneously dealing with several teams and secondly, students can require individual guidance during the independent research phase of PBL. In order to address these issues, this project sought to explore if a web-based application (known as a PBL coach) based on conversational agent (Chatbot) technology could be constructed to provide effective guidance to students.

The next section of this paper discusses the guidance required by students in PBL, and then explores how a type of conversational agent could provide guidance. The outline design of a prototype system is described followed by an initial evaluation of its usability and usefulness by undergraduate students.

PBL guidance requirements

The requirement for guidance that has been identified as an issue by the first author in his PBL classes is also supported by studies by Lloyd-Jones and Hak (2004) which reported that students experienced uncertainty with respect to what to learn and that they relied on their

peers and given faculty resources instead of selecting resources independently. Kivela and Kivela (2005) also showed that inexperienced PBL students still sought the teacher's approval to be sure they were on the right track and to overcome their uncertainty in their new learning environment. Kuhlthau's (1988) study of high school and college students involved in research assignments noted that the stage of prefocus exploration is often the one which generates the highest level of anxiety. In PBL terms this corresponds to goal setting and identification of learning issues where the formulation of learning objectives and evaluating the research to ensure it is fit for purpose is problematic (Uden & Beaumont, 2006). Studies analysed by Loyens et al (2008) highlighted that the self-generation of learning objectives is crucial for students' learning process (Verkoeijen et al. 2006) and that self-monitoring showed a significant correlation with performance.

Newman's (2008) analysis of help-seeking behaviour identified *adaptive* help-seeking – an indicator of cognitive, social and emotional maturity which is indicated by consideration of the necessity, content and target of the request. He further suggests that affective factors such as self-esteem and self-efficacy are important by enabling them to persist in the face of factors that can undermine help-seeking (eg ridicule from peers). In contrast, examples of non-adaptive help-seeking are *dependent help-seekers* –asking unnecessary questions before attempting the task or seeking help to complete all tasks as quickly as possible rather than to improve learning. Help-avoidance (when help is necessary) is another form of non-adaptive behaviour. In a study by Ryan et al (2005), help avoiders and dependent help-seekers had low learning goals, high performance-avoidance goals (not looking stupid), low perceived competence and experienced high anxiety in class. Newman (2008) suggests strategies for combating these non-adaptive behaviours such as teacher involvement with students to provide a supportive environment; supporting autonomy and stressing learning goals rather than grades while understanding personal learning goals and finally support for competence through modelling questions, scaffolding knowledge construction through use of hints rather than direct answers.

Whilst these studies indicate the areas in which guidance is required, additional detail was needed in order to determine specific requirements for the PBL coach; the authors therefore identified patterns in the type of guidance required in a multi-staged (11-week) PBL scenario which would subsequently be used as the test case for the PBL coach. This study analysed individual on-line dialogue in scheduled weekly 20-40 minute sessions in a small

sample of students (n=19). Whilst some students actively sought guidance, the number of questions asked varied from (a rather depressing) 0.5 to 9 questions per session.

Guidance required, gathered from normative suggestions of students and objective claims from the analysis of the data were categorised most usefully as:

- *Task-guidance* (clarification, planning, analysing, deadlines, deliverables, monitoring, evaluating fitness for purpose of research and assessment);
- *Scenario guidance* (clarification and requests for further information);
- *Learning resources*; (how and where to find information)
- *Group-work* (roles, dealing with issues) and
- *Subject-guidance* (understanding, elaboration, application).

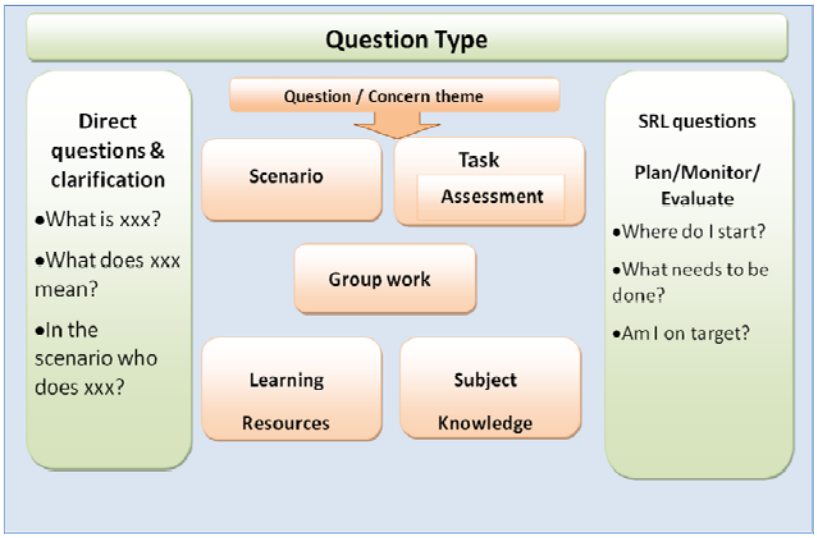

Figure 1 Detailed guidance requirements in a PBL scenario

Reassurance and motivation were also frequently reported as essential aspects of guidance required. Furthermore, students expected to be able to find out grades and obtain further information regarding assessment feedback. The most common concerns/questions expressed related to the task and assessment and subject knowledge (79%), closely followed by groupwork concerns (74%) with learning resource concerns (37%) and scenario clarification (32%) being less prevalent. Figure 1 also shows that questions can further be classified as those that relate to planning, monitoring and evaluation (SRL) or simpler, more direct clarifications.

Intelligent tutoring systems and pedagogical agents

The PBL coach needs to provide responses to natural language input from learners and which is adapted and personalised for their needs. This requirement suggested that an Intelligent Tutoring System (ITS) would be appropriate technology. Such systems have a long history (Evens & Michael 2006) and more recently the technology has been adapted for the development of web-based pedagogical agents (Kim & Baylor, 2005). Typically, ITS and pedagogical agents are complex, take many years to construct and are highly specialised with a focus on teaching *subject-specific* content. A typical ITS comprises a number of components: a learner model to represent a learner's knowledge and which is updated as the learner progresses; a pedagogical strategy to determine how to respond and interact with the learner; an inferential technique for reasoning; a subject knowledge base, and an interface which enables mixed initiative dialogue.

Now given the alignment of PBL with social constructivist principles, and the benefits of prolonged and focussed dialogue (Alexander, 2006), pedagogical agent technology appears suitable for providing support of PBL learners, particularly in the development of SRL skills. Developing an ITS from scratch is a huge undertaking, particularly if natural language input is being processed. However, technology is now available that can reduce the time to build simple systems by providing a framework for input and recognition of natural language text and selecting suitable responses. Chatbots are systems that provide natural-language conversation with users and have been used in education, commerce, and the public sector (Kerly *et al*., 2006) often with an avatar to provide an impression of a persona. Lingubot™ is one such commercially available technology which uses pattern-matching on input words and phrases to identify rules which match the input, and then executes the highest priority rule. This provides a ready-made framework for constructing a simple ITS: The pedagogical strategy and knowledge are coded into the rules, the chatbot can also store and retrieve information from a database, which together with a scripting language can provide both flexibility and persistence of data suitable for adapting responses and storing learner model data.

The design of a prototype PBL coach

Students' guidance requirements, as described earlier, were used to inform the design of a prototype coach which was constructed using the Lingubot Chatbot and is intended to provide guidance to learners in the initial stages of PBL; namely analysing the scenario and identifying suitable learning goals. The coach can operate in one of two modes: a 'quick consultation' and a 'full consultation'.

In a quick consultation the coach provides answers to students' questions (including a set of FAQ's). These questions were derived from the primary study of students' concerns, for example: 'What should I do next?'; 'When is XXX due?' relating to clarification of the task and scenario and some help on monitoring progress.

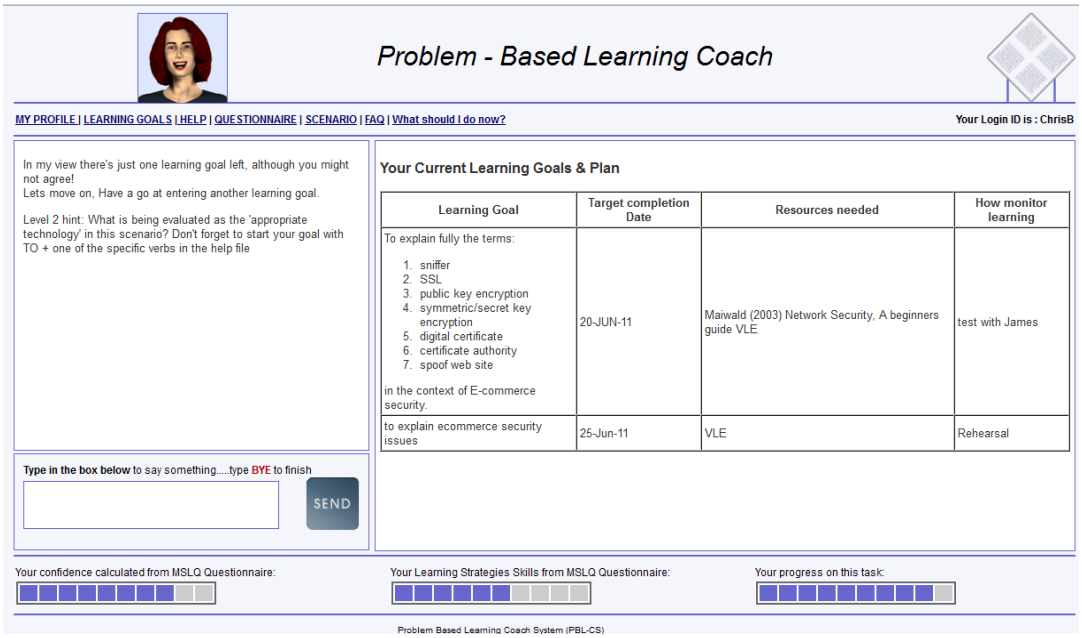

Figure 2: PBL Coach Interface, showing example dialogue and learning goal.

In the 'full consultation' mode the coach takes a more proactive approach by guiding students through the analysis of the scenario and prompting them to plan the structure of a report and create well-formed learning objectives. Well-formed objectives are defined as those which are specific enough to be achievable, and include the outcome, context and criterion for achievement. The coach also prompts students to identify the learning resources used to achieve the objective, set a completion date and state how they will monitor the completion of the objective. Learning objectives and progress are stored in the learner model, and can be retrieved and printed by the student.

Given the pedagogical imperative of an emphasis on SRL, the system has also been designed to incorporate a self-report measure of SRL: an abbreviated form (42 questions) of the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich *et al*., 1991) together with a help file to provide guidance on learning strategies and writing well-formed learning objectives. Students can view and explore their profile produced from their questionnaire results. In the study reported here, the self-efficacy and control of learning beliefs measures are used to predict a confidence value which is used to determine the level of guidance provided (higher confidence, less specific guidance). We hope to use these data, together with analysis of transcripts to refine the pedagogic strategy of the dialogue in our future development of the PBL coach.

As is common in an ITS, the coach provides hints to assist students. The coach currently provides 3 levels of hint, with higher levels of guidance providing more detail. The level given depends on the students' initial stated confidence, and can dynamically adapt depending on the quality of a student's answers throughout the dialogue. This aspect of adaptation was considered to be one of the most important design features in order to customise the guidance to students' individual needs.

PBL Coach Implementation

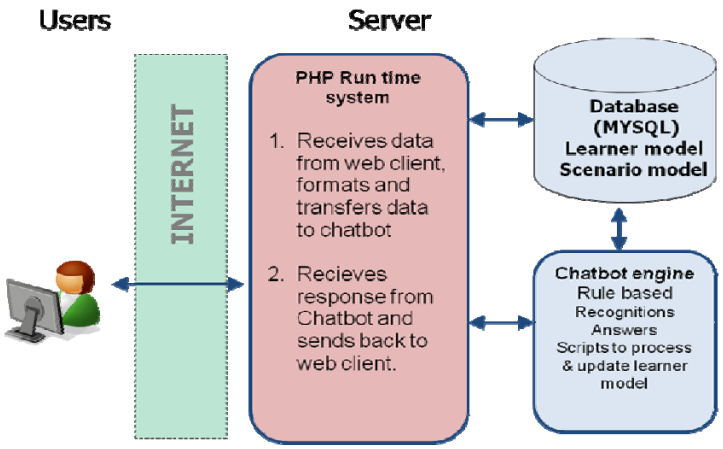

Figure 3: Block diagram of PBL coach structure.

The basic architecture of the system is shown in figure 3. Student users login through a web-page and their learner model, together with scenario information is stored in a database. The interface (fig 2) is provided by PHP scripts which communicate with the database and the chatbot engine. The chatbot incorporates over 1350 production rules which recognise the

natural language input and trigger appropriate responses and update the learner model. The rules also cater for 'smalltalk' and 'safety nets' to deal with off-task or unrecognised input. The interface comprises a dialogue area for chatbot conversational output, together with a larger display area for situations where more persistent or larger volumes of data are required (e.g. learning goals or a list of FAQs). Students' progress and their skills/ confidence summary are shown in progress bars. The avatar image changes depending on the input, to represent different emotions (e.g. excited, neutral, unhappy).

Testing and evaluation

Testing of the usability and usefulness of the system has occurred iteratively over several months, as each test revealed shortcomings, particularly in the recognition of user input. Initial tests were carried out with an opportunity sample of second and final year (n=30) undergraduates using a PBL scenario based on Information Security. Data were collected from logs of the dialogue and post-test focus groups. A subsequent set of tests were also conducted which involved an in-depth individual evaluation of the coach by a purposive sample of first and third year undergraduates (based on academic achievement, n=8). These tests focussed on usability and usefulness of the PBL coach and employed observation, think-aloud protocol, questionnaire and interview and analysis of PBL coach logs.

Students in the initial tests were generally positive about the coach in terms of usability and usefulness for the task, but three key areas for improvement stood out: the need to cater for a much larger range of responses; the need to abbreviate the MSLQ from its original 81 questions (subsequently halved) and the tendency of some students to indulge in 'gaming' behaviour, i.e. they attempted to break the PBL coach by going off task and in some cases using offensive language (a recognised issue with this technology).

The in-depth testing of each individual student showed some overall consistent messages, but also a wide variation, revealing differing approaches to studying the task. For example, while most students considered that the volume of text was appropriated, two stated that there was 'too much text'. Some students read the entire help file, and followed every help link, whereas others preferred to try out a response before using any help. The PBL coach was able to conduct prolonged dialogue inputs (from 34 to 84 inputs over a period of 32 to 72 minutes) over where all participants were able to specify appropriate learning goals. Overall, students considered that the usability of the interface was good, with particular

strengths being reported that it was clear what the student *should* do next, it helped students recover from mistakes, was intuitive, relevant to learning needs, consistent and easy to gain information needed to complete the task. The usefulness and adaptation of the hints to their level of confidence was cited as a positive feature and perhaps, most importantly, it helped them focus on the scenario and analyse it in detail.

The PBL coach was specifically designed to be encouraging and build confidence, and, students volunteered that it had a positive influence on how they felt, this small sample unanimously liked using it, using words such as "*useful*", "*helpfu*l", "*encouraging*" to describe it and all agreed that they would recommend it to others and stated that "*it felt good*" when they received positive feedback. Most students stated that it "*didn't make them feel bad if they got something wrong*".

There were, as mentioned above, a number of weaknesses cited by students, the most common being the inability of the coach to respond appropriately to all dialogue. At best there are minor issues which cause frustration, but at worst these can be confusing and impede learning, for example if the student entered something appropriate, which the coach rejected. While the coach cannot be programmed to recognise all input, it is possible to overcome this issue by providing a safety-net in which the coach explains it does not understand but asks the student if they wish to record the input.

A further issue cited with the current version was that students were not always clear what it was *possible* to do next. It would have been an improvement to be able to see the complete history of the dialogue, and on occasions "*go back*". One student with specific learning difficulties pointed out that he had short term memory issues and so this feature would be essential.

Conclusion

In this paper we have argued that self-regulation is an essential ability for success within Problem-based Learning and students, who are inexperienced in this type of learning approach, require scaffolding and guidance in order to develop effective SRL skills. In particular, task-related guidance, such as analysing the scenario, setting goals, planning, and monitoring learning were shown to be areas of high concern to the PBL students in our study. A coach was constructed to test the potential for using a conversational agent (chatbot) to provide the guidance. Key features that suggested that the chatbot was suitable were the use

of extended natural language dialogue, shown to be important in learning (Alexander,2006) and adaptability to the student's input and level of confidence/ knowledge.

The chatbot technology helps reduce the time and skill needed to produce a pedagogical agent; basic rules for language recognition using keywords/ phrases are simple to create, though some programming skill is required to create the scripts that will orchestrate the dialogue. The system took the equivalent of about 3 month's full time work to build. Commercial chatbot systems typically take from 10-12 weeks to build, and 12 to 18 months to optimise (Elzware, 2011).

It is still early days for the development of this PBL coach; tests showed that there is much to do to improve the dialogue, in particular in the adaptive help system which provides hints and follow up questions. Such improvements can only be made through iterative user testing, and they also shed light on the variety of meanings that students infer from text. A particular surprise to the first author was the lack of attention that these students initially gave to reading a scenario, and the variation in level of understanding; students needed repeatedly detailed guidance from the coach to direct them to parts of the text in order to locate key terms, concepts and issues for their learning objectives. This is a finding which has implications far beyond that of PBL and relates to the increasing concerns that academics have about students' readiness (and indeed their ability) to read in depth (e.g. Coburn, 2008)

Despite these shortcomings, initial indications suggest that chatbot technology can be used to create a simple adaptive guidance system that engages students effectively to analyse a scenario and plan their learning objectives. In particular the tests from a small sample showed positive affective influence, and students self-reported that it helped them analyse the scenario:

> *"It made me think more.. not letting me miss anything out, ..making me find from the scenario what I need to put in"*
> *"cause it made me see which terms I didn't fully understand, ... I wouldn't have looked at those at the start."*

These are not comments we would expect from a surface or superficial approach, and suggest that the technology has the potential for significant learning benefits for students who

are asked to take a problem-based learning approach to their studies. The next challenge is to measure the learning benefits.

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