Actively Supporting Collaboration in Virtual Learning Environments

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Abstract

Collaboration between peers is an important aspect of the learning process and can considerably augment learning in studying complex domains. To ensure that peer collaboration occurs within unfamiliar situations such as those provided by Virtual Learning Environments, support for collaborative activities needs to be offered to learners. This support can be provided using intelligent agents that actively support the formation of collaborative relationships and mediate collaboration between learners in Virtual Learning Environments. This paper describes intelligent agents developed to provide support for proctoring, a form of collaborative learning where learners adopt the role of tutor or tutee. This collaborative activity is described within the context of an environment constructed for the learning of Entity Relationship Modelling. The intelligent agents determine effective collaboration partners, based on the monitoring of learner behaviour and initiate the collaborative activity between these partners. Using this approach, learners interact as both tutor and tutee and experience different types of collaboration. Learners have identified positive learning experiences and can be seen to have an increased understanding of Entity Relationship Modelling as a result of these collaborative activities.

Introduction[1]

Virtual Learning Environments (VLEs) provide a learning experience where multiple participants interact within an educational environment, realised as a virtual space that is available over a computer network. Recently there has been considerable focus on the use of intelligent agents within VLEs, resulting in the development of what (Dillenbourg, Mendelsohn and Schneider 1994) term Intelligent Learning Environments (ILEs). In ILEs, learners are able to collaborate with a number of actors in the environment, including intelligent agents ranging from pedagogical agents (which take on the role of tutors) to peer agents (which take on the role of fellow learners) (Andriessen and Sandberg 1997).

Although collaboration within VLEs by learners can and does occur with both peer or pedagogical agents, there have recently been a number of applications involving the use of agents whose function is to directly support collaboration amongst groups of learners (Wasson 1998). Such agents focus on the collaboration and cooperation that can occur between human learners, rather than on the product that is constructed or the task that is attempted.

In (Plotzner et al 1996), paired collaborative learning is discussed, in a domain whose goal is the development and modification of shared concept maps. Learners select a collaborator from a menu of registered participants, and send their intention to collaborate as a new or partially developed concept map. Collaboration involves dynamic and temporary groupings, and learners can reject requests to collaborate. If the collaboration request is accepted, the learners use a range of computer-based tools such as shared workspaces and text-based talk tools to collaborate.

However, this reliance on learners deciding when and with whom to collaborate will not ensure that all learners experience collaborative learning. A possible solution is to allow the VLE itself to actively initiate and support collaboration. It has been suggested that collaboration is a composite skill that should be taught both explicitly and implicitly, with the need to support students as they learn to collaborate and collaborate to learn. (Fjuk 1995) notes that the learning application itself should provide a mediating role between the individual learner, peers, educators, agents and tasks and should be designed with this role in mind.

This paper discusses the continuing development of a VLE, focussing in particular on attempts to encourage collaboration between the learners who inhabit this environment. This is based on one of the main threads of Computer Supported Collaborative Learning (CSCL), that is the support of collaboration based on the idea of other students and teachers as a resource to support learning and as a means to provide external feedback. In this situation, the computer serves as a tool to mediate and support collaborative efforts, providing the medium that enables the learners to interact with one another. This paper focuses on a VLE for Entity Relationship Modelling, which is populated by agents which, amongst other things, are intended to facilitate collaborative learning.

Peer Tutoring as Collaborative Learning

Collaboration is an important aspect of learning problem-solving strategies, particularly where the domain is complex, extensive and difficult to master. Within the classroom, collaborative learning activities are encouraged and supported by educators using methods such as problem and project based learning, simulations and peer tutoring. In this paper, we focus on the latter where learners help each other and learn by teaching (Goodlad and Hirst 1989).

A peer is considered to be someone belonging to a group in society where membership is defined by status. Within education a peer usually refers to a fellow learner, that is someone who is not a professional teacher. Peer tutoring results in learners taking on the roles of tutors and tutees. Such roles are readily comprehensible for learners, reflecting typical interpersonal relationships experienced in everyday life. Generally, peer tutoring requires minimal intervention on the part of the educator once collaboration has been initiated and roles have been assigned.

Peer tutoring covers a range of teaching-learning relationships, including surrogate teaching, proctoring, co-tutoring and teacherless groups (Cornwall 1980). The greater the affective and cognitive difference between peers, the more that the teaching-learning relationship will resemble that seen between a learner and a professional teacher. The form of peer tutoring that we focus on in this paper is proctoring. Proctoring involves exchanges between students who are learning the same material and who are at the same stage in their education. It involves students taking on the role of individual tutors for fellow students who are at a similar or slightly lower stage in a course. In proctoring the tutor and tutee have a similar level of authority, but the tutor has attained a higher level of learning, resulting in a slight cognitive difference.

The tutors are students who have demonstrated their mastery of the appropriate course material, for example the tutor has completed more sections of the course than their tutee and has a greater level of knowledge on certain topics. Students can expect to take the role of both tutor and tutee during their learning experience through interactions with different peers. Acting as both tutor and tutee results in affective equality, a factor that encourages the tutee to learn within the exchange. Although the tutor will have achieved mastery of a specific section of the course, there is close cognitive congruence of the tutor and tutee, encouraging the tutor to empathise with the tutee and instinctively to appreciate or remember how it feels to be confused about the topic. The tutor has a greater possibility of understanding the tutee's perceptions of the material and will frequently aid the tutee through providing solutions that have worked in their experience (Beardon 1995).

Structured rather than unstructured tutoring results in a more successful learning experience for both the tutor and tutee. Such structured tutoring requires that the instructional materials are closely programmed so that the interaction between the tutor and the tutee is focused on specific, detailed tasks. In proctoring this enables more appropriate pairing of tutor and tutee, with the possibility of determining an appropriate cognitive distance between them. The tutor has to have sufficient mastery to ensure that they can adequately explain the problem and the solution to the tutee. However, this mastery must be only slightly greater than that of the tutee to enable the empathic benefits of cognitive congruence to be achieved.

Where peer tutoring has been used as a deliberate pedagogical strategy, research has shown that there are considerable academic and social benefits for the participants in comparison to other groups of learners (Slavin 1990), (Palinscar and Brown 1984). For tutees, benefits include individual instruction and more teaching than they would probably be given within a typical classroom situation. Further, tutees gain alternative viewpoints and additional problem solving strategies to those that they would normally be exposed to. For the tutor, (Slavin 1990) notes that an individual student's achievement is consistently positively related to the level of help that the student gives to others. Enhanced understanding results because the tutor must think about the material, develop examples and structure explanations. Both parties experience companionship and the development of social relationships within the learning environment. In general, peer tutoring can be seen to result in enhanced learning, increased self-esteem and self-confidence, improved communication skills and an openness to new and alternative ideas and solutions.

Proctoring in Virtual Learning

Environments

Collaboration frequently occurs spontaneously within the classroom, as learners realise that a peer has not completely understood an aspect of the course. Such awareness is typically based on observing the actions and reactions of peers, something that is very difficult to achieve within a virtual space. Within a VLE many actions and most non-verbal behaviours are hidden, with the result that learners may not realise that their peers are having difficulties. Further, learners may not know how to request or give help within an unfamiliar environment.

Proctoring does not rely on spontaneous collaboration, but rather involves the explicit pairing of learners by the

educator. Proctoring has been used with Keller's Personalised System of Instruction (PSI) (Keller 1968), an educational system that exhibits a number of similarities to remote learning. PSI is a system of learning whereby students are provided with study guides that give structure and organisation to the learning material and where the resources and materials used for learning are non-classroom based. The students then follow the course at their own pace, seeking to gain mastery of the material (determined through formative assessment) and have infrequent direct contact with teachers with the aim of such contact being to stimulate and motivate students.

This style of self-paced, student centred learning bears many similarities with remote learning where students are provided with materials and the structuring of these materials using a medium such as the web. However, the inclusion of proctoring within PSI ensures that students following this method of learning are exposed to collaborative activities: increasing exposure to information and providing alternative problem solutions for tutees and reinforcing and assimilating learning for the tutors.

Typically proctoring is initiated through educator involvement, pairing the tutors and tutees based on their current status of knowledge. This status is determined through formative assessment and does not necessarily rely on face-to-face interactions between the educator and the learner. In this paper we discuss the replacement of the educator by an intelligent agent who initiates and supports the pairing needed to enable proctoring to occur.

Supporting Collaboration in a Virtual Learning Environment

The domain in which we have constructed our VLE is in the teaching and learning of Entity Relationship (ER) Modelling (Chen 1976). This is a technique for capturing data requirements that is taught in the majority of computer science undergraduate programs and is widely used in industry. It is a complex, difficult technique that involves the refinement of a problem space into a model that can be used as a basis for database design.

ER modelling involves experiential learning, and in the classroom it is typically taught through the use of text-based scenarios. Learners collaborate with one another and with the educator in the construction of a pencil and paper model derived from the scenario. Where learners are geographically distributed, the classroom based approach to teaching ER modelling becomes impossible, and a VLE provides an alternative approach. VLEs aiming to support experiential learning are based on the idea that experience is constructed and refined through direct interaction with the problem domain, and that the development of knowledge is interwoven with experience. Entity

Relationship Modelling – Virtual Learning Environment (ERM-VLE) has been developed to provide such an environment for ER Modelling.

ERM-VLE is described in (Hall and Gordon 1998) and Figure 1 represents the current version incorporating both the Tutor Agent (see (Gordon and Hall 1998)) and Collaboration Agents. ERM-VLE is based around a text-based virtuality, that borrows much from the Multi-User Dimensions paradigm. Embodied in the world are a number of locations, objects, and actors, including learners. The learner's task is to move around in the virtual space, collecting and manipulating objects as she goes, and communicating with other actors. Distributed throughout the virtual space are elements of a text-based scenario, typically describing the data requirements of an information system. By collecting and manipulating elements of the scenario, the learner must construct a data model that captures the data requirements implicit within it. The left of Figure 1 represents the client interface that is used by the learner to interact with ERM-VLE. This client interface contains a text panel, in which the learner sends commands to and receives information from ERM-VLE, and a graphics panel, in which is represented the data model that the learner is in the process of constructing. The dotted lines in the figure represent network connections.

Figure 1 ERM-VLE and Collaboration Agent

Within ERM-VLE, the ER Modelling activity is decomposed into a series of potential operations linked to the various elements that learners can manipulate within the scenario presented by the VLE. For example, learners can manipulate elements to become entities and relationships. As there is a small predefined set of correct solutions to the scenario within ERM-VLE the Tutor Agent knows the level of completeness of a learner's solution and the degree of correctness that is exhibited by this solution.

The Tutor Agent is aware of the typical systematic errors that learners exhibit in relation to these elements and can identify the types of problems that the learner is experiencing. As it is possible for the learner to create any model they desire within ERM-VLE, the Tutor Agent can quickly determine when this model begins to contain incorrect elements and when the learning moves from appropriate activities to errors.

Previously, the Tutor Agent has given feedback to learners about their progress, however this agent has some important knowledge that can be exploited in terms of developing collaborative relationships between the various participants in the learning environment. At any given time the Tutor Agent knows who is online, which students are having difficulties with a particular modelling problem

and which students have solved which parts of a particular modelling problem. Thus, students are formatively assessed throughout their learning and the Tutor Agent provides information that can be used as a basis to enable the explicit creation of proctoring relationships.

With the introduction of the Collaboration Agent into ERM-VLE, the Tutor Agent no longer only gives feedback to the learner, it also informs the Collaboration Agent who will seek to ameliorate these problems by encouraging a proctoring relationship between the learner and a peer, if an appropriate peer is available. This is achieved through the Tutor Agent now transmitting its knowledge of student activities to the Collaboration Agent. The major aim of the Collaboration Agent is to help learners who have been identified by the tutor agent as having a problem which they cannot themselves solve.

The Collaboration Agent helps such students by instigating collaborative problem solving in the form of a proctoring relationship. The tutee within this relationship is the learner who is involved in incorrect activities. Information about the potential tutee is provided automatically to the Collaboration Agent by the Tutor Agent as soon as the learner begins to exhibit errors, ensuring that the Collaboration Agent is aware of learners who could possibly benefit from peer tutoring. This information describes the current status of the tutee, identifying the stage of learning (for example entity identification) and the nature of the error that the tutee is making (for example the creation of synonymous entities).

The Collaboration Agent attempts to identify possible participants who are currently on-line and who have achieved a level of mastery that would make them appropriate peer tutors. This identification is achieved through the Collaboration Agent making a request to the Tutor Agent to identify all participants who have achieved a certain level of mastery. For example, in the case of incorrect entity identification, the Collaboration Agent requests information on any participants who have successfully identified more (ideally all) of the entities for a given scenario. Where the Collaboration Agent is offered multiple potential tutors, it will determine the most appropriate tutor through reviewing that learner's past activities in conjunction with the Tutor Agent. For example, in the case of the synonymous entity, the most effective tutor will typically be a learner who has previously committed a similar error and then corrected it (whether through collaboration or on their own). Currently, due to the experimental nature of the VLE all participants are assumed to be willing to participate in proctoring relationships. Thus the Collaboration Agent can assume that both tutor and tutee will participate in collaborative activity once they have been requested to.

If appropriate collaboration partners can be identified, the Collaboration Agent sends a series of messages to the tutor providing information about the tutee and the problems they are experiencing. This sets the scene for the tutor and ensures that the collaborative interaction does not involve a frustrating initiation session where the tutor tries to guess what problems the tutee is experiencing. The tutee is also informed by the Collaboration Agent that a tutor will be arriving to help them with their current activities and explicitly states what these activities are, for example the identification of entities. Once both parties are aware of the goals of the activity and the focus of the proctoring relationship, the Collaboration Agent places both participants in the same geographical area of the VLE so that they can easily communicate and attempt to solve the tutee's problem collaboratively. Once the tutee has achieved the goals specified as being the aim of the proctoring relationship, this is dissolved and the tutor is returned to their previous location within ERM-VLE.

Discussion

We are in the process of implementing and testing the Collaboration Agent, using proctoring as a mechanism to support collaboration between learners. Results indicate that proctoring provides a useful collaborative mechanism within virtual space, particularly where no educator is present. Proctoring appears to be a useful strategy due to the relative simplicity of the proctoring model, where learners are viewed in terms of their level of mastery of the problem. Through using the Tutor Agent to monitor the status of all participants the cognitive congruence is transparent to the Collaboration Agent enabling it to rapidly identify the best possible proctoring relationship for learners. This interaction between the Tutor and Collaboration Agents replicates the activity of an educator in identifying the participants, determining the tutor and the tutee based on formative assessment.

Structuring the learning task into small, structured segments ensures that the goal of any proctoring session is clear and tangible with both participants being aware of the session's limits. This prevents the proctoring experience being aimed at the entire modelling problem and focuses the collaborative experience to the current activity.

As current experimentation focuses on collaboration (and this is known to participants) the issue of participant willingness to collaborate has been removed. However, in a real situation some learners may choose not to collaborate and this right to refuse has been identified as being of importance by current participants. This will require that the Collaboration Agent not only identifies potential proctoring relationships but also identifies that these relationships are practicable. For example, in a real situation, collaboration may be refused as a participant may have to leave the VLE soon after the collaboration

request is made. Alternatively, the potential tutor may be currently involved in working through some aspect of the problem and may not wish to change activity. Finally, in virtual space as in the classroom some pairings may simply not be acceptable to the participants due to interpersonal differences. Although collaboration is desirable and can be seen to aid learning, this will only occur when all participants wish to collaborate. Forcing collaboration may have negative rather than positive effects and we would hope to avoid this in our use of ERM-VLE.

In proctoring the roles of the participants are clear, with one learner acting as the tutor and the other as the tutee. However, this clarity of role does not ensure that the collaborative behaviour of the tutor will be appropriate. For example, a tutor could simply tell the tutee the correct solution without actually explaining why this is correct nor encouraging the tutee to explore the problem and to extend their knowledge. For the Tutor Agent, it will appear that the tutee has "learned" the correct solution, whilst in reality the tutee may simply be performing a series of actions given to them by the tutor. We recognise this as a potential problem of the use of proctoring and are seeking to reduce the likelihood of this arising through providing information on the nature and benefits of collaborative behaviour to learners.

Our experimentation with ERM-VLE as an environment for collaborative learning has had beneficial results, with learners identifying positive learning experiences and revealing an increased understanding of ER Modelling. However, this experimentation has involved willing participants who have been briefed on the need to adopt appropriate collaborative behaviours and been prepared to collaborate with any other learner within the environment. We are currently readying ERM-VLE to be used in a more realistic situation where participants can decide whether or not to collaborate and where the focus lies not on collaborative behaviour but on the use of ERM-VLE to learn ER Modelling. Briefing sessions on the benefits of collaborative activity and proctoring will be provided to learners, however, further work will involve the monitoring of learner behaviour to determine if appropriate collaborative behaviour continues to occur when the focus is on learning rather than collaboration.

Future work will concentrate on comparing the effectiveness of different learning strategies within the VLE, with different degrees of support being offered through the use of intelligent agents. This will have a focus on evaluating the effectiveness of collaboration as a learning strategy using a number of different collaborative approaches including agent-learner collaboration (with agents as peers), spontaneous / learner-initiated collaboration, proctoring and educator-instigated collaboration. We also intend to compare the effectiveness

of collaborative learning with agent based tutoring. This agent based tutoring will be of a number of forms ranging from the provision of minimal feedback within the confines of the VLE to an approach where the agent structures learning activities through providing dynamically generated customised web pages to the learner. Current experience suggests to us that learners should be given as many alternative learning strategies possible, thus placing the learner at the centre of the learning process and allowing them to select the approach that most closely reflects their learning needs and requirements.

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