

Supporting Collaborative Learning in Narrative-Centered Learning Environments

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ABSTRACT

Student collaboration in traditional classroom settings has been shown to contribute to learning gains, cognitive and metacognitive skills, and to accrue social advantages. However, creating effective cooperative learning environments is challenging. Forming groups expected to generate the most beneficial outcomes and monitoring or scaffolding group interactions is difficult, especially when students are first learning to work as a team. However, given the promise of collaboration, the intelligent tutoring systems community has begun to investigate the utility of computer-supported collaborative learning as a means for addressing traditional classroom impediments to collaborative learning. In particular, narrative-centered learning environments may be well equipped to address the complexities of collaboration. This paper discusses the advantages of narrative-centered learning environments for both student-student collaboration as well as student-agent collaboration.

General Terms

Design, Human Factors

Keywords

Computer-supported collaborative learning, narrative-centered learning environments, intelligent tutoring systems, intelligent virtual agents

1. INTRODUCTION

Collaborative learning involves multiple students working together towards a common goal. During collaborative learning interactions students communicate ideas, share knowledge and discuss alternatives, all of which lead to positive impacts on learning, motivation and social equity [1, 20, 26]. The success of collaborative practices in classrooms has led to a focus on developing collaborative computational learning environments. Work on computer-supported collaborative learning (CSCL) systems has shown promising successes mirroring those of classroom studies [4, 13, 15, 20, 21, 34]. These computational

environments offer significant potential for exploring collaborative behaviors. For example, collaborators are no longer geographically bounded and instructors may have access to student dialogues and collective representations of student knowledge. However, managing social behaviors within computational settings can introduce new challenges. Designing effective CSCL environments requires leveraging the capabilities of modern computational systems while recognizing, understanding and addressing the limitations presented by such systems.

A novel approach to CSCL is creating collaborative narrative-centered learning environments, which utilize rich virtual environments, interactive storylines and realistic, engaging characters. Narrative-centered learning environments contextualize educational content within the framework of an interactive story, capitalizing on functionalities that contribute to student motivation, memory and comprehension. These environments provide natural testbeds for studying and fostering collaborative behavior. Understanding how collaborative behavior unfolds in these complex environments is expected to provide important insights into CSCL as well as reveal beneficial phenomena associated with collaboration.

In this paper, we provide a brief overview of recent findings in collaborative learning and CSCL systems. We then discuss the underlying concepts of narrative-centered learning, followed by a discussion of CRYSTAL ISLAND, a collaborative narrative-centered learning environment that is currently under development. We conclude with a discussion of how the rich stories, environmental setting, and artificial intelligence technologies involved in narrative-centered learning environments can be utilized to advance understanding and support of collaboration.

2. BACKGROUND

Collaboration has become an important component of classroom learning in recent years because of its benefits to student learning and motivation. For example, students working in peer groups pose considerably more questions than when interacting in full classroom discussions [10]. Vygotsky's theoretical framework, the *zone of proximal development*, suggests that children of close but different levels of cognitive abilities can help to improve the skills that each other lacks [35]. Similarly, early implementations of collaborative classrooms followed models, such as Aronson's Jigsaw classroom, in which individuals become experts on specific topics and meet in groups to share their knowledge and have been found to be effective for promoting learning and collaboration [1].

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Growth of interest in collaborative learning in educational computer environments has mirrored the increased interest in collaboration in classroom-based learning. The education community has begun to focus on the power of computation to bridge barriers of distance, social status and resources to learners world-wide [20]. Recent years have seen increased activity in computer-supported collaborative learning (CSCL), which has gained momentum from findings that computers introduced into classrooms benefit learning. CSCL work seeks to expand the capabilities of learning environments to actively encourage and manage collaborative activities among students.

CSCL systems have shown that, in general, pairs perform better than individuals on learning tasks, especially tasks that are exploratory in nature [4, 21, 26]. Many explanations have been proposed for the positive effects on learning gains. For example, Lehtinen et al. present five main areas that may be responsible for this improved performance: motivation to achieve external group rewards, motivation out of concern for the well-being of the group, optimization of developmental differences among students, and increased elaboration through group dialogue and distribution of cognitive resources [20]. Similarly, work has shown that collaboration in virtual learning environments leads to a reduction of cognitive load [8], more elaborative discussion [26], formation of better hypotheses and tests [4], the ability to consider more hypotheses [9], and exploration of more solution paths [34].

CSCL systems have also been shown to have positive effects on the social aspects of learning as well. Collaboration has long been touted as a means for promoting equity in the classroom by building dependence relationships and encouraging students to collaborate with students of other genders, ethnic and educational backgrounds. The same benefits may be offered by CSCL, and may also be increased by the capabilities of these systems to support remote and virtual interactions. For example, recent work has shown that CSCL environments offer particular benefits to female students [14, 24] and students who are typically low performers [4]. When used properly, CSCL has the ability to “level the playing field” among students from diverse backgrounds with very different approaches to learning tasks.

2.1 CSCL State of the Art

A key focus of much CSCL research is developing methods for conducting and supporting collaboration. For instance, an important distinguishing feature of CSCL systems is whether users interact *around* the computer, in which multiple individuals collaborate in the same physical setting, or *through* the computer, using virtual means of communication [20]. There are also many different mechanisms for virtual communication including instant messaging, email, message board systems, and collaborative work environments. Additional distinctions can be made based on how much support and scaffolding is given to the users. For example, systems may merely provide a rich platform for communication or may provide tools for monitoring, advising and improving the collaborative efforts of student users [15]. Collaboration may even take place with non-human agents who are designed to replicate the collaborative patterns used by real student or mentor users [6].

How these systems are designed strongly determines the types of interactions that take place and how information is learned. For instance, Knowledge Forum is a collaborative knowledge generation environment in which students can contribute new “nodes” of knowledge to relevant topics and examine nodes created by students [30]. The types of interaction promoted here

include discussion of the quality and appropriateness of others and one’s own contributions. Knowledge Forum has been shown to produce discussion that achieves learning gains and also contributes to sophisticated epistemological beliefs, or beliefs about the acquisition of knowledge [12]. The Belvedere system similarly consists of students contributing knowledge to a working model, though this interface focuses explicitly on the logical and causal relations that connect theories and ideas [32]. Students are encouraged to assess the contributions of others and are able to label these contributions accordingly if they agree or disagree. These labels promote discussion and argumentation skills as students work together to form a complete model. Another CSCL system, CoVis, focuses on emulating the collaborative behavior of real professional scientists for high school students [7]. These students use digital video conferencing, shared workspace, collaborative notebooks and a variety of other tools to share science information with a focus on collaboration with remote users. In contrast, the Telecommunicando system focuses on both local and remote collaboration [20]. Here, students work together in small groups to create hypertext applications, which are then evaluated by similar teams at distant schools. These distant teams work together to suggest revisions, which are then discussed and implemented at the local group level.

2.2 Issues in CSCL

The variety of implementations of CSCL systems has revealed fundamental questions about the development of these systems. First, it raises the question of what means of collaboration is most appropriate for particular goals and how can software provide appropriate support for the collaboration. Current work on scaffolding and guiding collaborative behavior in CSCL environments has shown little positive effects [4, 5]. Additionally, comprehensive studies have not yet determined how goal structure and collaboration structure interact to impact system design needs.

In addition to these issues of technical implementation, there are many social issues involved in promoting good collaboration. Krijns et al. note that there are many group qualities that are necessary to ensure that collaboration takes place and is beneficial to all group members [18]:

- Social interaction must be organized and encouraged;
- Groups must have a sense of cohesion and unity;
- Groups must be socially positive, promoting a sense of warmth;
- Communication should be rich and multimodal to simulate natural conversation.

With regard to cooperative collaboration within American classrooms, cultures stressing interpersonal relationships more than Americans, students who speak English as a second language, student income levels, and gender should all be taken into account when forming groups [27]. These issues are difficult to address in typical learning environments that are often ineffective at manipulating group dynamics. Computer learning environments with rich visual and interactive environments, complex social settings and increased group purpose are likely to alleviate many of these issues and provide a means for monitoring and understanding collaborative behaviors. In addition, technology-based learning environments can be especially beneficial for students with poor English skills because they can give students tools to eliminate the language barrier for enhanced student-student collaboration [23]. It is for these reasons that we

propose narrative-centered learning environments as a novel testbed for examining and facilitating collaborative learning.

3. NARRATIVE-CENTERED LEARNING

Narrative-centered learning environments afford unique opportunities for natural collaboration [31]. These types of environments embed educational content within a narrative structure in which the student plays the protagonist in a storyworld with rich settings, characters, and resources. Previous work in developing similar narrative-centered learning environments has shown these types of systems to be effective at promoting learning and engagement [29]. The details of narratives can be adapted to accommodate a particular learning goal, and as character interactions are a common component of narratives, the story's plot itself serves as a natural scaffold for various forms of user-agent collaboration [31]. Multi-user learning environments have successfully developed worlds that permit student-student collaboration via virtual spaces, such as chat boxes [2, 16]. We illustrate our discussion of collaboration within a narrative-centered learning environment with CRYSTAL ISLAND, a narrative-centered learning environment under development in our laboratory.

3.1 CRYSTAL ISLAND: UNCHARTED DISCOVERY

Together with colleagues in our laboratory, we are creating CRYSTAL ISLAND: UNCHARTED DISCOVERY, a narrative-centered learning environment for fifth grade science education (Figure 1). The curriculum underlying the CRYSTAL ISLAND mystery narrative is derived from the state of North Carolina's standard course of study for landforms and ecosystems. Although the overarching goal of this environment is science education, the environment is also intended to support learning strategies such as problem-solving, critical thinking, and metacognitive skill development in an applied setting.

The environment is designed as a supplement to traditional classroom instruction. Students playing CRYSTAL ISLAND take on the role of a gender-matched protagonist who is one of several ship-wrecked passengers stranded on a cluster of volcanic, fictional islands in the Oceania region of the Pacific Ocean. The player character is an adventurous adolescent who enthusiastically takes on problem solving tasks to help sustain the local village, such as working to divert an imminent lava flow from destroying the village. As the plot progresses, the player is introduced to a companion agent who works closely with the student throughout the remainder of the interaction. There are numerous missions and quests players can undertake in a player versus environment fashion (e.g., solving puzzles, exploration) as well as some player versus player competitions (e.g., fastest time to complete a task). The missions serve to advance the storyline and grant access to new areas of the world, while quests provide opportunities for problem-solving and content learning. For example, in one quest, the player is charged with creating a topological map of the village for the other villagers. To succeed, the student must complete various tasks including familiarizing herself with landform types, characteristics, and identification, map scaling, elevation, and map legends. The student can seek council from the village cartographer, local landform experts, and other villagers. The player must submit her map to the village cartographer after which the two reason together about the correctness of the student's work.



Figure 1. CRYSTAL ISLAND: UNCHARTED DISCOVERY

4. NARRATIVE BENEFITS FOR COLLABORATION

The benefits of collaboration for learning are significant, but collaborative learning poses serious challenges as well. Forming effective student dyads or groups while considering abilities and social dynamics can be difficult. Persistently monitoring many groups' productivity is also impractical for a single instructor to manage. However, given the familiar structure of narrative and its common use of various character interactions, it may be possible to promote collaborative learning without the use of formal scaffolds [17]. Moreover, by capitalizing on intelligent narrative technologies (see [22, 25, 33]), non-player characters within the narrative-centered learning environment can be dynamically adapted to effectively accommodate the state of the student. We hypothesize that the use of collaborative narrative centered learning environments can capitalize on the impressive findings of other collaborative learning environments [4, 26] while providing novel mechanisms for exploring and scaffolding student interactions. Below we suggest potential approaches for leveraging the key elements of narrative for this purpose.

4.1 Student-Agent Collaboration

Student-agent collaboration within narrative-centered learning environments involves cooperation between the player and a computer agent (or agents) designed to support the student's progression through the story. Intelligent agents are particularly beneficial as they can adapt to the student's performance, ability level, and interests in order to develop a learning environment within the student's zone of proximal development. Collaborative learning works best when students are paired with individuals of differing abilities [13, 35]. In other words, assessing students' abilities and forming groups that will promote the most beneficial collaboration becomes unnecessary as the system can dynamically adapt to the student based upon theoretically ideal group dynamics. Moreover, analogous to characters in a traditional narrative, computer agents can serve as a resource for the student as conversation with these characters can provide story-related foreshadowing to enhance student motivation and engagement or pertinent content information required to complete sub-goals. *Companion agents*, which are virtual computer agents who perpetually maintain a close relationship with the player, can provide the student with subtle scaffolding or knowledgeable feedback informed by past student behaviors. The role of the agent with respect to the student can play an important part in how collaboration takes place and the effects on student learning and motivation [3]. "Mentor" companion agents can provide insight

and model learning skills, while “apprentice” companion agents can request the student to provide action justification and concept. Lastly, these agents can also be used to reduce social distances by portraying certain characters in non-traditional roles. For example, women or minorities can take on the role of mentors and lead scientists.

4.1.1 Mentor Companion Agents

Mentor companion agents provide guidance as well as delegate responsibility. As with traditional mentors, mentor agents possess a breadth of knowledge that is disseminated to the student within the environment through direct conversation, modeling desirable behaviors or strategies, or subtle prompting. For example, during the map-making quest described above, the cartographer (mentor) first models map-making to the student by explaining the steps for creating a different type of map. Then, the student, under the guidance of the mentor, attempts to create the topological map of the village. During this quest, the cartographer can elicit goal setting by asking the student the specific steps for creating this map, probe the student to justify, reason, and reflect on completed actions, and prompt the student to form a reasonable argument for why the completed map is correct or needs revising. The student thereby learns the subject matter and also applies an appropriate problem-solving technique, develops critical thinking skills, and learns how to form well-constructed arguments, all through natural, narrative-centered conversation.

Through the use of role, mentor agents can also serve as superior figures, such as an occupational supervisor, that require the student to fulfill certain duties. This form of mentor-student collaboration is less intimate as the agent’s interventions are intermittent. Again, subtle student goal monitoring can easily be achieved through this relationship. The superior agent can periodically ask the student to report on her progress towards the overall goal by reporting what has been accomplished and what remains. Moreover, the agent can require the student to complete an investigation form, a form of note-taking. Mentor agents have the ability to help students improve their problem-solving abilities.

In addition to being domain knowledge experts and aiding students with problem-solving skills, mentor agents should also possess social and motivational characteristics that are beneficial to the student. Mentor agents that focus on student motivation in addition to their learning processes have been shown to have positive impacts in both areas as compared to agents who focus on only one aspect of student growth [3]. To this end, mentor agents should form a bond with the student that suggests warmth and nurturing. Mentor agents should encourage students to remain persistent in the face of obstacles and to enjoy the learning process. By incorporating affective and social components to the mentor agent’s role students will receive multifaceted support that is most beneficial to the student.

4.1.2 Apprentice Companion Agents

Apprentice companion agents are virtual characters embedded within the narrative as assistants to the player. These characters can take on many plot-specific roles, and provide a scaffolding mechanism. This character can appear to be curious and captivated by the player’s work and through natural conversation with the player character can inform the adaptive component of the system, share cognitive load, and develop cognitive skills. For example, in interactions with CRYSTAL ISLAND involving landform identification, after the student incorrectly identifies a plateau as a

mountain, the apprentice agent can explicitly ask the student, “Will you indicate to me what characteristics make this a mountain?” Following the student’s response, he might retract his incorrect identification, or give an incorrect explanation.

Collaboration with an apprentice agent is expected to be beneficial to the student in many ways and builds on findings that suggest that group learning is best achieved with students of different cognitive abilities [13, 35] and that teaching others is often an effective means for learning information oneself [19]. First among these benefits is explanation formation. In order to properly assist the apprentice agent, students must engage in active reflection of their own knowledge and the formation of well-constructed arguments that convey this information. These strategies are vital cognitive skills, particularly in the areas of inquiry-based learning. The apprentice agent can also aid the student in refining her arguments and knowledge by prompting when information is incomplete or inconsistent. For instance, the companion agent can reply to the student’s faulty explanation with, “Well, what makes this landform different than a plateau?” Therefore, without the use of explicit scaffolding mechanisms, but rather masked in natural interactions, the environment is able student’s study skills and knowledge base.

An additional benefit from interactions with apprentice agents is expected increases in student self-efficacy and confidence in learning. When paired with an agent of lower cognitive ability, students are likely to feel proud of their own knowledge and be pleased that they are able to disseminate this knowledge to a companion who is not as advanced as themselves. This build in confidence is expected to lead to positive affect, increased motivation to continue with the game and positive attitudes towards learning.

Finally, iterative explanation dialogues with companion agents can be a valuable resource for monitoring student learning and providing intelligent supports. By providing their understanding of the material to the apprentice agent, the student is simultaneously providing artifacts that can be analyzed and used in a variety of ways. Primarily, this feedback will inform future dialogue with the apprentice agent but it also will provide information on how students form arguments, the techniques they use to reason and where they are lacking valuable information. By understanding these aspects of the system, an intelligent learning environment can provide supports to improve upon any areas the student lacks as well as direct and focus learning in directions that will be most beneficial for the student.

4.2 Student-Student Collaboration

Technology-supported student-student collaboration has been shown to yield key learning and social benefits [7, 30, 32] but open problems remain [18]. As noted above, multi-user learning environments can take the form of multiple students on the same computer, multiple students (each with his or her own computer), or virtual collaboration. During virtual collaboration students are not necessarily near one another, but the students are collaborating via their player characters in the virtual world. Within the context of narrative-centered learning environments, student-student collaboration occurs in a similar fashion as student-agent collaboration. Each student player takes on a different, yet equally important, character role. In this case, the CRYSTAL ISLAND narrative would involve a team of adolescents trying to save the village together. Similar to Aronson’s Jigsaw method [1], each player character is assigned a specific role in the narrative,

but it is not until the entire team works together that problems can be solved. Therefore, each student is responsible for teaching the other student's his or her area of assigned expertise. Ultimately, each student is assessed individually on each topic to ensure thorough explanations were elicited. The system can intelligently account for misconceptions or gaps in instruction and scaffold the learning to student to be more comprehensive. Beyond the jigsaw method's learning benefits, it offers several social benefits as well when incorporated within a narrative-centered learning environment. One of the primary challenges for cooperative collaboration is forming socially positive groups, but unfortunately, this can be a difficult task. However, when students are assigned to roles and virtual characters, they take on a different persona, perhaps eliminating some real-world classroom social differences.

For example, in CRYSTAL ISLAND, each student's character is assigned the role of a particular landform expert (i.e., river expert). From there, the student explores the island and acquires as much information about his or her particular landform. Finally, the group comes together and shares their information with each of the other students through a virtual collaborative workspace. In this situation, similar to student-agent collaboration, the student serves as both the mentor and the apprentice agent, and the narrative itself naturally scaffolds communication between the other players.

While these environments have several benefits, there are also pitfalls including off-task conversation and behaviors. However, the use of narrative can mitigate some of these problems. In fact, recent work has shown that off-task behavior in narrative-centered learning environments has little to no effect on overall learning gains [28], perhaps because students may be utilizing the rich features of the environment to disengage from learning activities at situationally appropriate times, then reengage when they are ready to resume learning. In the context of collaboration, these behaviors may provide additional social benefits for increasing group cohesion.

5. CONCLUSION

Collaboration has shown great promise in both classroom and computer environments. Support for this paradigm is widespread and includes improvements at the affective level (e.g., motivation and interest), the educational level (e.g., deeper explanations and better hypothesis development and testing), and at the social level (e.g., promoting classroom equity). While these findings indicate the potential benefits of collaborative environments, achieving these goals poses significant challenges. Among these are determining the best forms of interaction, fostering positive social environments and providing adaptive scaffolding to promote positive interactions. Narrative-centered learning environments provide an effective "laboratory" for observing and understanding collaborative behaviors in computer learning environments. We hope that by exploring many different approaches for effectively embedding cooperative behaviors, we may gain a better understanding of how to use collaboration to reach maximum learning, affective and social improvements.

While we have identified several promising approaches to studying and incorporating collaborative behavior in narrative-centered learning environments, there are still many areas of future work that must be explored. First, empirically investigating different levels of student-student collaboration will be an important step in informing the design of narrative-centered

learning environments. It will be useful to examine how collaborative behavior occurs naturally, compare different group demographics and settings, and discover the tools that promote collaborative learning. Next, developing the tools to analyze these interactions and interpret their implications will be important for developing intelligent agents that can serve as mentor or peer collaborators in virtual environments or formulating a model of collaborative behavior for the purpose of providing adaptive support to the student collaborators. Finally, integrating and testing these models and intelligent agents will be critical in iteratively refining narrative-centered learning environments. It is hoped that this line of investigation will yield new insight into collaborative learning that will serve as the foundation for a new generation of collaborative learning technologies.

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Both authors of this paper are new investigators in an advanced degree program and are within three years of receiving their last degree.

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