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Proposing a Collaborative Multi-agents System for English Learning Support

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Abstract: Collaborative learning has been as advocated as a promising approach for stimulating higher achievement among learners. However, its benefits can only be maximized in active and cooperative teams. In this paper, we propose a collaborative English learning environment where the learner teams up with two computer-driven agents. In the proposed system, depending on the learning stage, learners and agents fulfil different roles, thereby offering learners the opportunity to not only observe but also teach and get taught by agents in a collaborative fashion. We conducted a preliminary evaluation experiment of the proposed system, and obtained results tend to confirm the meaningfulness of the proposed approach for enhancing learners' engagement towards learning.

Keywords: Learning by teaching, Teachable agent, Collaborative learning, English learning

1. Introduction

Collaborative learning is widely recognized as an effective educational approach. Its benefits have been investigated from various perspectives (Laal et al., 2012), and its learning effects are fostered through cooperative interactions among learners. However, some difficulties, such as learners' recruitment and cooperative relationships building, often arise and prevent achieving effective collaborative learning (Le, 2018). Therefore, there have been several efforts to propose computer-mediated collaborative learning involving computer driven peer agents and learners.

For instance, Teachable Agents (TA) are a typical example of pedagogical agents that aim at interacting in a collaborative fashion with learners. TA are designed to provide learning by teaching opportunities to learners (Blair et al., 2007; Brophy, 1999). Learner's act as a tutor and provide knowledge to the TA; the TA, on the other hand, demonstrates the task based on the knowledge given by the learner. It has been shown that learners are influenced by the protégé effect in their interactions with the TA, given that the protégé effect has the effect of increasing learners' motivation (Chase et al., 2009).

Nevertheless, although TA can be effective in helping learners demonstrate and deepen their understanding of previously learned contents, such agents are not necessarily intended to provide new knowledge to learners, as a tutor agent would do for example. Therefore, our idea is to propose a collaborative learning environment where the learner teams up with two computer-driven agents. One agent is more knowledgeable than the learner and provides new knowledge to the learner. In the other hand, the second agent has less knowledge than the learner and is designed to behave like a teachable agent. In other terms, the proposed learning environment embed both a tutor agent and a teachable agent, thereby providing learners opportunity to both acquire new knowledge and demonstrate such knowledge in a collaborative fashion.

In addition, to the extent of fueling within team interactions, we introduce a new learning method which allow the learner and the agents to play different roles while carrying out picture description task in English. The method provides a step-by-step learning process for the learner by rotating the roles of the learner and the agents according to the learner's progress. The act of rotating roles is consistent with effective collaborative learning group behavior (Dillenbourg, 1999). This also offers the learner the possibility to observe the agents from different perspectives.

2. Proposed System

2.1 Collaborative Learning Environment with Multiple Agents

In the proposed collaborative learning environment, we refer to the tutor agent (i.e., more knowledgeable) agent as the Superior Agent. The Superior Agent has more knowledge than the learner and is responsible for providing tutoring content to the learner. The Superior Agent selects and presents the learner with new learning contents and provide feedback as necessary. The other agent is called the Inferior Agent. This agent has less knowledge than the learner and is responsible to provide learner the opportunity to teach or demonstrate acquired knowledge.

In this learning environment, the learner learns new knowledge by interacting with a Superior Agent. The learner can then teach the learned knowledge to the Inferior Agent. The inferior agent grows according to the knowledge it learns from the learner. Therefore, the learner is at the heart of the learning interaction and has the role of transferring the knowledge held by the superior agent to the inferior agent. The goal of this learning environment is for the learner and inferior agent to acquire more knowledge and take on more advanced tasks.

2.2 Picture Description Task based English Grammar Learning

Picture description task is an effective way to learn a foreign language (Albino, 2017). Learners are presented with a picture and asked to describe it. Learners describe the picture using as much vocabulary and grammar rules as they know.

Our proposed system provides game-style learning based on a scene description task involving three roles: Game Master, Describer and Illustrator. As mentioned earlier, the system features two agents and a learner, and they progressively switch roles as the interaction evolves. At the beginning of the game, the screen shown in Figure 1 is displayed. The first player, called the Game Master (GM) is responsible for crafting the scene to be described. To such extent, the GM is prompted to click on any of the red buttons appearing on the screen. Upon clicking, a list of objects is presented. Then, the GM selects one of the objects and the corresponding object is displayed at the position of the selected red button. The GM may add more objects to the scene according to the instructions.

When the GM's task is completed, the interface shown in Figure 2 is displayed. This interface also shows the scene previously created by the GM on the top-hand side of the window. Here, the second player, the Describer, is prompted to observe the displayed scene and describes its contents. At the bottom of the interface, buttons with 6 types of parts of speech are placed. By pressing each of these buttons, the Describer is presented with a list of words belonging to each category. Upon selection of a given word, it appears on the text box placed on the center of the screen.

After the Describer's task is completed, the interface shown in Figure 3 is displayed. The text written by the Describer is displayed at the bottom of the screen. Then, the third player, the Illustrator, reads the text and tries to reproduce the scene described by the Describer. Note that here, the operation of the interface is similar to Figure 1.

When the Illustrator's task is completed, the interface shown in Figure 4 is presented to the learner. The picture created by the GM is displayed in the upper left corner of this screen. In the upper right corner, a picture created by the Illustrator is displayed. The text written by the Describer appears at the bottom of the two pictures. This review interface is used by the GM to provide feedbacks to the Describer, and by the Describer to evaluate the Illustrator.

The proposed learning system is considered to have learning effects from three perspectives. The first perspective is the learning effect of the role task. The Describer is given the task of faithfully describing the picture created by the GM in English. Therefore, by taking on the role of Describer, learners improve their ability to describe what they see through writing. The Illustrator is given the task of reading the English text created by the Describer and reproducing it in picture. Therefore, by taking on the role of the Illustrator, learners improve their ability to read and understand the text correctly. The GM is given the task of generating meaningful scenes according to the instructions. Therefore, by taking on the GM role, learners are given the opportunity to think about the picture description task in a structured manner.

The second perspective is the learning effect of collaborative learning. In the proposed system, the goal is for the Illustrator to reproduce the scene originally created by the GM. Hence, success of this task is bound to both the Describer's writing skills and the Illustrator's reading skills. Learners need to provide appropriate feedbacks to other players as they play the roles of GM and Describer. The GM, for instance should adjust the difficulty of the scene to help the Describer or Illustrator learn advanced

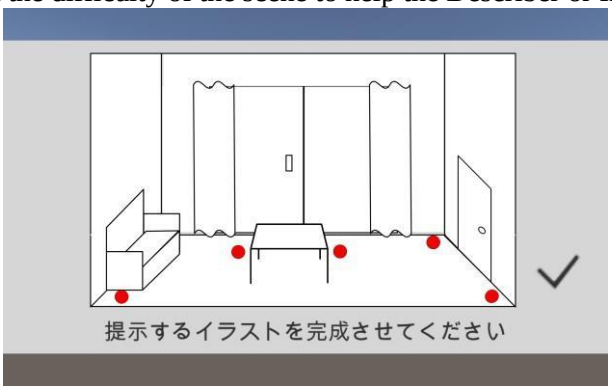

Figure 1. Game Master's Interface

Figure 2. Describer's Interface

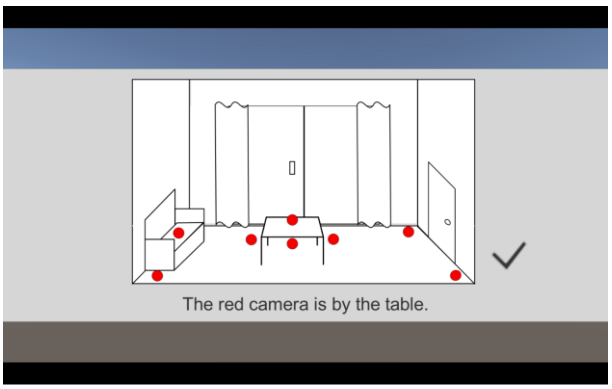

Figure 3. Illustrator's Interface

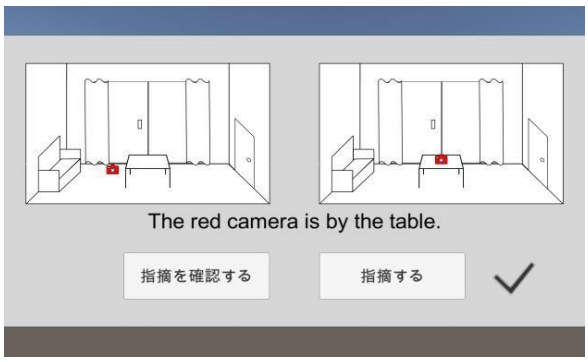

Figure 4. Review Screen

expressions. The GM also needs to keep track of the learning progress of other players in order to provide them with description tasks of appropriate difficulty. Therefore, the learner needs to deeply observe the results of tasks performed by other players.

The third perspective is cognitive apprenticeship-based learning and teaching. Learner and agents can learn and teach based on cognitive apprenticeship by rotating their roles. Cognitive apprenticeship is a method that allows traditional apprenticeship to be applied to education (Collins et al., 1991). The core processes of this model are Modeling, Coaching, and Scaffolding. Modeling is when the expert performs a task and allows the student to observe how it is done. Coaching is the intervention by the expert to help the student execute the same performance as the expert. Scaffolding is the expert helping the student perform the task.

Learner and agents switch roles in three phases. In the first phase, the learner plays the role of Illustrator, the Inferior Agent is the GM, and the Superior Agent is the Describer. In the second phase, the learner plays the role of Describer, the Superior Agent plays the GM, and the Inferior Agent plays the Illustrator. In the third phase, the learner plays GM, the inferior agent plays Describer, and the superior agent plays Illustrator. Each phase is completed when the Illustrator is able to reproduce the GM's illustration.

These three phases are intended to reproduce an expert-student relationship from the standpoint of Cognitive Apprenticeship, as far as the Superior Agent-Learner and the Learner-Inferior Agent interactions are concerned. First of all, in the first phase (i.e., learner: Illustrator, Inferior Agent: GM, and Superior Agent: Describer.), the system controls the Inferior Agent to present the Superior Agent with a picture description task that requires knowledge about the learner's unmastered domain. Here, the Superior Agent performs Modeling for the learner by providing correct responses to the task. Next, In the first half of the second phase (i.e., learner: Describer, Superior Agent: GM, and Inferior Agent: Illustrator.), the Superior Agent presents the learner with a picture description task that requires knowledge of the same domain as the task in the first phase. At this time, the Superior Agent provides Coaching through feedback and Scaffolding through hints. By the end of the second phase, the learner is expected to have mastered the domain knowledge if he/she is able to provide a correct answer. Learner's correct answers at this point of the interaction serve as Modeling to the Inferior Agent. Finally, in the third phase (learner: GM, Inferior Agent: Describer, and Superior Agent: Illustrator), the learner coaches and scaffolds the inferior agent, thereby fostering the mastering of learned contents by the Inferior Agent.

3. Pilot Study

3.1 Outlines

To the extent of investigating the meaningfulness of the proposed system, we carried out a preliminary pilot evaluation of the system in which subjects experienced the process of learning English prepositions (i.e., in, on, under, beneath, etc) using a prototype system. The prototype system was developed using Unity, a game development engine. Participants were 10 male and female students attending a Japanese university. Subjects experienced various situations that could possibly occur when interacting with agents in the system, through three phases. In Phase 1 and Phase 2, subjects were instructed to purposefully provide an incorrect response and later to provide the correct response after being pointed out by the Superior Agent. In Phase 2 and Phase 3, the inferior agent was set to give an incorrect response and the subject was instructed to point it out.

Note that the prototype system used in this experiment does not embed the function to adjust the difficulty of the task according to the subject's knowledge. Therefore, in order to minimize differences in subjects' knowledge, we explained to them that they should operate the system under the assumption that they were currently studying prepositions.

Table 1 shows the questionnaire items used in the evaluation experiment. The questionnaire items were rated on a 5-point Likert scale going from agree / slightly agree / neither / slightly disagree to disagree. In addition, a free-writing section was also included so as to collect subjects' opinions on the system.

Table 1. *Questionnaire Items*

Number	Question
Q1	Was the system easy to use?
Q2	Was the task difficulty level appropriate?
Q3	Was the task you worked on enjoyable?
Q4	Would you like to use this system in the future for learning English grammar?

3.2 Results and Discussions

From the results of the questionnaire, we discuss whether the use of the proposed system for learning English is meaningful for learners. The questionnaire results are shown in Figures 5-8.

Q1 asks about the usability of the system. We found that all subjects answered "agree" or "slightly agree". In this experiment, only the operating procedure was explained orally, but all subjects were able to perform the task. Therefore, our system has an intuitive UI design that can be operated by many people. In the free-writing section, some subjects responded that they would like a function to return to the previous screen when they made a mistake. This suggests that the reason why 90% of the subjects answered "slightly agree" instead of "agree" was because there were some minor aspects of the system interface that could be improved.

Q2 and Q3 ask whether the tasks performed in the proposed learning system provide a good learning experience for the learners. We found that 80% of subjects responded "agree" or "slightly agree" to Q2, and all subjects responded "agree" or "slightly agree" to Q3. This result suggests that the proposed system gives learners a satisfactory learning experience. In the free-writing section, one subject responded, *"I enjoyed visual learning of English in the game".* This suggests that the proposed system can provide learners with a more sensory and enjoyable learning experience than conventional learning methods using textbooks.

Q4 asks about their motivation for using the proposal system. We found that 80% of the subjects responded "agree" or "slightly agree". This result indicates that many subjects are motivated to use the system. This suggests that learners can learn more actively by using the proposed system.
In the free-writing section, we received comments such as *"I felt that being aware of what I was doing now would enhance my learning"*. On the other hand, one subject commented, *"I found it difficult to know my role and what I was supposed to do,"* and *"I felt the system should indicate who wrote the pictures and text".* Therefore, it was suggested that posting information on the UI, such as the user's role and the actions currently required, could enhance learning effectiveness by increasing the learner's awareness of their role during the scene description task.

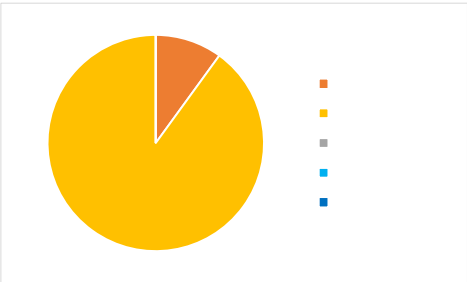

Figure 5. Q1 Questionnaire Results

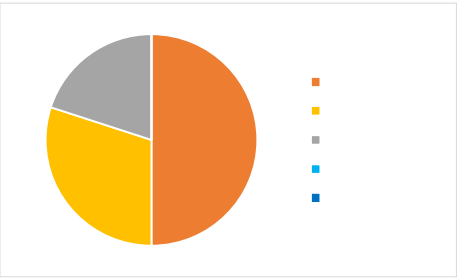

Figure 6. Q2 Questionnaire Results

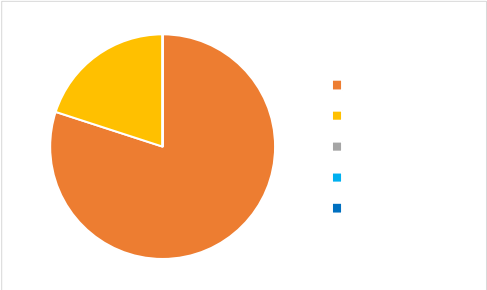

Figure 7. Q3 Questionnaire Results

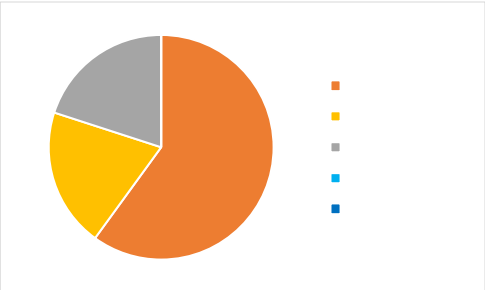

Figure 8. Q4 Questionnaire Results

4. Conclusion

Collaborative learning has been as advocated as a promising approach for stimulating higher achievement among learners. However, its benefits can only be achieved in active and cooperative teams. In this study, we proposed a collaborative learning support system in which the learner and two computer driven agents with different abilities, perform picture description tasks while fulfilling different roles. Moreover, roles are progressively rotated so that the learner cannot only observe, but also learn from and teach the agents depending on their role. We then, carried out an experimental evaluation to evaluate the system's usability and meaningfulness. We found that the proposed system provides an intuitive and enjoyable learning experience to learners. We also found that there is still room for improvements as far as the UI and interaction design is concerned. The relatively small number of subjects during the pilot evaluation is also a limitation that we acknowledge.

Future works will be dedicated to tackle the above issues and also devise a method for dynamically generating scene description tasks based on learner's knowledge. We will also work on improving the feedbacks presented to learners throughout the interactions. In addition, a formal study with pre-testing and post-testing should be conducted using the completed system.

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