Take the Initiative: Mixed Initiative Dialogue Policies for Pedagogical Agents in Game-Based Learning Environments

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Abstract. Pedagogical agents have been shown to be highly effective for supporting learning in a broad range of contexts, including game-based learning. However, there are key open questions around how to design dialogue policies for pedagogical agents that support students in game-based learning environments. This paper reports on a study to investigate two different agent dialogue policies with regard to conversational initiative, a core consideration in dialogue system design. In the User Initiative policy, only the student could initiate conversations with the agent, while in the Mixed Initiative policy, both the agent and the student could initiate conversations. In a study with 67 college students, results showed that the Mixed Initiative policy not only promoted more conversation, but also better supported the goals of the game-based learning environment by fostering exploration, yielding better performance on in-game assessments, and creating higher student engagement.

Keywords: Pedagogical Agents · Game-based Learning · Initiative.

1 Introduction

Pedagogical agents have shown great promise for supporting learning in a wide range of domains including literacy [9], mathematics [10], and science [3]. Recent years have seen advances in virtual agents that are capable of conducting multi-party dialogues [2], generating and understanding emotion [4, 5], and producing and interpreting body language [1]. However, previous work has not considered the effects of dialogue initiative policy for pedagogical agents in environments where the conversation is not the central activity. Initiative policy plays a crucial role in defining a pedagogical agent's interaction with students. As defined by Jurafsky and colleagues, the participant who controls the flow of a conversation (through actions such as seeking information or changing the topic) has the initiative [7]. Dialogue systems typically use one of three policies for handling initiative: system initiative, user initiative, or mixed initiative. A system-initiative

policy gives the system the responsibility for controlling and directing the conversation, whereas user-initiative systems support a conversation that the user directs and controls. A mixed-initiative policy combines these approaches: the user can control the topic or direction of the conversation, while the system is responsible for clarifying and asking questions to advance the conversation or complete a task.

2 Conversational Pedagogical Agent

The pedagogical agent that is the focus of this paper (Figure 1) is accessible to students at any time during their gameplay through an in-game smartphone interface. The game-based learning environment, Crystal Island, is an open world with many possible paths for students to take while completing the game. However, it is essential that students explore the game world and gather information, forming and testing hypotheses as they progress. More details about Crystal Island and the agent implementation can be found in prior work [11]. The pedagogical agent, Alisha, plays the role of a virtual assistant from the Center for Disease Control (CDC), the United States' health protection agency. Before describing the architecture of the agent, we first review the context into which she is integrated.

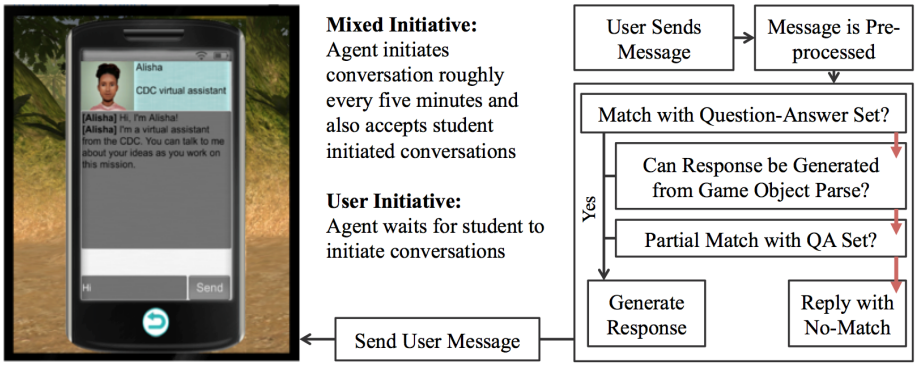

Fig. 1. Pedagogical agent's dialogue system design (The thick red arrows represent the flow if the condition is not met).

We developed two versions of the pedagogical agent, a Mixed Initiative version in which the agent starts a conversation with the student every five minutes during their gameplay session, and a User Initiative version in which the agent never initiates the conversation. The user can initiate conversation at any time in both conditions, and the agent and user can communicate with one another regardless of the player's location in the physical space of the game world.

3 User Study and Results

This study took place at a large land-grant university in the southeastern United States. Students were recruited from two introductory computer science courses offered by the college in which they would receive extra credit for participating in a research study. Of the 67 students, 34 were assigned to the Mixed Initiative condition and 33 to the User Initiative condition.

After an hour of gameplay, surveys were used to assess self-reported engagement with the game [8], student experience with the pedagogical agent, and overall student affective experience [6]. A content knowledge post-test (identical to the pre-test) was administered upon the completion of the gameplay session.

Table 1. Students' Gameplay Differences ($* : p < 0.05; ** : p < 0.01$)

		Mixed Init.	User Init.	p-value
Agent Interaction	**Student Utterances**	**21.59**	10.48	0.0004**
	Student Words	**81.73**	48.12	0.0039**
Gameplay	**NPC Conversations**	**88.7**	64.3	< 0.0001**
	Number of Books Read	8.62	7.09	0.0683
	Book Questions Missed	4.97	**6.75**	0.0344*
Student Outcomes	Normalized Learning Gain	0.26	0.21	0.4904
	User Engagement	**3.97**	3.59	0.0189*
	Frustration	26.6	30.0	0.5408

As shown in Table 1, the Mixed Initiative condition's students have significantly more conversations with students interacted with non-player characters (NPCs), a valuable source of information, but there are no significant differences in the number of books read or tests for contaminated objects. However, students missed significantly fewer questions in the embedded assessments given in the Mixed Initiative condition.

After an hour of gameplay, the students completed the post-test and surveys. We hypothesized that there would be differences in the cognitive and affective outcomes of the sessions because of the differences in the conditions. Table 1 displays the differences between the normalized learning gain, user engagement, and frustration that the students experienced during their gameplay. The students in the Mixed Initiative condition had higher engagement with no significant differences in learning or frustration scores.

4 Discussion and Conclusion

There are significant differences in dialogue, gameplay, and outcomes across the two dialogue conditions. First, we observed more user utterances and more total words typed by students in the Mixed Initiative condition. This result is perhaps an expected artifact of the design difference in dialogue policy, since in the

Mixed Initiative condition the agent initiated more conversations (μ=33.06 versus μ=14.12), and we would expect to see students respond accordingly. As for differences in gameplay, NPCs more frequently in the Mixed Initiative condition. This is likely because the agent, upon reaching out to the student, would often advise students to seek out NPCs who have essential information for the learning task. The significant difference observed in NPC interactions suggests that students took the pedagogical agent's advice even if they had not specifically solicited it. Another gameplay difference observed between conditions is that students missed fewer questions on in-game reading assessments in the Mixed Initiative condition. It is possible that while interacting more with NPCs, students gained additional content knowledge needed to succeed on the in-game assessments. Rather than just reading the content in the books, the content was also reinforced by the NPCs. Another possibility is that in the Mixed Initiative condition, students were more aware of the pedagogical agents' presence, which may have led to an increased feeling of accountability on the reading tasks and assessments.

Finally, we observed significantly increased self-reported engagement in the Mixed Initiative condition. This increased end-of-game engagement is a promising benefit of the Mixed Initiative condition, as we did not see a significant trade-off with learning gains or increased frustration. This increased engagement may also be a reason for higher conversation levels and interaction with NPCs in the Mixed Initiative condition. The frustration scale and user engagement survey (UES) both include items that measure perceived cognitive load, and the results point to no significant increase in load for the Mixed Initiative policy. We believe that when the agent was taking the initiative, students valued the agent's input more highly and followed the advice more promptly. The Mixed Initiative condition removes some burden from students, providing help incrementally and potentially redirecting disengaged students back onto a productive track, resulting in a greater sense of engagement with the system.

Pedagogical agents hold significant promise for supporting learning and affective outcomes, especially in open learning environments in which students are determining their trajectories through the experience. However, pedagogical agents can become distractions in complex learning environments with learning goals beyond the student-agent interaction. A critical component in facilitating effective agent-student interactions lies in how the agent initiates conversation with the student. In this paper, we reported on a study that investigated the effects of pedagogical agents using different initiative policies in game-based learning. We found that when pedagogical agents utilized a mixed initiative policy, in which both the student and the agent could initiate conversations, the interaction promoted not only more conversation, but also yielded productive in-game behaviors and increased user engagement without increased frustration.

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References

1. Abdullah, A., Adil, M., Rosenbaum, L., Clemmons, M., Shah, M., Abrahamson, D., Neff, M.: Pedagogical agents to support embodied, discovery-based learning. In: International Conference on Intelligent Virtual Agents. pp. 1–14. Springer (2017)
2. Al Moubayed, S., Lehman, J.: Regulating turn-taking in multi-child spoken interaction. In: International Conference on Intelligent Virtual Agents. pp. 363–374. Springer (2015)
3. Borjigin, A., Miao, C., Lim, S.F., Li, S., Shen, Z.: Teachable agents with intrinsic motivation. In: International Conference on Artificial Intelligence in Education. pp. 34–43. Springer (2015)
4. D'mello, S., Graesser, A.: Autotutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. ACM Transactions on Interactive Intelligent Systems (TiiS) **2**(4), 23 (2012)
5. Girard, S., Chavez-Echeagaray, M.E., Gonzalez-Sanchez, J., Hidalgo-Pontet, Y., Zhang, L., Burleson, W., VanLehn, K.: Defining the behavior of an affective learning companion in the affective meta-tutor project. In: International Conference on Artificial Intelligence in Education. pp. 21–30. Springer (2013)
6. Hart, S.G., Staveland, L.E.: Development of nasa-tlx (task load index): Results of empirical and theoretical research. In: Advances in psychology, vol. 52, pp. 139–183. Elsevier (1988)
7. Jurafsky, D., Martin, J.: Dialog systems and chatbots. Speech and language processing (2017)
8. O'Brien, H.L., Toms, E.G.: The development and evaluation of a survey to measure user engagement. Journal of the American Society for Information Science and Technology **61**(1), 50–69 (2010)
9. Panaite, M., Dascalu, M., Johnson, A., Balyan, R., Dai, J., McNamara, D.S., Trausan-Matu, S.: Bring it on! challenges encountered while building a comprehensive tutoring system using readerbench. In: International Conference on Artificial Intelligence in Education. pp. 409–419. Springer (2018)
10. Ternblad, E.M., Haake, M., Anderberg, E., Gulz, A.: Do preschoolers 'game the system'? a case study of children's intelligent (mis) use of a teachable agent based play & learn game in mathematics. In: International Conference on Artificial Intelligence in Education. pp. 557–569. Springer (2018)
11. Wiggins, J.B., Kulkarni, M., Min, W., Boyer, K.E., Mott, B., Wiebe, E., Lester, J.: User affect and no-match dialogue scenarios: An analysis of facial expression. In: Proceedings of the 4th International Workshop on Multimodal Analyses Enabling Artificial Agents in Human-Machine Interaction. pp. 6–14. ACM (2018)