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When educational agents meet surrogate competition: Impacts of competitive educational agents on students' motivation and performance

Zhi-Hong Chen [a,*], Sherry Y. Chen [b]

[a] Department of Information Communication, Yuan Ze University, Taiwan
[b] Graduate Institute of Network Learning Technology, National Central University, Taiwan

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ABSTRACT

The design of educational agents increasingly attracts researchers' attention recently. One of major reasons is that educational agents could enhance student learning in various aspects. Although research in this area has mushroomed, such research mainly emphasizes on students in higher education. It is still unclear how educational agents influence young student learning. In addition, competition is a significant element, but fewer studies take competition into account while designing educational agents. Although some studies have indicated that educational agents in competitive environments has positive effects on students' perception and attribution, its impacts on students' motivation and performance are unclear. Thus, the study develops an integrative agent that combines educational and competitive elements for young students, and further examines its influences, in terms of motivation and learning performance. The results revealed that such competitive educational agents could enhance students' motivation and learning performance.

1. Introduction

Educational agents refer to computer-simulated characters that interact with students for enriching their individual learning by acting as social participants (Chou, Chan, & Lin, 2003). In recent decades, the development of educational agents has attracted increasing researchers' interests. Two possible reasons might explain this situation. The first reason is that *advanced multimedia technology* facilitates the development of educational agents to behave as what human do. For example, animated techniques could endow educational agents with human's body language, such as nodding, eye-gazing, and gestures to convey instructional information (Johnson, Rickel, & Lester, 2000).

The second reason is that such educational agents can bring a number of *learning benefits*, such as exploration (Höök, Persson, & Sjölinder, 2000), reflection and articulation (Goodman, Soller, Linton, & Gaimari, 1998; Tholander, Karlgren, Rutz, Johannesson, & Ramberg, 1999), communication (Lester et al., 1997), and negotiation (Bull, 2004). These learning benefits have great cognitive impacts on the development of educational agents. In addition to cognitive impacts, the development of educational agents should also consider its affective impacts on students' motivation (Wolf, 2009). This is due to the fact that improving students' learning performance is not good enough to attract them to interact with the educational agents (Barnard & Sandberg, 1996; Bull, 2004; Kay, 1995). Thus, there is a need to provide them with engaging and joyful learning experience, which could positively promote students' affective perception so that their cognitive impacts can also be promoted.

Due to such significance, a number of studies (Baylor & Kim, 2003; Baylor, Shen, & Huang, 2003; Gulz, 2004, 2005) examined this issue. Nevertheless, most of them emphasize on the design of educational agents for students in higher education, ignoring the needs of young students. On the other hand, competition recently has been regarded as useful strategies to enhance students' participatory motivation. However, fewer studies consider integrative agents, which combine educational and competitive elements. Unlike the roles of "tutor", "tutee", or "companion" identified in previous works (e.g., Chou et al., 2003), such integrative agents play as intermediates between each

* Corresponding author. Tel.: +886 3 463 8800 2641; fax: +886 3 463 8277.
E-mail addresses: zhchen@saturn.yzu.edu.tw, hon@cl.ncu.edu.tw (Z.-H. Chen).

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student. For instance, educational agents could serve as "surrogates" (i.e., on-screen characters on behalf of the students) to facilitate students' interaction. Although such surrogate competition has positive effects on students' perception (Chen, Chou, Biswas, & Chan, 2012) and attribution (Chen & Chen, 2013), its impacts on students' motivation and performance are unclear. Thus, it is essential to address this issue. In short, two issues are neglected by previous studies. One is that young students are paid less attention while the other is that the impacts on students' motivation and performance are unknown.

In this vein, we develop an Edu-Pet system, which combine competitive element and educational agents. The development of such integrative agents contributes to the application of educational agents. To this end, two research questions are examined in this study: (1) *How is an integrative agent developed with competitive and educational elements? and* (2) *What are the impacts of competitive educational agents on young students' learning in terms of motivation and learning performance?*

We begin this paper by reviewing related work about the design of educational agents from social, cognitive, and affective aspects as well as surrogate competition. The development of a competitive learning system, Edu-Pet, with competitive educational agents is presented next, and then we proceed to discuss an empirical study on the influences of the system. Subsequently, the findings of the empirical study are discussed and the conclusions are made to respond to the research questions.

2. Literature review

2.1. Educational agent

Educational agents simulate *human-like characteristics*, which are designed to improve *students' learning* in individual environments through *virtual participants* (Chou et al., 2003). This definition covers three aspects: social, cognitive, and affective aspects. This is due to the fact that *human-like characteristics* are associated with the affective aspect, *students' learning* is related the cognitive aspect, and *virtual participants* are linked with the social aspect.

Among the three aspects, the social aspect of educational agents is a basic consideration because students' performance could be improved by social interactions (Vygotsky, 1978). If educational agents can provide such social interactions, these educational agents, in a sense, create a social context that is beneficial to student learning. Owing to such significance, there is a need to explore how educational agents could support social interaction by playing different educational roles, such as authoritative tutors with expert knowledge (Wolf, 2009), learning companions with similar novice knowledge (Chan, 1996), and teachable agents with less knowledge (Biswas, Leelawong, & Schwartz, 2005).

In terms of the *cognitive aspect*, the ultimate goal of educational agents is to improve students' learning performance. One-to-one tutoring is one of effective pedagogical approaches to improve students' learning performance (Bloom, 1984). Within one-to-one tutoring, educational agents play as a tutor to interact with students because they can mimic the knowledge of human tutors. For example, one-to-one tutoring systems are applied in different subject domains, such as AutoTutor in Newtonian physics (Graesser et al., 2008), and SQL-Tutor in query language of database (Mitrovic, 2003).

In terms of the affective aspect, the more we can understand students, the more we can adapt systems to students. de Vicente and Pain (2002, 2003) and Gulz (2004) found that educational agents have potentially positive effects on student learning when motivational tactics are considered. In other words, there is also a need to detect students' motivational state (del Soldato's work, 1994). To this end, various approaches are applied to enhance students' motivation by different approaches, such as virtual appearance (e.g., Groom, Nass, Chen, Nielsen, & Scarborough, 2009), persona (McQuiggan & Lester, 2007), and attachment (Chen, 2012). Although such previous works revealed some potential values, they merely focused on the affective and cognitive aspects, seldom describing the social aspect, especially in a competitive learning environment.

2.2. Surrogate competition

In competitive learning environments, competitive elements are incorporated into activity structure to enhance learning goals. Based on the activity structure, competitive environments can be categorized as *direct competition* and *surrogate competition* (Chen et al., 2012). The former is about competition where individual students are directly involved in a face-to-face context. For example, the Teams Games Tournament (TGT) allows group students to work together to compete against other groups (Slavin, 1990).

In contrast, the latter provides students with virtual "surrogates" (i.e., on-screen characters) to compete against others. Various forms of surrogates have different impacts on student learning. For example, the avatar-styled surrogates have been shown to enhance students' sense of success when compared with the name-styled surrogates (Chen et al., 2012). This might be due to the fact that embodied avatars can visualize where students go and what students do, which further enhance their feeling and experience. On the other hand, pet attachment plays an important role in children's lives (Kusahara, 2000; Melson, 2001). Thus, pet-styled agents have potential value in educational applications (Chen & Chen, 2013; Chen et al., 2012).

Furthermore, competition, on one hand, is regarded as a useful factor to motivate students to learn (Yu & Liu, 2009). On the other hand, competition might have negative effects on students' confidence and learning development (Stapesl & Koomen, 2005). This is due to the fact that competition involves social comparisons, where students are exposed to a number of negative and comparative information. Consequently, the competitive element should be carefully used. Nevertheless, it is still unclear the impacts of such competitive educational agents on students' motivation and learning performance. Therefore, there is a need to investigate this issue.

3. System development: Edu-Pet

To address the first research question, we develop an Edu-Pet system, where each student learns with a virtual pet named as My-Pet, and also uses the My-Pet as a surrogate to compete against others.