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Promoting science learning in game-based learning with question prompts and feedback

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A B S T R A C T

The purpose of this study was to examine the effects of the types of question prompts (Knowledge vs. Application Prompts) and feedback types (Knowledge of Correct Response (KCR) vs. Elaborated Response (ER) on science learning outcomes in a game-based learning environment. One hundred and five students from a secondary school in Taiwan were randomly assigned into four conditions: Knowledge-KCR, Knowledge-ER, Application-KCR, and Application-ER in a game-based learning environment to learn the concepts of force and motion. The results suggested that students with the knowledge prompts out-performed students with application prompts. In addition, we found that the types of question prompts and the types of feedback had an interaction effect on students' learning. Specifically, students with ER feedback performed better than those with KCR feedback when knowledge prompts were given; however, students with KCR feedback performed better than those with ER feedback when application prompts were given.

1. Introduction

Although game-based learning (GBL) have received a lot of attention in education, the effectiveness of games on learning is still unclear. Some educational researchers support the use of educational games, (e.g., Tüzün, Yilmaz-Soylu, Karakus, Inal, & Kızılkaya, 2009), but others argue that game-based learning environments may not allow enough articulation and reflection on the target content knowledge for learning purposes (e.g., van der Meij, Albers, & Leemkuil, 2011). In a meta-analysis of GBL, Young et al. (2012) found inconsistent findings in GBL research in the context of science education. Some of the studies found that games had significant impacts on science learning, while some studies found insignificant relationships between GBL and science learning. They argued that the disconnection between games and actual science leads to those non-significant results. Therefore, it is important to include scaffold in educational games to encourage students to reflect on the content knowledge and bridge the knowledge between the game and real life (Young et al., 2012).

Young's conclusion of inclusion of scaffold in GBL is confirmed by other meta-analyses of GBL. For example, Ke (2009) suggested that instructional support features are necessary to foster learning in game-based learning environments; otherwise, learners will focus on the game, but not the knowledge to be learned through gameplays. Wouters, van Nimwegen, van Oostendorp, and van der Spek (2013) also found that games are more effective when they were supplemented with other

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instructions. They argued additional instructions in games including explicit practices could enable learners to articulate their knowledge. As a result, gamers would be able to integrate new knowledge with their prior knowledge. In another meta-analysis of instructional games, Sitzmann (2011) also found similar results that supplemental instructional methods could increase the learning effects of simulation games.

Recently, Barzilai and Blau (2014) examined the effect of external scaffold on game-based learning. In their study, students were provided two different types of external scaffolds. First, external study units (outside of the game) that explained the key underlying concepts of the game were given. Moreover, students were also provided the mathematical formula of relationships among the variables. They found that external scaffolds which were provided after the gameplay reduced perceived learning, and the learning outcomes of the groups with question prompts after gameplay was not significantly different from the control groups. Their study suggested that providing external scaffold such as question prompts in a GBL environment may or may not necessarily work. In order to strengthen the effects of external scaffolds, in the current study, we provided two types of question prompts and two types of feedback within question prompts to examine the effect of question prompts and feedback on science learning in a GBL environment.

1.1. Question prompts in GBL

Scaffolds embedded in games, such as cues and in-game feedback, have been found to be frequently used in GBL literature (Ke, 2016). Besides in-game scaffolds, external scaffolds, such as concept maps and classroom discussion outside of the game, have also been used to connect the game with the underlying knowledge of the game (e.g., Neulight, Kafai, Kao, Foley, & Galas, 2006; Peters and Vissers, 2004). One type of external scaffolds in GBL is question prompts. Question prompts can be used to guide learners to focus on specific tasks, to articulate thoughts, and to reflect their learning processes (Ge & Land, 2003). However, it is unclear what kinds of prompts should be provided and when to provide prompts to the students in game-based learning environments.

The use of question prompts has been found successful to support students' learning and problem solving (e.g., Choi, Land, & Turgeon, 2008; Ge & Land, 2003). Different kinds of questions prompts, such as process prompts, elaboration prompts, and reflection prompts have been discussed in question prompt literature (e.g., Ge & Land, 2003). Specifically, reflection prompts have been found effective in knowledge integration (Davis & Linn, 2000), math learning, (Lee & Chen, 2009), self-regulated learning competence (van den Boom, Paas, van Merriënboer, & van Gog, 2004), and problem solving (Kauffman, Ge, Xie, & Chen, 2008). In a GBL study that compared the effectiveness of procedural prompts and reflection prompts, Lee and Chen (2009) found that students who were prompted to elaborate and reflect performed better than the students who were prompted with game procedures. The above results confirmed the effectiveness of external prompts, especially those that require students to reflect on the game knowledge and prompt them to apply the knowledge to real life contexts.

What can we prompt students to reflect in a learning environment? For instance, Papadopoulos, Demetriadis, Stamelos, and Tsoukalas (2009, 2011) suggested the use of context-oriented question prompts in authentic learning environments to prompt students to reflect on the target conceptual knowledge, as well as applying the knowledge in different situations. They found that the combination of providing different prompts improved learning outcomes. However, it was unclear which kind of reflection prompts led to better learning outcomes. In GBL research, we observed that *knowledge prompts* were given to guide students to reflect on the conceptual understandings the underlying knowledge within the game context (e.g., Tsai, Kinzer, Hung, Chen, & Hsu, 2013). To allow students to practice the transfer of game knowledge, some studies provided *application prompts* that guide students to reflect the conceptual understandings the underlying knowledge of the game and apply them outside of the game contexts (e.g., Barzilai & Blau, 2014).

Besides the content of the prompts, some researchers also examined the timing of external scaffold in GBL (Barzilai & Blau, 2014; Tsai et al., 2013). Those studies found that students who were provided scaffolds *before* and *within* the game performed better than those who had the scaffold without the games or those who were not provided scaffolds. Those results suggested that it is important to prompt some content knowledge *before* the game as well as allow students to reflect on the content knowledge *during* the game. Thus, the game we developed for the current study included some instructional materials that students have to go over before playing the game, and additional external scaffolds provided during the game.

1.2. Feedback in GBL

Embedded external scaffolds in the game-based learning seem to promote the use of in-game contents (Tsai et al., 2013). Some researchers found that provision of direct and immediate feedback to the external scaffolds can reduce players' frustrations and prevent them from getting illusions of understanding (e.g., Hsu & Tsai, 2013). Feedback helps learners to understand the conceptual knowledge and give them clear guidance on how to improve their learning. Researchers have found correlation between feedback and achievement in computer learning environments (e.g., Corbalan, Kester, & van Merriënboer, 2009; Lee, Lim, & Grabowski, 2010). Generally, feedback types can be varied depending on their length, timing and complexity (Shute, 2008). In the current study, we focused on the *knowledge of correct response* (KCR) feedback and *elaborated response* (ER) feedback as they have been shown to facilitate learners' learning effectively in the field of multimedia learning (Corbalan et al. (2009). KCR provides learners with the correct answer following an incorrect response, and it has been found to improve learners' ability to retain information and perform deeper cognitive processing (Mealor & Dienes, 2013; Scott & Dienes, 2008). Timmers and Veldkamp (2011) also found that learners reported higher utility and more