

Introduction

Assessment is a critical element of teaching and it is part of teachers' daily routine. Using formative assessments, teachers can gather information on students' performances and each student learning processes and difficulties, and thereby adapt their teaching approaches to improve students' learning performance (Black & Wiliam, 1998a; Sadler, 1989; Wiliam & Black, 1996). Formative assessments are usually conducted in written form, which is the form most familiar to students, and can aid them in engaging in mastery learning. However, students are generally less willing to perform paper and pen (P&P) assessments, which they tend to regard as uninteresting (Castellar, All, de Marez, & Van Looy, 2015). Moreover, teachers must attend to many students simultaneously and consider course progress and time pressure, they cannot always provide timely and meaningful feedback on each assessments (Wang, 2011). However, feedback is an essential factor in formative assessment (Sadler, 1989). Timely feedback effectively enhances student learning and encourages students to voluntarily improve their learning self-efficacy (Marriott, 2009; Tsai, Tsai, & Lin, 2015; Wilson, Boyd, Chen, & Jamal, 2011). By contrast, conventional paper-based formative assessments involve numerous problems.

Following the rapid progress of technology and the Internet, computer-based assessments (CBAs) and online assessments have gained increasing popularity (McDonald, 2002). Terzis, Moridis, and Economides (2012) summarized the advantages of CBAs, such as satisfactory accuracy and fairness, timely feedback, and high repeatability. Nevertheless, previous studies have suggested that the same assessments conducted using both P&P and CBA modes may not necessarily yield the same outcomes. Therefore, test mode effects cannot be ignored (Clariana & Wallace, 2002). Similarly, McDonald (2002) reported that CBAs and P&P assessments afford different experiences for testers; individual differences, such as the experience of and anxieties and attitudes toward computer use, can lead to varied assessment results. Wu, Kuo, Jen, and Hsu (2015) also found that the visual representation (i.e., dynamic or static) of CBA items can complicate assessment, which only senior students who have more mature cognitive judgment can manage. Therefore, how different assessment approaches affect learning should be reviewed. According to Wang (2008), replacing P&P formative assessments

with web-based formative assessments will not necessarily cause substantial differences in student learning achievement. Moreover, CBAs and online assessments tend to cause the same problems as discussed by Tsai et al. (2015); that is, the deficiency in interpersonal interactions and timely assistance can reduce the motivation of learners to learn.

Responding to the rise in game-based learning in recent years, game elements have been integrated into students' learning processes. Such digital game-based learning (DGBL) is mostly advantageous in eliciting students' intrinsic motivation and interest in learning (Malone & Lepper, 1987; Ricci, Salas, & Cannon-Bowers, 1996). Information technology (IT)-based equipment has been introduced into campuses, causing DGBL to gradually gain popularity among students and thus be adopted as a new learning mode (Aldrich, 2004; Becker, 2007; Prensky, 2001; Squire, 2005). DGBL can be combined with assessment. Attali and Arieli-Attali (2015) applied a game scoring-mechanism into an assessment and found the problem-solving speed of testers was accelerated. Tsai et al. (2015) and Ventura and Shute (2013) have suggested that combining formative assessment and DGBL can stimulate learner motivation for undertaking assessment and yield accurate feedback that learners can use to maximize learning achievement according to learning ability.

Moreover, previous studies have discovered that most types of DGBL can stimulate a flow experience among learners (Hwang, Chiu, & Chen, 2015; Hwang, Wu, & Chen, 2012) that can enhance learning achievement (Barzilai & Blau, 2014; Domínguez et al., 2013; Sung, Hwang, & Yen, 2015), promote learning attitudes and self-efficacy (Sung & Hwang, 2013), and reduce cognitive load (Hwang, Yang, & Wang, 2013). Therefore, this study explored whether DGBL combined with formative assessment can enhance learning achievement. Moreover, the proposed game-based formative assessment (GBFA) was compared with a general formative assessment to investigate the different effects on student learning. This study mainly focused on the fraction learning of elementary school students to conduct an experiment addressing the following two research questions:

1. Can students using the GBFA learning mode attain a significantly enhanced achievement and develop a substantially more active attitude and improved self-efficacy in fraction learning than can students using the general formative assessment learning mode?

2. Are students using the GBFA learning mode subject to a significantly lighter cognitive load than are students using the general formative assessment learning mode?