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Implementation of Web-based dynamic assessment in facilitating junior high school students to learn mathematics

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ABSTRACT

This research adopts the Graduated Prompting Assessment Module of the WATA system (GPAM-WATA) and applies it to the remedial teaching of junior high school mathematics. The theoretical basis of the development of GPAM-WATA is the idea of 'graduated prompt approach' proposed by Campione and Brown (1985; 1987, pp. 92–95). In GPAM-WATA, when examinees fail to answer items correctly, they obtain instructional prompts (IPs) in a graduated way. This research developed the contents of IPs based on the mathematical problem-solving theory of Mayer (1992, pp. 458–460). A quasi-experimental design was adopted. Ninety-six junior high school seventh graders from three different classes participated in this research. The three classes were randomly divided into the GPAM-WATA group ($n = 31$), the N-WBT group ($n = 31$) and the PPT group ($n = 34$). All students received traditional mathematics instruction from the same teacher. After traditional mathematics instruction, all students took the pre-test of the summative assessment. The students in the three different groups then respectively received remedial teaching in the form of GPAM-WATA, normal Web-based test (N-WBT), and paper-and-pencil test (PPT). After the remedial teaching, all students took the post-test of the summative assessment. The results indicate that compared with other groups, performing remedial teaching using GPAM-WATA has significantly better effectiveness. Moreover, it is found that the IPs in GPAM-WATA are effective in remedial teaching for not only those students most lacking in different types of mathematical problem-solving knowledge but also all the other students.

1. Introduction

Assessment plays an important role in teaching activities and has significant effects on learning (Campbell & Collins, 2007; Marriott, 2009; Wang, 2010; Wang, Wang, & Huang, 2008). If teachers can properly perform assessment in teaching activities, student learning effectiveness can be improved (Campbell & Collins, 2007; Wang, 2010; Wang et al., 2008). The positive effects of assessment on learning primarily result from the feedback it provides (Wang, 2008). According to Marriott (2009), the meaningful feedback learners receive during assessment can assist them in performing self-assessment and reflection and improve their motivation and self-esteem. Meaningful feedback that helps improve learning effectiveness has to be 'timely feedback' (Marriott, 2009; Wang, 2007, 2008) and 'continuous feedback,' meaning that opportunities for feedback should occur continuously, but not intrusively, as a part of instruction (Bransford, Brown, & Cocking, 2000, p. 140). Moreover, instead of focusing only on scores, the contents of meaningful feedback should also tell learners what must be done (Wiliam & Black, 1996). With meaningful feedback, learners can improve their weaknesses in learning and thinking, increase and transfer learning, and learn to value the opportunities to revise (Bransford et al., 2000, p. 141; Wang, 2007). However, since teachers have to deal with many learners at a time and are often pressured by teaching schedule and time, it is difficult for them to provide meaningful feedback while administering assessment (Buchanan, 2000; Wang, 2008).

In recent years, with the development of Information Communication Technology (ICT), researchers have begun to use ICT to develop Web-based assessment systems, and use these systems to help teachers administer assessment and provide learners with timely feedback and more learning opportunities (e.g. Ashton, Beevers, Korabinski, & Youngson, 2006; Buchanan, 2000; Wang, 2007, 2008, 2010). Ashton et al. (2006) developed an online mathematics assessment system that separated the original question into several small questions and

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awarded these small questions with partial credit. This design of online mathematics assessment system allows learners to answer questions step by step and make use of computers to assist their learning. Marriott (2009) argued that ICT could help teachers construct innovative e-assessment (computer-assisted assessment or computer-supported assessment), and that such e-assessment could provide learners immediate automated feedback (timely feedback), which allowed learners to improve their own learning effectiveness through step-by-step revision. Wang (2008) also noted that in e-Learning environments, learners could interact directly with Web-based assessment systems. When learners encounter difficulties during assessment, if Web-based assessment systems can provide them timely feedback, the feedback cannot only motivate them to actively perform self-assessment but also improve their learning effectiveness (Wang, 2008). Regarding the contents of feedback, Narciss (1999) argued that the informativeness of feedback determined its effectiveness because the informativeness of feedback could affect both information processing and learner motivation. Wang noted that if the databases of Web-based assessment systems were pre-equipped with helpful information, when learners encountered difficulties during assessment, the Web-based assessment systems could provide learners with proper and meaningful feedback by querying and processing the information in the databases (Wang, 2008). Such feedback helps learners correct their own mistakes and recover from the impasse of misconceptions effectively (Wang, 2008).

Based on the above statements, this research constructs a Web-based assessment system and then applies it to facilitate remedial mathematics teaching in a junior high school. After receiving traditional mathematics instruction, learners participate in this Web-based assessment system in an individualized way to receive remedial mathematics teaching and in turn experience more learning opportunities and better learning effectiveness.

The Web-based assessment system adopted in this research is a Web-based dynamic assessment system termed 'Graduated Prompting Assessment Module of the WATA system' (GPAM-WATA) (Wang, 2010). Its development is based on the dynamic assessment theory, which is based on the idea of 'Zone of Proximal Development (ZPD)' of L. S. Vygotsky (Elliott, 2003; Haywood, Brown, & Wingenfeld, 1990). ZPD refers to the difference between the cognition level learners can achieve with and without the assistance of others such as teachers and outstanding peers (Elliott, 2003; Vygotsky, 1978; Wang, 2010). According to Elliott, early dynamic assessment was mainly used to evaluate the real ability of examinees and categorize them for specific training and education. However, in recent years, dynamic assessment has been used to serve more educational functions (Elliott, 2003; Haywood & Lidz, 2007, p. 177; Poehner, 2008, pp. 20–21; Wang, 2010). It helps teachers develop individualized educational interventions to facilitate learning (Elliott, 2003). With consolidated teaching activities and assessment, learners can achieve better learning by interacting with teachers. During dynamic assessment, teachers can help learners improve learning effectiveness by providing them with support (Wang, 2010). Based on the idea of 'taking assessment as teaching and learning strategy (Wang, 2010),' this research expects that the Web-based dynamic assessment system, GPAM-WATA, can play the role of teachers or outstanding peers. In an e-Learning environment, the system directly interacts with learners and provides them timely feedback carrying instructional messages to facilitate learning.

According to Sternberg and Grigorenko (2001), there are two formats of dynamic assessment: the sandwich format (SF) and the cake format (CF). In the SF dynamic assessment, instruction is performed between pre-test and post-test. The pre-test is a static test. After the pre-test, examinees receive instruction individually or in groups and the teaching contents cover the skills evaluated in the pre-test. If examinees receive instruction individually, the instruction may or may not be individualized. If it is individualized, the type and amount of instruction will vary individually. If they receive instruction in groups, the type and amount of instruction will be the same for everyone. After the instruction, examinees will take the post-test. Its contents are almost the same as that of pre-test (Sternberg & Grigorenko, 2001). The CF dynamic assessment is administered individually. Examinees are required to answer items one by one. If they answer correctly, they can proceed to the next item; if they answer incorrectly, they will receive a graded series of hints. These successive hints provide instruction to the examinees. They gradually reveal the answer by guiding examinees to find it step by step. Examinees may receive a different number of hints depending on how many tries it takes for them to answer an item correctly. However, most of the time, the contents of the hints they receive each time for each item are the same (Sternberg & Grigorenko, 2001).

The Web-based dynamic assessment system adopted in this research, GPAM-WATA, is designed as a CF dynamic assessment. GPAM-WATA is used to perform remedial teaching after traditional mathematics instruction in a junior high school. When learners encounter difficulties when answering items in the Web-based dynamic assessment, GPAM-WATA provides timely feedback to help them. Since the feedback carries instructional messages, it is also called an instructional prompt (IP) (Wang, 2010).

The key element of the CF dynamic assessment is a graded series of hints (Wang, 2010), which follow the 'graduated prompt approach' proposed by Campione and Brown (1985; 1987, pp. 92–95). According to Campione and Brown, the hints in the 'graduated prompt approach' are presented in a pre-set order. 'General hints' are provided first and then more 'specific hints' are delivered. 'General hints' are less related to the answers and not specific, while 'specific hints' provide learners complete guidance to the answer (Campione & Brown, 1985; 1987, pp. 92–95). Following this approach, GPAM-WATA thus progressively provides examinees with three IPs in a pre-set order when they have problems answering assessment items (see Sections 2.2.3 and 2.3). In designing the contents of the three IPs, this research refers to Mayer's mathematical problem-solving theory (Mayer, 1992, pp. 458–460). Mayer argued that the solving of mathematical problems involved two steps, 'problem representation' and 'problem solution,' and four sub-processes, 'translation,' 'integration,' 'planning and monitoring,' and 'execution.' Learners would not be able to solve a mathematical problem if they lack required knowledge in any of the steps and sub-processes. Therefore, the three IPs (IP_1, IP_2, IP_3) for each item are designed to compensate for the required knowledge students lack in each step and sub-process. IP_1 is designed for the required knowledge in the 'translation' sub-process, which includes 'linguistic knowledge' and 'semantic knowledge.' IP_2 is designed for the required knowledge in the 'integration' sub-process, which includes 'schematic knowledge.' IP_3 is designed for the required knowledge in the 'planning and monitoring' and 'execution' sub-processes, which includes 'strategic knowledge' and 'procedural knowledge.' A detailed explanation is presented in Section 2.2.3. It is expected that these IPs not only compensate for the required mathematical problem-solving knowledge learners lack but also improve their learning effectiveness.

Based on the above, this research addresses the following two questions:

1. How effective is GPAM-WATA in the remedial teaching of junior high school mathematics as compared to normal Web-based test (N-WBT) and paper-and pencil test (PPT)?
2. How effective is the GPAM-WATA feedback mechanism in facilitating junior high school students to learn mathematics?