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Hybrid learning style identification and developing adaptive problem-solving learning activities

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ABSTRACT

Learning style refers to an individual's approach to learning based on his or her preferences, strengths, and weaknesses. Problem solving is considered an essential cognitive activity wherein people are required to understand a problem, apply their knowledge, and monitor behavior to solve the issue. Problem solving has recently gained attention in education research, as it is considered an essential ability for effective learning. This study aims to investigate the relationship between learning styles and learning performance. To provide adaptive suggestions for optimizing problem-solving abilities, developed a hybrid learning style identification (HLSI) mechanism based on a k-means clustering algorithm was developed. The participants were 67 undergraduate students. The experiment demonstrated that HLSI can successfully cluster learning styles into three or four combinations based on learning performance, which suggests that the data mining technique can successfully explore multiple learning styles in problem-solving abilities. Additionally, 13 teachers were included in the study to discuss the effectiveness of the HLSI mechanism, and the results indicated a 95% probability of obtaining an above-average acceptance of the proposed system.

1. Introduction

Problem solving is a cognitive activity to deal with problems in daily life (Jonassen, 2000b). Compared with solution finding, problem solving is viewed as part of strategy shaping (Wüstenberg, Greiff, & Funke, 2012), for which people actively acquire knowledge, develop strategies, monitor behavior, and then adjust the strategy to solve the problem (Funke, 2001). Problem solving is generally defined as a critical ability, and thus, learning through problem solving is popular in e-learning development. Recently, learning systems incorporating web techniques and problem solving have attracted researchers' attention (Fessakis, Gouli, & Mavroudi, 2012; Hwang, Wu, & Chen, 2012; Tsai, Lee, & Shen, 2013). For example, computerized adaptive tutorials are applied to assess problem-solving skills (Nirmalakhandan, 2007). Jonassen (2000a) developed instructional materials that support problem-solving outcomes. However, various learning styles influence learners' approach to problem solving (Felder & Silverman, 1988). Learning styles are an integral part of various types of learning systems, and to develop personalized or adaptive learning systems, data mining technology is combined with learning styles. Students who learn using adaptive learning mechanisms significantly have better learning performance (Chen, 2009; Jung & Graf, 2008).

Although each learning style has a unique learning process (Graf, Lin, & Kinshuk, 2008; Lau & Yuen, 2010; Ross, Drysdale, & Schulz, 2001), few studies have investigated whether learning styles are associated with learning performance in game-based problem-solving activities. Using a k-means algorithm, this study investigated learning styles to determine their relevance in problem-solving abilities in a game-based environment. The HLSI mechanism aims to provide adaptive learning suggestions for teachers to adapt learning activities to various learning styles. The goals of this study are as follows:

(1) To explore how different learning style combinations affect a learner's problem-solving abilities.
(2) To analyze whether adaptive suggestions can have a positive effect for teachers in problem-solving activities.

2. Related work

2.1. Problem-solving activities

The relevant literature demonstrates that problem solving is an

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essential ability to determine the cause, analyze the problem, make a plan, and test the plan (Chan & Wu, 2007; Polya, 1957). According to Polya (1957), problem solving has four phases: understanding the problem, devising a plan, executing the plan, and reviewing. Davidson, Deuser, and Sternberg (1994) identified the meta-cognitive processes of problem solving as defining and identifying the problem, analyzing the problem by mentally representing it, planning to allocate resources to implement the solution, monitoring the problem-solving process, and evaluating the optimal solution. Problem solving is an integral approach to learning (Jonassen, 2000a; Yang, 2012) that has intellectual, social, and cultural value (Jonassen, 2000a). It is important in many areas such as virtual chemistry (Scherer & Tiemann, 2012), computer programming (Fessakis et al., 2012), cognitive psychology (Sonnleitner, Keller, Martin, & Brunner, 2013), and science education (Van Merriënboer, 2013). Studies have reported that problem-solving skills can be fostered through learning activities in computer-based environments (Hwang et al., 2012; Johnson & Mayer, 2010). In recent years, the development of web-based problem-solving activities has attracted considerable attention (Chen, 2010; Fessakis et al., 2012; Hwang, Tsai, Tsai, & Tseng, 2008; Hwang et al., 2012; Tsai et al., 2013). Problem-based learning using web-based technology has a positive effect on learners (Taradi, Taradi, Radić, & Pokrajac, 2005). To enhance individual problem-solving skills, web-based learning can be an effective approach for problem-solving activities (Hwang, Sung, Hung, & Huang, 2013; Kuo, Hwang, & Lee, 2012; Rae & Samuels, 2011).

Moreover, game-based materials can stimulate learners' internal motivation to solve problems (Johnson & Mayer, 2010; Liu, Cheng, & Huang, 2011; Tennyson & Jorczak, 2008). Game-based learning can be an effective approach to improving learning performance by promoting student interactions during game play (Hwang et al., 2012). Csikszentmihalyi (1990) proposed that challenge and focused attention are integral features of games, both of which can lead to a "flow" state. If there are clear goals, rules, challenges, and a sense of achievement, these features can also enhance student collaboration (Shih, Shih, Shih, Su, & Chuang, 2010). Game-based learning might also help learners engage in problem solving (Bayliss, 2007; Ozcelik, Cagiltay, & Ozcelik, 2013). To support this view, Lee and Chen (2009) showed that clear game feedback can enhance students' reasoning in nonmathematical problems. Kim, Park, and Baek (2009) reported that applying problem solving to game scenarios benefits learning performance. Furthermore, digital games provide a meaningful framework for problem solving (Annetta, 2008; Liu et al., 2011), in which learners can link abstract concepts to the concrete game experience to solve problems (Lewis & Massingill, 2006). Tan and Biswas (2007) confirmed that learners had better opportunities to construct their own learning experiences and thereby acquire a deeper understanding of problem-solving skills when playing games.

2.2. Data mining technology for supporting learning systems

Employing machine learning in personalized learning systems has received considerable attention, and recently, data mining techniques have been considered useful for optimizing personal learning (Jung & Graf, 2008; Chang, Hung, & Lin, 2015; Lin, Yeh, Hung, & Chang, 2013; Romero, Ventura, & García, 2008; Romero, Ventura, Zafra, & Bra, 2009). There has also been increasing interest in employing data mining in educational systems (Romero et al., 2008; Wang & Liao, 2011), making educational data mining the focus of a new and growing research community (Romero & Ventura, 2007). For example, a study by Romero et al. (2008) used data mining in course management systems. There are four types of data mining techniques: classification, association, clustering, and sequential pattern mining. Recently, it has been suggested that by using data mining techniques, a learning system can provide personalized and adaptive learning programs to improve learning abilities. Studies have indicated that the clustering algorithm can distinguish learner seeking strategies and similar help-seeking behaviors among learners in the same learning environment (Vaessen, Prins, & Jeuring, 2014). The most useful patterns have been those obtained using the clustering algorithm (Hartigan & Wong, 1979). Currently, this clustering technique has been widely applied in learning programs across various domains, such as intelligent tutoring systems (Vaessen et al., 2014) and history exams (Rodrigues & Oliveira, 2014). Steinley (2006) used the k-means clustering algorithm to explore the use of different help-seeking strategies, whereby the segments were clustered on selected state transition probabilities. The k-means clustering algorithm uses a centroid to represent the cluster, and thus, it is sensitive to outliers, as a data object with an extremely large value may disrupt the data distribution. This technique has the following strengths: (1) It is relatively scalable and has computational efficiency. (2) The results, which are presented graphically or with rule expressions, can be easily understood and explained. Wang, Chatzisarantis, Spray, and Biddle (2002) applied the k-means algorithm to identify subgroups of pupils based on achievement goals and perceived competence.

2.3. Personalized learning and learning styles in problem-solving activities

Brusilovsky's (1999) analysis of available technologies and their place in large-scale web-based education revealed that adaptive applications are important for web-based courseware because the courseware has to be used by a much wider variety of students than any "standalone" educational application. Personal traits play an essential role in personalized learning, and learning styles involve various types of behavioral features that can be analyzed to provide personalized learning strategies. Personalized learning has received considerable attention, with many researchers considering learning styles when developing educational adaptive systems (Dascalu et al., 2015; Graf & Liu, 2010; Graf, Viola, Leo, & Kinshuk, 2007). Graf et al. (2007) indicated that learning styles are increasingly incorporated into learning systems. Some researchers proposed an adaptive hypermedia system based on student learning styles to enhance student learning using course hypermedia (Carver, Howard, & Lavelle, 1996). Al-Azawei and Badii (2014) demonstrated learning style applied in adaptive learning.

Felder and Solomon (2001) described learning styles across four dimensions: Sensing/Intuiting, Visual/Verbal, Active/Reflective, and Sequential/Global. By including learning styles as a part of materials development, learners' learning interests and learning processes can be considered, which can also facilitate the use of adaptive teaching strategies for instructors. For example, the "sensing/intuitive" dimension of a learning style can influence innovation (Graf et al., 2007), whereas the global learning style is associated with creativity (Felder & Silverman, 1988). Reflective learners require situations that provide opportunities to think about the information; thus, an independent or one-on-one situation could be more suitable (Felder & Silverman, 1988, p. 679). Table 1 shows a description of eight learning styles (Felder & Silverman, 1988, p. 679; Felder & Solomon, 2001).

Self-efficacy is associated with the sequential learning style (Direito, Pereira, & Duarte, 2012). Moreover, as learning styles influence the approach to problem solving, the studies discussed above have also suggested that problem-solving abilities may be influenced by learning style. This study investigates the correlation between the learning styles and learning performance through the