



Assessing the effects of different multimedia materials on emotions and learning performance for visual and verbal style learners

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ABSTRACT

Multimedia materials are now increasingly used in curricula. However, individual preferences for multimedia materials based on visual and verbal cognitive styles may affect learners' emotions and performance. Therefore, in-depth studies that investigate how different multimedia materials affect learning performance and the emotions of learners with visual and verbal cognitive styles are needed. Additionally, many education scholars have argued that emotions directly affect learning performance. Therefore, a further study that confirms the relationships between learners' emotions and performance for learners with visual and verbal cognitive styles will provide useful knowledge in terms of designing an emotion-based adaptive multimedia learning system for supporting personalized learning. To investigate these issues, the study applies the Style of Processing (SOP) scale to identify verbalizers and visualizers. Moreover, the emotion assessment instrument emWave, which was developed by HeartMath, is applied to assess variations in emotional states for verbalizers and visualizers during learning processes. Three different multimedia materials, static text and image-based multimedia material, video-based multimedia material, and animated interactive multimedia material, were presented to verbalizers and visualizers to investigate how different multimedia materials affect individual learning performance and emotion, and to identify relationships between learning performance and emotion. Experimental results show that video-based multimedia material generates the best learning performance and most positive emotion for verbalizers. Moreover, dynamic multimedia materials containing video and animation are more appropriate for visualizers than static multimedia materials containing text and image. Finally, a partial correlation exists between negative emotion and learning performance; that is, negative emotion and pretest scores considered together and negative emotion alone can predict learning performance of visualizers who use video-based multimedia material for learning.

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1. Introduction

Educational materials are no longer limited to static text; that is, presentation is being transformed from text-based materials to multimedia materials to harness learner attention and interest. Particularly, considerable attention has focused on developing interactive multimedia materials to promote learning motivation and performance (ChanLin, 1998; Lowe, 2003). However, whether different multimedia materials with the same learning content and objectives have the same effects on learners' emotions and performance for learners with different cognitive styles must be clarified. Since each learner has a different cognitive learning style that is associated with multimedia material learning, presenting inappropriate multimedia learning materials to learners may negatively affect learning.

Emotions can affect attention, meaning creation, and the formation of memory channels. Hence, emotional status and learning are strongly correlated (LeDoux, 1994). Kort, Reilly, and Picard (2001) indicated that emotion sets with positive–negative oppositions, including anxiety–confidence, boredom–fascination, frustration–euphoria, dispirited–encouraged, and terror–enchantment, are likely relevant to learning. Additionally, many psychologists and neurologists have demonstrated that emotions and motives are important to cognitive learning (Izard, 1984). Goleman (1995) noted that depressed, angry, and anxious students have difficulty learning. According to Piaget

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(1989), human emotions can arise from or interfere with learning. Izard (1984) analyzed the degree to which cognitive activities are adversely affected by negative emotions and enhanced by positive emotions. In other words, identifying the cognitive and emotional states of students during instruction can facilitate the development of positive learning experiences for learners (Reilly & Kort, 2004).

Most current methods for assessing learner's emotional states are post hoc subjective assessments of emotion according to learner's self-reporting on a set of questions (Schutte, Malouff, & Bhullar, 2009). However, these methods are often not sensitive to changes in emotion. Also, how to design a set of questions that can obtain an accurate assessment of the learners' emotional states is difficult since learners may find it difficult to express their own feelings. In recent years, emotion-recognition technologies based on human physiological signals have been developed for practical application (Bi & Fan, 2011; Chen & Lee, 2011; Shen, Wang, & Shen, 2009), such that investigating the correlation among different multimedia materials, learner emotional states, and learning performance is now practicable. Particularly, many past studies demonstrated that heart rate variability (HRV) patterns are directly responsive to changes in emotional states (Latham, 2006; McCraty, Atkinson, Tiller, Rein, & Watkins, 1995; Tiller, McCraty, & Atkinson, 1996). The emWave, which is a stress detector of emotional state developed by HeartMath (<http://www.heartmathstore.com/>), uses HRV human physiological signals to recognize the emotions of individual learners as positive, peaceful or negative. The emWave has been successfully applied as biofeedback-based stress management tool in medical field to reduce physician stress and identified that it was confirmed as a simple and effective stress-reduction strategy for physicians (Bedell & Kaszkin-Bettag, 2010; Lemaire, Wallace, Lewin, de Grood, & Schaefer, 2011). It has also been applied in educational settings to facilitate social, emotional, and academic learning (McCraty, 2005). Using HRV human physiological signals for the objective and real time assessment of learner's emotion provides an opportunity to objectively detect small variations in emotion in real time.

By applying emWave to analyze emotional data, our previous study (Chen & Wang, 2011) demonstrated that video-based multimedia material provided to 170 Grade 5 elementary school students for energy education generated the best learning performance and most positive emotions among static text and image-based multimedia material, video-based multimedia material, and animated and interactive multimedia material. Moreover, a partial correlation exists between negative emotions and learning performance. Importantly, pretest scores and negative emotions considered simultaneously can predict learning performance of learners who use video-based multimedia material for learning. Notably, female learners are more affected by different multimedia materials than male learners (Chen & Wang, 2011). However, an important goal is to determine whether individual differences in the visualizer-verbalizer dimension affect learning performance and emotions of learners using different multimedia materials for learning. The study thus deals with emotional variations and the corresponding learning performance when learners with visual and verbal learning styles are presented different multimedia materials.

2. Problem statement

Although many studies have argued that different learning materials affect learners' emotional states and learning performance (Chen & Lee, 2011; Chen & Wang, 2011; Large, Beheshti, Breuleux, & Renaud, 1994; Um, Plass, Hayward, & Homer, 2011), few empirical studies have examined individual differences in emotional states and learning performance between learners with visual and verbal cognitive styles while using different multimedia materials for learning. Based on its broad literature survey, this study examines whether learning performance and emotions of visualizers and verbalizers are significantly affected when multimedia materials that conflict with individual cognitive style for learning are used. This will provide knowledge of personalized learning performance based on the visual and verbal cognitive styles while using multimedia materials for instruction. However, recognizing learner emotions in real time environment is extremely challenging. Emotion-recognition technologies based on human physiological signals have recently been developed for practical application (Bi & Fan, 2011; Chen & Lee, 2011; Shen et al., 2009), such that investigating correlations among different multimedia materials, learner emotional states, and learning performance is now practical.

3. Literature review

3.1. Theoretical basis for designing multimedia materials to support effective learning

Multimedia materials integrate two or more media (Mayer, 1997). As curriculum presentation becomes increasingly diversified, educational materials are no longer limited to static text; additionally, multimedia materials instead of paper-based materials are being used to promote learner attention and interest. Multimedia materials—consisting of pictures (such as animation, video, or static graphics) and words (such as narration or onscreen text)—offer a potentially powerful venue for improving student understanding in computer-based learning environments. However, how to design multimedia messages that promote meaningful learning should be considered because all multimedia messages are not equally effective (Mayer & Moreno, 2002). The dual coding theory (DCT) (Paivio, 1990), a well-known cognitive theory applied to multimedia learning, models different information retrieval and information processes in human cognitive behavior and emphasizes that both verbal and visual systems, which are part of the human cognitive system, play important roles in human learning activities. The verbal channel takes input initially from the ears and ultimately produces verbal representations; the visual channel takes input initially from the eyes and ultimately produces pictorial representations (Mayer & Moreno, 2002). Moreover, DCT argued that verbal and nonverbal systems leads to the inference that visual images for objects may be more directly connected to other nonverbal components of emotion than are verbal representations for objects (Clark & Paivio, 1991). That is, DCT conceptualizes emotion as a complex pattern of activation among interconnected nonverbal and verbal representations. Using dual coding theory, Large et al. (1994) demonstrated that learning retention can be enhanced by pictures in two ways that promote activation of dual coding. According to Large et al., the two codes have additive effects, such that the likelihood of remembering information is increased. Further, pictures are more likely than words to be dual coded; thus, when one memory is lost, the other remains available. Conversely, Mousavi, Low, and Sweller (1995) noted that when multimedia materials contain visual text narration and auditory narration, which generates the split-attention effect, learning is inefficient. The split-attention effect exists when the same media modality (e.g., visual and visual) is used for different information types. To learn from such materials, learners must split their attention between these materials to understand and use the materials provided.

Additionally, cognitive load theory, which has been widely applied in designing instructional materials, provides a general framework and conceptual toolkit for instructional designers to minimize and control the conditions that create unwanted cognitive loading in learning

materials. This theory is based on a cognitive architecture consisting of a limited working memory with partly independent processing units for visual and auditory information, which interact with unlimited long-term memory (Paas, Renkl, & Sweller, 2003). Cognitive load is comprised of intrinsic cognitive load and extraneous cognitive load (Sweller, Van Merriënboer, & Paas, 1998). Intrinsic cognitive load is solely from the intrinsic characteristics of learning materials such as content that is difficult to learn. Extraneous cognitive load is generated by poor learning materials, curricula design, or learning activities; however, it can be reduced by modifying the design of learning material. Since the cognitive resources of each learner's information processing system are limited, Mayer and Moreno (2003) argued that the primary challenge for designers of multimedia materials is the potential for cognitive overload, which occurs when the intended cognitive processing exceeds a learner's available cognitive capacity. Therefore, multimedia instruction should be designed to minimize unnecessary cognitive loading (Mayer & Moreno, 2003). Based on cognitive load theory, Li, Ouyang, and Luo's study (2010) suggested that the interactive pattern of emotion and working memory was modulated by cognitive load. Their study demonstrated that interaction of emotion and working memory was similar and nonspecific under the condition of low cognitive load. In contrast, with the increasing of cognitive load, interaction of emotion and working memory became specific and selective. The study mainly focused on identifying whether different types of multimedia materials with the same learning content and objectives have the same effects on learners' emotions and performance for learners with different cognitive styles. To avoid cognitive load affecting emotion, this study selected multimedia learning materials that have low cognitive loads, including both intrinsic and extraneous cognitive loads.

3.2. Differences between visualizers and verbalizers in learning preferences and performance while using multimedia materials

Childers, Houston, and Heckler (1985) demonstrated that differences in individual information processing may result from two factors: (1) cognitive ability to process information; and, (2) preferred processing strategies or styles, *i.e.*, verbal *versus* visual. Identifying individual differences in cognitive styles for processing multimedia material are important because they add to existing knowledge of processing preferences and enhance our understanding and the predictive ability of personality variables. Messick (1984) showed that cognitive style is a constant latent tendency of information processing modes of individual learners. Moreover, Keefe (1987) argued that cognitive style does not change over time with learning scenarios because it is both consistent and stable. Keefe (1987) asserted that cognitive style is an information-processing preference of individual learners during learning processes. Ernest (1977) also noted that individual differences in imagery can significantly impact cognitive functions, including learning, memory, perception, and problem solving. Interest in cognitive styles for information processing has developed from at least two research streams—mental imagery research and the information processing paradigm in psychology (Gould, 1990). Mental imagery research assessed information processing in various modes, including auditory, olfactory, gustatory, and kinesthetic modes. The information-processing paradigm is based on the assertion that humans process the information they receive, rather than merely responding to stimuli.

Among the many cognitive styles addressed in previous studies, the visualizer–verbalizer hypothesis of Mayer and Massa (2003) states that some people process words more effectively (verbalizers) and some people process pictorial representations more effectively (visualizers). Based on this hypothesis, Sojka and Giese (2001) study confirmed that individuals with a high need for cognition (NFC) prefer to process verbal information while individuals with a high need for affect (NFA) prefer to process visual information. The NFC in psychology is a personality variable reflecting the extent to which people engage in and enjoy effortful cognitive activities (Cacioppo & Petty, 1982). Individuals who are high in NFC are more enjoyed in the effortful engagement of arguments, the evaluation of ideas, and the analysis of problems and their solutions. By contrast, NFA is a separate motivational construct that captures the degree to which people enjoy experiencing strong emotions (Maio & Esses, 2001). Individuals who are high in NFA are more likely to view emotions as useful when making judgments. Moreover, Smith and Woody (2000) claimed that multimedia material benefits students who prefer visual representations. The visualizer–verbalizer hypothesis is particularly relevant to the design of multimedia materials because multimedia materials typically present information to learners using words and pictures simultaneously (Mayer & Massa, 2003). Further, Massa and Mayer (2006) tested the attribute–treatment interaction (ATI) hypothesis, which asserts that visualizers learn best with visual instruction, whereas verbalizers learn best with verbal instruction. Using 14 measures of the verbalizer–visualizer dimension and an online science lesson that provides help screens with printed text (text group) or illustrations (pictorial group), they demonstrated that there was not strong support for the ATI hypothesis that verbal learners and visual learners should be given different kinds of multimedia materials. Moreover, Kollöffel (2011) examined the relationships between cognitive style (*i.e.*, visualizers and verbalizers), cognitive abilities (spatial and verbal abilities), and learning performance. They showed that the visualizer and verbalizer cognitive styles and learning outcomes were unrelated, concluding that learning results are influenced by cognitive ability (particularly spatial visualization) and the extent to which a format allows cognitive processing, rather than a match between the preferred format and the format administered. That is, students should not choose learning materials based on their preferences, because this may lead to the selection of a format that is not effective for learning.

Understanding the relationships between multimedia presentation types and individual traits can be used in designing effective learning materials that are likely to be processed by certain individuals because the format is consistent with an individual's processing preferences. Therefore, identifying how the cognitive styles of visualizers and verbalizers, which are associated with information-processing capability, affect learners' emotions and performance is a worthwhile research issue.

3.3. The impacts of learners' emotions on learning performance

Many researchers pointed out that emotions are important to learning and also affect learning performance (Goleman, 1995; John-Steiner, 2000; Piaget, 1989; Vygotsky, 1994). Additionally, many psychologists and neurologists have also demonstrated that emotions and motives have important roles in cognitive learning (Izard, 1984). Izard (1984) claimed the performance of cognitive activities that are adversely affected by negative emotions, but raised by positive emotions. Goleman (1995) noted that students who are depressed, angry, or anxious have trouble learning. Additionally, Shen *et al.*'s study (2009) indicated that using emotional data could greatly improve the performance of e-Learning system, particularly in the categories involving user-centered learning. Also, Pekrun, Goetz, Frenzel, Barchfeld, and Perry (2011) found that students' achievement emotions are linked to their control and value appraisals, motivation, use of learning strategies, self-regulation of learning, and academic performance.

Generally, different illustration types of multimedia materials will affect emotion and learning performance. Park and Lim's study (2007) demonstrated that the illustration types of multimedia materials generated a significant effect on learners' motivation and found that learners pay more attention to learning materials when emotional interest illustrations are presented than when text-only information is presented. Additionally, their study also showed that the emotional interest group had a significantly higher relevance score than did the text-only group. Um et al. (2011) indicated that applying emotional design principles to learning materials can induce positive emotions and that positive emotions in multimedia-based learning facilitate cognitive processes and learning, thus suggesting that emotions should be considered an important factor in the design of multimedia learning materials. Our previous study (Chen & Wang, 2011) also confirmed that correlation exists between negative emotion and learning performance and simultaneously considering pretest score and negative emotion can predict learning performance of learners who use video-based multimedia material for learning. Due to the importance of emotional states to learning, whether emotional states of learners with different cognitive learning styles are highly related to learning performance with different multimedia materials needs to be further confirmed.

4. Research methodology

4.1. Research variables and hypotheses

This study's goal is to elucidate how information processing styles of learners with different cognitive styles affect emotional states and performances while using different multimedia materials for learning via emotion-recognition technology. Learning materials with text only are not the concerned issue of the study because curricula presentation is being transformed from text-based materials to multimedia materials in order to increase learner attention and interest in modern education. Generally speaking, individuals with the verbal learning style may prefer to be involved with multimedia materials with verbal information, such as static text and image-based multimedia materials, while highly visual individuals may prefer to be involved with multimedia materials with visual information, such as video-based or animated and interactive multimedia materials.

Moreover, the study further examines relationships between learner emotions and learning performance for visualizers and verbalizers who were presented different multimedia materials for learning. This study utilizes the following three multimedia materials to investigate these relationships: static text and image-based multimedia material containing static text, images, and graphs; video-based multimedia material containing moving images, audio, and subtitles; and animated and interactive multimedia material containing animated pictures, text, and audio. To compare how different multimedia materials affect the learners' emotions and learning performance of visualizers and verbalizers, learning materials in this study are from the same education unit, such that they have the same content and learning objectives; that is, learning materials are only presented in different formats. The aim of course content is to teach students how to identify energy types. Learner emotions are identified by the emWave system, which uses HRV physiological signals to identify three emotional states: positive, peaceful, and negative. Additionally, the assessment of learning performance is based on the difference between pretest and posttest scores; both multiple-choice tests have the same questions but are in different sequences. This reduces the probability of an examinee guessing a correct answer. Fig. 1 shows the relationship framework of the discussed research variables. Based on this framework and the literature review, this study proposes the following research hypotheses, which are tested at the significance level of $p = .05$:

Hypothesis 1. There are significant differences in positive and negative emotions when visualizers and verbalizers are presented with different multimedia materials for learning.

Hypothesis 2. There are significant differences in learning performance when verbalizers and visualizers are presented with different multimedia materials for learning.

Hypothesis 3. There are significant relationships in learners' emotions and learning performance when verbalizers and visualizers are presented with different multimedia materials for learning.

4.2. The used multimedia materials

To reduce the cognitive loads of difficult learning materials (*i.e.*, intrinsic cognitive load), and the efforts required from learners (*i.e.*, extraneous cognitive load), this study selected learning materials that have low cognitive loads, including both intrinsic and extraneous

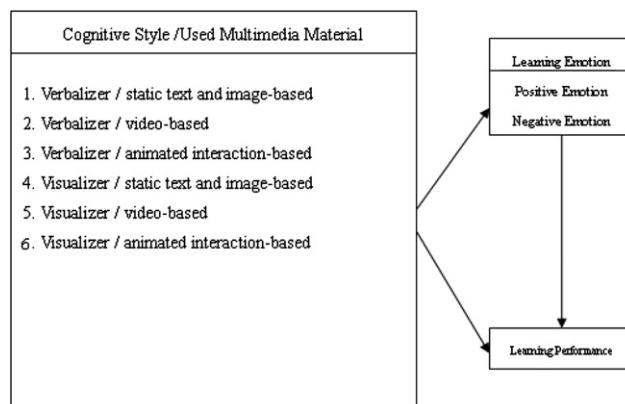


Fig. 1. Relationship framework of the research variables discussed in this study.

cognitive loads. This study assesses the correlations among learning performance and learners' emotional states associated with three different multimedia materials. Learning materials for energy education used in this study were designed by professional members of the national energy education project (<http://energy.ie.ntnu.edu.tw/>), which was supported by Bureau of Energy, Ministry of Economic Affairs of Taiwan. Thus, the effect of learner extraneous cognitive load was reduced as much as possible (Sweller et al., 1998). Additionally, the content of learning materials is set at a basic level, thus minimizing intrinsic cognitive load. The learning objective is simple—students learn to identify energy types. The three types of multimedia materials have the same energy education units, learning content and learning objectives; however, the multimedia techniques differ. This study uses the emWave system to identify emotional status of verbalizers and visualizers in response to different multimedia materials. That is, this study explores the correlations among learners' emotions, learning performance, and different multimedia materials for verbalizers and visualizers, with the goal of contributing to the educational field.

4.3. The style of processing (SOP) scale for identifying verbalizer and visualizer

According to Jonassen and Grabowski (1993), the Verbalizer–Visualizer Questionnaire (VVQ) is primarily used to identify visual and verbal cognitive styles. However, Childers et al. (1985) developed a new measure, the Style of Processing (SOP) scale, which is a modified version of the VVQ, and is applied to identify visualizers and verbalizers. The SOP scale has two subscales, each with 11 questions. Responses are on a four-point Likert scale, ranging from 4 for “always true”, usually true, usually false, and 1 for “always false,” to identify the cognitive styles of visualizers and verbalizers. This study uses a revised SOP scale with 20 questions, which was modified by Childers et al. (1985). The revised SOP scale has two subscales, the verbal and visual subscales, to create two categories—verbalizer and visualizer. The reliability of the each subscale in the revised SOP scale in recognizing cognitive styles of visualizers and verbalizers is 0.81 and 0.86, respectively, by Cronbach's alpha. The global reliability of the SOP scale is 0.88. Overall, reliability of the revised SOP scale for identifying visual and verbal cognitive styles is sufficient.

Although the revised SOP scale has two subscales, Childers et al. (1985) tend to prefer to use it as a single scale. However, they also pointed out that the value of using the scale in its two component form was worthy of further research. Gould's study (1990) divided two SOP subscales at the median and combining them to create four categories including Low Processors – low verbal/low visual, High Verbal – high verbal/low visual, High Visuals – low verbal/high visual, and High Processors – high verbal/high visual for consideration. To identify how cognitive style influences emotion and learning performance while using different multimedia materials for learning, the study adopted the SOP as a single scale to identify all participants as verbalizers and visualizers. That is, the participants who have the SOP scores that are higher and lower than the mean SOP score are identified as visualizers and verbalizers, respectively.

4.4. Research participants

Steinberg's research (2005) shows that there are significant differences in cognitive skills and affective experiences between different ages. Therefore, the study recruited 160 grade 5 students from Jhuang Jing Primary School in Taoyuan City, Taiwan to take part in the experiment. To consider the research ethics of the designed experiment that involves recording emotional states of school children, written informed consent was obtained from the children and their parents following full explanation of the experiment. Among 160 participants, there are 73 and 87 students who were respectively identified as verbalizer and visualizer. Table 1 displays the identified number of verbalizers and visualizers who were presented with different multimedia materials and the corresponding descriptive statistics of the SOP score. This study mainly focused on investigating how different multimedia materials affect emotions and performance of the learners who have verbal and visual cognitive styles.

4.5. Experimental procedure

Before performing the formal study, a pilot study was conducted in Jhuang Jing Primary School in Taoyuan City, Taiwan, in order to assess whether the intrinsic and extraneous cognitive loads of the learning materials were appropriate for the age group being assessed. To avoid the cognitive load affecting emotion, this study adopted three different multimedia materials with basic level to control that the emotion effects mainly come from different multimedia materials, not from cognitive load. The results of the pilot study confirmed that participants could leisurely view the three different multimedia materials and learn the content within 10 min well. This pilot study also confirmed that the cognitive load (i.e., intrinsic and extraneous) of the learning materials was appropriate to students in grade 5, because the learning performance promotion of all participants in the pilot study reached a significant level.

To assess the effects of different multimedia materials on learners' emotions and performance based on emotion-recognition technology, all participants were randomly divided into 3 groups for learning three different multimedia materials—static text and image-based multimedia materials, video-based multimedia materials, and animated interaction-based multimedia materials in the formal study. Restated, each participant is only presented with one type of the three different multimedia materials. Before performing the learning experiment, the entire learning processes containing pretest, learning, and posttest was first explained. Moreover, this study designed both

Table 1

The number of verbalizers and visualizers who were presented with different multimedia materials and the corresponding descriptive statistics of the SOP score.

| Cognitive style | The used multimedia material | Number of learners | Mean of SOP score | Std. of SOP score |
|-----------------|---|--------------------|-------------------|-------------------|
| Verbalizer | Static text and image-based multimedia material | 25 | 45.16 | 3.253 |
| | Video-based multimedia material | 27 | | |
| | Animated interaction-based multimedia material | 21 | | |
| Visualizer | Static text and image-based multimedia material | 29 | 56.78 | 3.513 |
| | Video-based multimedia material | 31 | | |
| | Animated interaction-based multimedia material | 27 | | |

the test sheets of pretest and posttest that contain the same 10 questions with different sequences of selecting items in a multiple-choice design. The aim is to control both the test sheets have the same difficulty and to reduce the probability of an examinee to give a correct answer based on guessing. Also, each correct answer can get 1 point. Thus, the highest score of the pretest and posttest is 10 points. All participating learners also knew that the test sheet of the posttest is the same with the pretest in advance. Initially, each participant was given a 3-min pretest. The aim is to know prior knowledge of learners on identifying energy type. In other words, all participating learners knew that the learning object is on correctly identifying energy types. After that, each learner was given 10 min to view the multimedia materials and learn the content. At the same time, all learners wore an emWave earplug that collected emotion data during learning. Additionally, all participating learners were reminded to notice the learning contents on identifying energy types while using different types of multimedia materials for learning. After finishing the assigned unit, learners were required to complete a 3-min posttest to assess learning performance. The entire experimental procedure for each learner was approximately 16 min; that is, all learners were instructed to finish the experimental procedure at the same time. After finishing the whole experimental procedure, all participants were asked to fill out the revised SOP scale for identifying their cognitive styles as verbalizers and visualizers.

4.6. Emotion recognition by the emWave system

Past research has revealed that heart rate variability (HRV) patterns, or *heart rhythms*, are directly responsive to changes in emotional states (Latham, 2006; McCraty et al., 1995; Tiller et al., 1996). HRV is a measure of the continuous interplay between sympathetic and parasympathetic influences on heart rate that yields information about autonomic flexibility and thereby represents the capacity for regulated emotional responding (Latham, 2006). Latham's review (2006) indicated that there are two major theoretical frameworks including Polyvagal theory and Neurovisceral Integration theory that articulate the role of HRV in emotional responding. The emWave system, which is a stress detector for emotional states developed by the Institute of HeartMath, uses an ear sensor to determine HRV based on heart rate power spectral density analysis for identifying human emotion (McCraty et al., 1995) (Fig. 2). The emWave system has an easy-to-use software program with a heart rhythm monitor and an emotion-recognition algorithm for identifying emotional states (Fig. 3). Fig. 3 shows the heart rate as a curve of cumulative heartbeats per minute; below is Coherence Ratio, derived from the power spectral density analysis of heart rate. Per this analysis, the Coherence Ratio corresponding to different coherent states can be identified as three color-rendered indexes. The red part is the low-frequency zone of the power spectral density, which represents a change in sympathetic activity; according to analytical results, it also represents a negative emotional state. The blue part is the medium-frequency zone of the power spectral density, representing changes in parasympathetic nervous activity, or a peaceful emotional state. The green part is the high-frequency zone of the power spectral density, representing parasympathetic nervous activity changes, or a positive emotional state. When an emotion arises, the emWave system calculates the Coherence Ratio of these three color indexes, presents them as a percentage of a learner's emotional state, and maps them as the Accumulated Coherence Score (ACS) (bottom left in Fig. 3). The curve of the ACS with



Fig. 2. Ear sensor used in the emWave PC stress relief system for human pulse signal detection.



Fig. 3. The emotion analysis interface of the emWave PC stress relief system based on human physiological signals.

a positive slope indicates that the learner relaxed and had a positive emotional state. When the curve slope is negative, the learner is feeling pressured and in a negative emotional state. The ideal state is when the slope remains positive. With this system, one can assess how human emotions affect HRV through the user-friendly graphics displayed on a computer monitor.

Currently, the emWave has been applied in educational settings to facilitate social, emotional, and academic learning, and indicated that classroom-based programs incorporating this intervention can facilitate improvements in emotional health, social behaviors, and academic performance in diverse student populations (McCarty, 2005). Additionally, Lemaire et al. (2011) employed emWave as a biofeedback-based stress management tool to reduce physician stress and identified that it may be a simple and effective stress-reduction strategy for physicians. Thurber, Bodenhamer-Davis, Johnson, Chesky, and Chandler (2010) also demonstrated that the HRV biofeedback training via emWave had a large effect on decreasing mental, emotional, and physiological aspects of music performance anxiety and subjective improvement of performance for university students. Therefore, this study adopted the emWave system to measure changes in learner emotional states when presented with different multimedia materials with same learning content in order to identify how different multimedia materials affect individual learning performance and emotion, and what relationships are between learning performance and emotion.

The method for computing the percentage of positive and negative emotions based on the coherence value (CV), the accumulated coherence score (ACS) (bottom left in Fig. 3) and heart rate artifacts (HRA) detected by the emWave system for assessing the emotional state of individual learners during learning are addressed in our previous study in detail (Chen & Wang, 2011), and briefly summarized as follows:

$$CV(t) = \begin{cases} -1, & \text{if } Coherence(t) = 0 \text{ and } HRA(t) = 0 \text{ (negative emotion)} \\ +1, & \text{if } Coherence(t) = 1 \text{ and } HRA(t) = 0 \text{ (peaceful emotion)} \\ +2, & \text{if } Coherence(t) = 2 \text{ and } HRA(t) = 0 \text{ (positive emotion)} \end{cases}, t = 1, 2, \dots, m \quad (1)$$

where $CV(t)$ is the coherence value at the t th sampling time; $Coherence(t)$ is the coherence state at the t th sampling time; $HRA(t)$ is the HRA value at the t th sampling time; and m is the times of emotional states that are recognized.

Based on the CVs obtained by Eq. (1), the ACSs of positive, peaceful and negative emotions during learning can be respectively formulated as follows:

$$ACS \text{ of Positive Emotion} = \sum_{t=1}^m CV(t), \text{ if } Coherence(t) = 2 \text{ and } HRA = 0 \quad (2)$$

$$ACS \text{ of Peaceful Emotion} = \sum_{t=1}^m CV(t), \text{ if } Coherence(t) = 1 \text{ and } HRA = 0 \quad (3)$$

$$ACS \text{ of Negative Emotion} = \left| \sum_{t=1}^m CV(t) \right|, \text{ if } Coherence(t) = 0 \text{ and } HRA = 0 \quad (4)$$

Therefore, the occupied percentage of positive and negative emotions can be respectively formulated as follows:

$$\text{Positive Emotion} = \frac{\text{ACS of Positive Emotion}}{\text{ACS of Positive Emotion} + \text{ACS of Peaceful Emotion} + \text{ACS of Negative Emotion}} \times 100\% \quad (5)$$

$$\text{Negative Emotion} = \frac{\text{ACS of Negative Emotion}}{\text{ACS of Positive Emotion} + \text{ACS of Peaceful Emotion} + \text{ACS of Negative Emotion}} \times 100\% \quad (6)$$

5. Experimental results

This section statistically tests the three hypotheses (Section 4.1). Section 5.1 assesses whether learners' emotions differ significantly when learners view different multimedia materials. Section 5.2 confirms whether learning performance is significantly different when learners view different multimedia materials. Section 5.3 determines whether learning performance is affected significantly when learners have differing emotions.

5.1. Statistical tests of hypotheses 1

Tables 2 and 3 show descriptive statistics of the emotions of verbalizers and visualizers for the three multimedia materials, respectively. Interestingly, the percentage of negative emotion is ranged in about 60%–75% percent no matter what cases. It is thus clear that learning activities frequently lead to stress (*i.e.*, negative emotion) during learning processes. That is, appropriate stress may have been a necessary factor in a meaningful learning activity. Based on these descriptive statistics, this study applies one-way analysis of variance (ANOVA) to assess differences in emotional states of verbalizers and visualizers who were presented with the three multimedia materials. Analytical results show that differences in the emotional states of verbalizers and visualizers were significant, regardless of whether emotional states are positive (verbalizers, $F = 2.714$, $p < .05$; visualizers, $F = 2.884$, $p < .05$) or negative (verbalizers, $F = 2.301$, $p < .05$; visualizers, $F = 2.567$, $p < .05$). Thus, this study analyzes the impact between positive emotions and negative emotions associated with each multimedia material via the Scheffe test in one-way ANOVA with a *post hoc* multiple comparison for hypothesis 1. Tables 4 and 5 show comparison results for positive and negative emotions of verbalizers who were presented with the three different multimedia materials. These comparison results confirm that the video-based multimedia material had a greater effect in retaining a positive emotion than static text and image-based multimedia material, and animated and interactive multimedia material when verbalizers were already in a positive emotional state; however, this study could not determine whether static text and image-based multimedia material and animated and interactive multimedia material is better in maintaining a positive emotional state. When verbalizers were in a negative emotional state, static text and image-based multimedia material and animated and interactive multimedia material had a significantly greater ability to generate a negative emotional state than video-based multimedia material. These analytical results suggest the video-based multimedia material generated the most positive emotion for verbalizers; while static text and image-based multimedia material and animated and interactive multimedia material generated the more negative emotions in learners. Obviously, the video-based multimedia material caused emotions of verbalizers to vary more than did static text and image-based multimedia material and animated and interactive multimedia material.

Tables 6 and 7 show comparison results of positive and negative emotions of visualizers who were presented with the three different multimedia materials, respectively. Analytical results show that regardless of whether the emotional state of a learner is positive or negative, the emotions of visualizers did not differ significantly when they were presented with the three multimedia materials. The likely reason is that the three learning materials presented material visually, and contained images, videos, or/and animation. This design characteristic may lead visualizers to generate similar variations of emotions. Therefore, no significant difference between positive and negative emotions is reasonable, even though visualizers were presented three different multimedia materials.

5.2. Statistical tests of hypotheses 2

To identify the correlation between learning performance and different multimedia materials in hypothesis 2, this study first applied the one-way analysis of variance (ANOVA) to respectively assess whether the prior knowledge (*i.e.*, pretest score) of energy education of verbalizers and visualizers who were presented with the three multimedia materials differed significantly. Analytical results show that the prior knowledge of energy education of verbalizers and visualizers who were presented with the three multimedia materials did not differ significantly. Thus, this study further applied the paired sample *t*-test to identify learning performance based on the difference between pretest and posttest scores. Table 8 shows assessment results for learning performance of verbalizers and visualizers who were presented with the three different multimedia materials by the paired sample *t*-test. Analytical results confirm that the learning performance of verbalizers who were presented with the video-based multimedia materials improved significantly ($t = 2.81$, $p < .01$); however, the learning performance of verbalizers who were presented with the static text and image-based multimedia material ($t = 1.69$, $p > .05$) and animated and interactive multimedia material ($t = 1.12$, $p > .05$) did not improve significantly. Moreover, the learning performance of visualizers who

Table 2
Descriptive statistics of verbalizers' emotions corresponded to three different multimedia materials.

| Emotion state | Type of multimedia material | Number of learners | Emotion mean (%) | Emotion std. dev. (%) |
|------------------|---|--------------------|------------------|-----------------------|
| Positive Emotion | The static text and image-based multimedia material | 25 | 15.75 | 14.71 |
| | The video-based multimedia material | 27 | 24.25 | 17.28 |
| | The animation interaction-based multimedia material | 21 | 11.42 | 9.57 |
| Negative Emotion | The static text and image-based multimedia material | 25 | 71.96 | 18.45 |
| | The video-based multimedia material | 27 | 62.40 | 18.27 |
| | The animation interaction-based multimedia material | 21 | 75.01 | 13.13 |

Table 3

Descriptive statistics of visualizers' emotions corresponded to three different multimedia materials.

| Emotion state | Type of multimedia material | Number of learners | Emotion mean (%) | Emotion std. dev. (%) |
|------------------|---|--------------------|------------------|-----------------------|
| Positive Emotion | The static text and image-based multimedia material | 29 | 17.75 | 15.55 |
| | The video-based multimedia material | 31 | 19.28 | 13.77 |
| | The animation interaction-based multimedia material | 27 | 19.32 | 17.61 |
| Negative Emotion | The static text and image-based multimedia material | 29 | 69.30 | 18.24 |
| | The video-based multimedia material | 31 | 67.31 | 15.66 |
| | The animation interaction-based multimedia material | 27 | 66.23 | 16.91 |

were presented with the video-based multimedia material ($t = 2.35$, $p < .05$) and the animated and interactive multimedia material ($t = 3.08$, $p < .01$) improved significantly; however, the learning performance of visualizers who were presented with the static text multimedia material did not improve significantly ($t = 1.12$, $p > .05$), implying that video-based multimedia material generated the best learning performance, meeting the educational objective for energy learning. That is, regardless of whether verbalizers or visualizers were presented video-based multimedia material, learning performance had significant effects. Obviously, dynamic multimedia materials containing video and animation, such as video-based multimedia material and animated and interactive multimedia material, are most appropriate for visualizers.

5.3. Statistical tests of hypotheses 3

Table 9 summarizes correlations between emotions and learning performance for visualizers who were presented with video-based multimedia material by Pearson correlation coefficient analysis for hypothesis 3. Experimental results indicate that emotion and learning performance were strongly correlated only for visualizers who were presented with video-based multimedia material for energy education learning (positive emotion, $p < .05$; negative emotion, $p < .01$). The correlation coefficients for positive and negative emotions were 0.378 and -0.482 , respectively. Thus, this study applies stepwise multiple regression analysis with pretest score, positive emotion, and negative emotion as independent variables; posttest score was the dependent variable. Table 10 shows analytical results, confirming that negative emotion only ($R = 0.48$, $p < .01$) or pretest score and negative emotion combined ($R = 0.60$, $p < .01$) can predict the learning performance of visualizers who are presented with video-based multimedia material for energy education learning. When using the variable negative emotion for forecasting learning performance, the explained variance of video-based multimedia material was 23%. The prediction variable was the negative emotion ($\beta = -0.04$, $p < .01$). Furthermore, when using both pretest score and negative emotion to forecast learning performance, the explained variance of video-based multimedia material was 36%. The primary prediction variable was pretest score ($\beta = 0.38$, $p < .05$), and the secondary prediction variable was negative emotion ($\beta = -0.04$, $p < .01$).

6. Discussion

This section discusses several issues. First, experimental results demonstrate that video-based multimedia material generates the best learning performance and the most positive emotions for verbalizers. Clark and Paivio (1991) indicated that pictures elicit higher ratings of

Table 4

Comparison of the positive emotions of verbalizers who were presented with three different multimedia materials by the Scheffe test of one-way ANOVA with post hoc multiple comparison.

| Emotion state | Cognitive style/the used multimedia material (I) | Cognitive style/the used multimedia material (J) | Mean difference (i – j) | p value | Result |
|------------------|--|--|-------------------------|---------|---|
| Positive Emotion | Verbalizer/static text and image-based multimedia material | Verbalizer/video-based multimedia material | –8.50 | 0.037* | Verbalizer/video-based multimedia material > Verbalizer/static text and image-based multimedia material |
| | | Verbalizer/animated interaction-based multimedia material | 4.33 | 0.315 | – |
| | Verbalizer/video-based multimedia material | Verbalizer/static text and image-based multimedia material | 8.50 | 0.037* | Verbalizer/video-based multimedia material > Verbalizer/static text and image-based multimedia material |
| | | Verbalizer/animated interaction-based multimedia material | 12.83 | 0.003** | Verbalizer/video-based multimedia material > Verbalizer/animated interaction-based multimedia material |
| | Verbalizer/animated interaction-based multimedia material | Verbalizer/static text and image-based multimedia material | –4.33 | 0.315 | – |
| | | Verbalizer/video-based multimedia material | –12.83 | 0.003** | Verbalizer/video-based multimedia material > Verbalizer/animated interaction-based multimedia material |

*indicates $p < .05$; **indicates $p < .01$.

Table 5
Comparison of the negative emotions of verbalizers who were presented with three different multimedia materials by the Scheffe test of one-way ANOVA with post hoc multiple comparison.

| Emotion state | Cognitive style/the used multimedia material (I) | Cognitive style/the used multimedia material (J) | Mean difference (i – j) | p value | Result |
|------------------|--|--|-------------------------|---------|---|
| Negative Emotion | Verbalizer/static text and image-based multimedia material | Verbalizer/video-based multimedia material | 9.56 | 0.036* | Verbalizer/static text and image-based multimedia material > Verbalizer/video-based multimedia material |
| | | Verbalizer/animated interaction-based multimedia material | –3.05 | 0.528 | – |
| | Verbalizer/video-based multimedia material | Verbalizer/static text and image-based multimedia material | –9.56 | 0.036* | Verbalizer/static text and image-based multimedia material > Verbalizer/video-based multimedia material |
| | | Verbalizer/animated interaction-based multimedia material | –12.61 | 0.009** | Verbalizer/animated interaction-based multimedia material > Verbalizer/video-based multimedia material |
| | Verbalizer/animated interaction-based multimedia material | Verbalizer/static text and image-based multimedia material | 3.05 | 0.528 | – |
| | | Verbalizer/video-based multimedia material | 12.61 | 0.009** | Verbalizer/animated interaction-based multimedia material > Verbalizer/video-based multimedia material |

*indicates $p < .05$; **indicates $p < .01$.

Table 6
Comparison of the positive emotions of visualizers who were presented with three different multimedia materials by the Scheffe test of one-way ANOVA with post hoc multiple comparison.

| Emotion state | Cognitive style/the used multimedia material (I) | Cognitive style/the used multimedia material (J) | Mean difference (i – j) | p value | Result |
|------------------|--|--|-------------------------|---------|--------|
| Positive Emotion | Visualizer/static text and image-based multimedia material | Visualizer/video-based multimedia material | –1.53 | 0.682 | – |
| | | Visualizer/animated interaction-based multimedia material | –1.58 | 0.685 | – |
| | Visualizer/video-based multimedia material | Visualizer/static text and image-based multimedia material | 1.53 | 0.682 | – |
| | | Visualizer/animated interaction-based multimedia material | –0.04 | 0.992 | – |
| | Visualizer/animated interaction-based multimedia material | Visualizer/static text and image-based multimedia material | 1.58 | 0.685 | – |
| | | Verbalizer/video-based multimedia material | 0.04 | 0.992 | – |
| | | | | | |
| | | | | | |

emotionality than do words. Mayer (2001) and Reiss's (2007) findings also confirmed the instructional effects of video-based multimedia material in learning. Restated, this analytical result does not support the ATI hypothesis, which states that verbalizers learn best with verbal instruction, but is consistent with findings in studies by Massa and Mayer (2006) and Kollöffel (2011). Restated, learners should not choose learning material based on their preference, because they may select a format that is not effective for learning. Additionally, experimental results show that dynamic multimedia materials containing video and animation, such as video-based multimedia material and animated

Table 7
Comparison of the negative emotions of visualizers who were presented with three different multimedia materials by the Scheffe test of one-way ANOVA with post hoc multiple comparison.

| Emotion state | Cognitive style/the used multimedia material (I) | Cognitive style/the used multimedia material (J) | Mean difference (i – j) | p value | Result |
|------------------|--|--|-------------------------|---------|--------|
| Negative Emotion | Visualizer/static text and image-based multimedia material | Visualizer/video-based multimedia material | 1.99 | 0.635 | – |
| | | Visualizer/animated interaction-based multimedia material | 3.07 | 0.480 | – |
| | Visualizer/video-based multimedia material | Visualizer/static text and image-based multimedia material | –1.99 | 0.635 | – |
| | | Visualizer/animated interaction-based multimedia material | 1.08 | 0.801 | – |
| | Visualizer/animated interaction-based multimedia material | Visualizer/static text and image-based multimedia material | –3.07 | 0.480 | – |
| | | Verbalizer/video-based multimedia material | –1.08 | 0.801 | – |
| | | | | | |
| | | | | | |

Table 8

Summary results of learning performance assessment for verbalizers and visualizers who were presented with three different types of multimedia materials by pair sample *t*-test.

| Cognitive style | The used multimedia material | Performing evaluation | Number of Learners | Mean | Std. dev. | <i>t</i> | <i>p</i> value |
|-----------------|---|-----------------------|--------------------|------|-----------|----------|----------------|
| Verbalizer | The static text and image-based multimedia material | pretest | 25 | 7.84 | 1.70 | 1.69 | 0.091 |
| | | posttest | 25 | 8.36 | 1.47 | | |
| | The video-based multimedia material | pretest | 27 | 7.33 | 1.71 | 2.81 | 0.005* |
| | | posttest | 27 | 8.30 | 1.54 | | |
| Visualizer | The animated interaction-based multimedia material | pretest | 21 | 7.48 | 2.25 | 1.12 | 0.262 |
| | | posttest | 21 | 8.05 | 1.80 | | |
| | The static text and image-based multimedia material | pretest | 22 | 7.59 | 1.50 | 1.12 | 0.264 |
| | | posttest | 22 | 8.09 | 1.57 | | |
| | The video-based multimedia material | pretest | 18 | 7.22 | 1.63 | 2.35 | 0.019* |
| | | posttest | 18 | 8.11 | 1.49 | | |
| | The animated interaction-based multimedia material | pretest | 26 | 7.00 | 1.92 | 3.08 | 0.002** |
| | | posttest | 26 | 8.31 | 1.76 | | |

*indicates $p < .05$; **indicates $p < .01$.

Table 9

Correlation between emotional states and learning performance for visualizers who were presented with video-based multimedia material by Pearson correlation coefficient analysis.

| Cognitive style/the used multimedia material | | | Positive emotion | Negative emotion | Posttest |
|--|----------|---------------------------------------|------------------|-------------------|----------|
| Visualizer/video-based multimedia material | Posttest | Pearson correlation <i>p</i> value | 0.378 0.036* | −0.482 0.006** | 1 |

*indicates $p < .05$; **indicates $p < .01$.

Table 10

Results of stepwise multiple regression analysis for visualizers who were presented with the video-based multimedia material under considering the pretest score and negative emotion as independent variables and the posttest score as dependent variable.

| Cognitive style/the used multimedia material | Model summary | | | | ANOVA | | Standardized coefficients | | |
|--|---------------|-------------------|----------|-----------------------|----------|-------|---------------------------|----------|----------------|
| | Model | Selected variable | <i>R</i> | <i>R</i> ² | <i>F</i> | Sig. | β distribution | <i>t</i> | <i>p</i> value |
| Visualizer/video-based multimedia material | 1 | Negative Emotion | 0.48 | 0.23 | 8.80 | 0.006 | −0.04 | −2.97 | 0.006** |
| | 2 | Pretest | 0.60 | 0.36 | 7.92 | 0.002 | 0.38 | 2.37 | 0.025* |
| | | Negative Emotion | | | | | −0.04 | −2.95 | 0.006** |

*indicates $p < .05$; **indicates $p < .01$.

and interactive multimedia material, are more appropriate for visualizers than static multimedia material, such as static text and image-based multimedia material. This experimental result partially supports the visualizer–verbalizer hypothesis of Mayer and Massa (2003), stating that visualizers process pictorial representations more effectively than word-based representations; however, there was not support that verbalizers process words more effectively. Moreover, analytical results support the ATI hypothesis, stating that visualizers learn best with visual instruction methods. In sum, this study claims that no matter what students' preferences of cognitive styles are, designing learning materials as video-based multimedia material may be a better approach when incorporated in the right multimedia design, because video-based multimedia material can facilitate students' positive emotion and learning performance.

Further, many education scholars have demonstrated that emotions directly affect learning performance (Goleman, 1995; Piaget, 1989); the study findings partially support this view. Particularly, this study demonstrates that negative emotion and pretest score combined and negative emotion alone can predict the learning performance of visualizers who are presented video-based multimedia material. That is, this study shows that learner negative emotions affect their learning performance more than positive emotions when presented with video-based multimedia material. The result is consistent with findings in study by Lang (1984). That is, high imagers have stronger physiological reactions to imagined emotional situations than do low imagers. Moreover, the negative emotion (stress) may have been a necessary factor during learning processes, but giving learners too much stress may result in an unchanged learning performance.

Finally, some study limitations merit consideration. First, this study uses a single topic and single set of multimedia materials, such that research results cannot be transferred readily to other learning topics and multimedia materials. Second, this study focused only on a particular age group of children in assessing the effects of different multimedia materials on emotion and learning performance. Thus, research results cannot be applied to other age groups with different cognitive skills and affective experiences.

7. Conclusions

The study investigates whether different multimedia materials lead to significant differences on emotion and learning performance for learners with visual and verbal cognitive styles, and examines the relationship between learning performance and emotion. Experimental results show that emotion of verbalizers is strongly affected by only video-based multimedia material; however, the emotion of visualizers is not strongly affected by the three multimedia materials in the study. Moreover, experimental results only indicate that visual learners should be given dynamic multimedia materials containing video and animation, such as video-based multimedia material and animated and interactive multimedia material. Notably, video-based multimedia material is appropriate for verbal learners. That is, the ATI hypothesis is partially supported by the finding that visualizers learn best with visual instruction methods, whereas verbalizers learn best with verbal

instruction methods. Moreover, this study demonstrates that video-based multimedia material generates the best learning performance, as it positively affected the learning performance of both visualizers and verbalizers. Finally, this study confirms that a correlation exists between emotion and learning performance for visualizers who were presented video-based multimedia material for learning. Although many studies have claimed that learning emotion directly affects learning performance, analytical results are only partially supported in the case of negative emotion. This study determines that negative emotion alone, and pretest score and negative emotion combined, can predict the learning performance of visualizers who use video-based multimedia material for learning.

Moreover, additional studies are warranted. First, learning attention is another factor that may affect learning performance (Wickens & McCarley, 2008). That is, a learner who has a positive emotion and focuses on learning may achieve good learning performance. Learning attention can be potentially assessed using a system that monitors human–computer interactions such as the eye-tracking system (Mayer, 2010) and brainwave system (Haapalainen, Kim, Forlizzi, & Dey, 2010). In addition to assessing the effects of different multimedia materials on emotion and learning performance for students with verbal and visual cognitive styles, future studies can explore other cognitive styles, such as sensing and intuition, associated with information processing (Felder, 1993). Moreover, in addition to realizing the relationships between learner emotions and learning performance, a future study should explore the relationship between learner emotion and cognitive load for a relatively more in-depth and multi-dimensional understanding of multimedia materials. Also, this study served the two subscales of the SOP as a single scale to identify all participants as verbalizers and visualizers based on the suggestion of Childers et al. (1985). The participants who have the SOP scores that are higher and lower than the mean SOP score are identified as visualizers and verbalizers, respectively. Further work can consider identifying verbalizers and visualizers by more extreme approach than does the current approach, such as identifying the participants with highest SOP scores (top 27%) as visualizers and lowest SOP scores (lowest 27%) as verbalizers. Finally, based on understanding the relationships between emotions and learning performance of learners with different cognitive styles, who were presented with different multimedia materials, an emotion-based adaptive multimedia learning system can be developed for supporting personalized learning.

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