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The Impact of Affective Tutoring System and Information Literacy on Elementary School Students' Cognitive Load and Learning Outcomes

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Abstract: In this study, an affective tutoring system (ATS) is developed by integrating dengue fever prevention courses with an intelligent tutoring system (ITS) under a semantic identification module for a teaching experiment. A one-group pretest-posttest research design is adopted for this teaching experiment, which involves 66 research participants and lasts for two weeks. Further, students are divided into a high score group and a low score group based on students' information literacy and cognitive load, and nine students are selected to participate in a focus group interview. Our research team uses a "primary school information literacy questionnaire" and a "primary school student's cognitive load scale", qualitative research methods, and auxiliary quantitative research methods to cross-verify the effect of the dengue fever prevention affective tutoring system on the cognitive load and learning outcomes of primary school students with different level of information literacy.

According to results of this study, both qualitative and quantitative analysis endorse the hypothesis that the dengue fever prevention affective tutoring system enhances students' learning outcomes. Students with varied information literacy show significantly different cognitive load, yet there is no significant difference in students' overall cognitive load, content of cognitive load, and learning outcomes. Quantitative analysis shows partially significantly negative correlation between students' information literacy and cognitive load, yet the correlation between students' information literacy, cognitive load, and learning outcomes is not endorsed by quantitative analysis.

Keywords: Affection Tutoring System, Intelligence Tutoring Systems, dengue fever, information literacy, cognitive load

1. Introduction

Dengue fever, which is rampant in southern Taiwan every summer, is an acute infection transmitted by the bite of a mosquito infected with dengue viruses. Due to the general public's inadequate knowledge of mosquito species that transmits dengue fever, the time when these mosquitos are active, and how dengue transmission happens, people tend to pay little attention to environmental hygiene and end up aggravating the severity of dengue fever outbreaks in metropolitan areas. To reinforce the promulgation of dengue fever prevention knowledge, the government is devoted to advocating the importance of dengue fever prevention in schools at all levels. In this study, our research team observed that in the course of receiving traditional indoctrination, students may be subject to various influencing factors, develop negative emotions in the process of learning, and end up having learning outcomes that are below expectation.

Given that a growing number of recent studies have pointed out the important impact of emotions on learning, we suggest integrating an affective tutoring system (ATS) with courses of dengue fever prevention, which involves discerning students' emotional state in the process of interacting with students, giving timely feedback, and adjusting the pace of teaching. Such teaching mode can only be performed through students' human-computer interaction. At present, students are accustomed to being surrounded by abundant information. Nevertheless, whether students are equipped with better information literacy to minimize cognitive load caused by an overall curriculum in the process of learning, sources of such cognitive load,

along with the interplay between students' cognitive load and learning outcomes are still what researchers are curious about. As such, with the aid of the innovative teaching mode, we propose to examine the interplay of cognitive load and learning outcomes of students with dissimilar information literacy in students' learning process. Through this study, we also aspire to suggest more diverse promotion approaches of dengue fever prevention to teachers in the field of education.

2. Literature Review

2.1 ITS & ATS

An intelligent tutoring system (ITS) is a system which provides students with personalized guidance or direct feedback through computer analysis (Sarrafzadeh, 2002). Knowledge of an intelligent tutoring system is constructed by three modules: a student module made up of students' knowledge, a tutoring module made up of teaching-related knowledge, and an expert module made up of knowledge in specific fields. Further, knowledge of an intelligent tutoring system and the user interface module are integrated to make a comprehensive intelligent tutoring system structure (Koedinger& Corbett, 2006). Also, an intelligent tutoring system, which determines the content and methods of teaching based on individual students' characteristics, is like a real tutor. As such, an intelligent tutoring system enjoys more advantages as it provides useful, uncritical, and tailor-made feedback (Anderson, Corbett, Koedinger, & Pelletier, 1995; Johnson, Rickel & Lester, 2000).

Affective tutoring systems, which are developed from intelligent tutoring systems, are expected to improve intelligent tutoring system and further make intelligent tutoring systems like a real tutor, adapt to learners' emotional state, and help learners learn effectively (Sarrafzadeh et. al., 2003; Alexander, Sarrafzadeh & Hill, 2006). A tutoring research group at the University of Memphis attempted to add emotional components into the AutoTutor of an intelligent tutoring system and used this system to conduct a test on approximately 1,000 learners with physics or computer background knowledge. The result was that learners had achieved remarkable learning outcomes in both surface-level knowledge and deeper learning (Craig, Graesser, Sullins & Gholson, 2004). Moreover, in the course of real teaching and teaching through an intelligent tutoring system, learners' common emotions such as joy, frustration, surprise, curiosity, wonder, etc. had stronger correlation with and made great impact on learners' learning experiences (Burleson & Picard, 2004; Craig et al., 2004; D'Mello et al., 2008; Graesser et al., 2006). On the other hand, Picard's research put forward a conceptual module which could affect learners' emotions while learning, identify learners' emotional state, give timely feedback, and improve learners' learning (Picard, Kort & Reilly, 2001).

2.2 Identifying semantics and emotions in Chinese language

Through natural language processing and semantic analysis, we could effectively understand the semantic content, acquire correct information from the semantic content, and assist to identify emotions (Yan, Bracewell, Ren& Kuroiwa, 2008; Quan & Ren,2009). This is because subsequent actions such as emotion recognition and feedback could only be performed after the acquisition of correct information. However, in practice, semantic and emotion recognition methods would vary according to a sentence or an article's hierarchical structure (Kao et.al,2009; Quan &Ren,2010; Xu, Meng &Wang,2010).

Calix(2012) extracted descriptive texts from fairy tales and incorporated these texts into the Support Vector Machines (SVM) training corpus, determined learners' emotions based on learners' textual inputs of learners after training, and let a specially-designed 3D character model show corresponding emotional responses based on learners' emotions. In 2009, Goh & Huang mentioned about using text mining algorithms to search for wordings which convey negative emotions on blogs as a way to prevent teenage depression and suicide incidents.

Sun, Chen, Liu, Liu & Soo(2010) used the Chinese word segmentation system developed by Academia Sinica Institute of Information Science to segment words and phrases. Also, the popular social networking site "Plurk" was used as the source where words and phrases were gathered from. Further, the collected short Chinese phrases were categorized based on these phrases' emotions and the characteristic lexicons were converted to vectors and joined with a probability model, which was from the semantic dictionary developed by the Natural Language Processing Laboratory at National Taiwan University, to form a hybrid model to analyze emotions of short Chinese phrases. As indicated by studies in recent years, results of research on Chinese semantic identification technology have been good. Marvelous progress in Chinese semantic identification technology has strengthened its potential of enhancing the effectiveness of emotion recognition research.

3. Research Method

3.1 Research Architecture

With the one-group pretest-posttest design as the research design and the research framework in Figure 1, this study proposes the following three hypotheses:

H1: Teaching by means of an affective tutoring system can enhance students' learning outcomes.

H2: Students with varied information literacy would experience significantly different cognitive load while receiving teaching through an affective tutoring system.

H3: Students with varied information literacy would have significantly different learning outcomes after receiving teaching through an affective tutoring system.

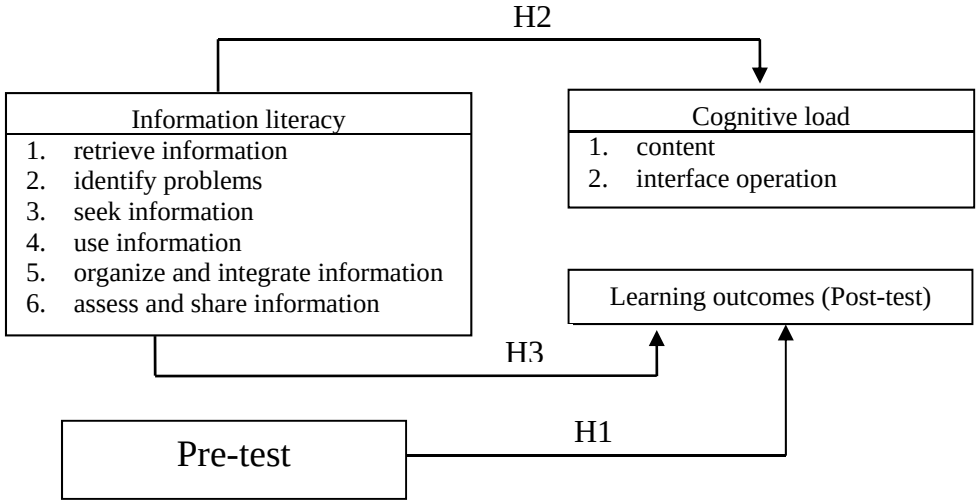

Figure 1 Research Architecture

3.2 Participants and Instrument

77 students in grades 5-6 from a public primary school in Kaohsiung were chosen as research participants in this study. 77 questionnaire copies were distributed and 70 questionnaire copies were collected, a response rate of 91%. After four invalid questionnaire copies with incomplete data or answers were removed, 66 valid questionnaire copies were left, an effective response rate of 94%.

Research instruments of this study include: an affective tutoring system about dengue fever prevention, a primary school students' information literacy questionnaire, a primary school students' cognitive load scale, and a quiz of students' dengue fever prevention knowledge.

3.2.1 Affective Tutoring System about dengue fever prevention

Other than using dengue prevention courses designed and distributed by the environmental protection administration as teaching materials, our research team also added the module of semantic and emotion recognition and relevant modules to this teaching mode. This system,

which can be divided into affective computing and course teaching, consists of four modules: a semantic identification module, a pedagogical assistant agent module, a dengue fever prevention teaching materials module, and a teaching strategies module.

(1) semantic identification module

The procedures of building a semantic identification module under the category of affective computing include compiling a dictionary of emotions, processing semantic structures, and using Semantic Clues Emotion Voting Algorithm (SeCeVa) to identify emotions. Methods of how the semantic identification module was constructed and the operating procedures are shown in Figure 2:

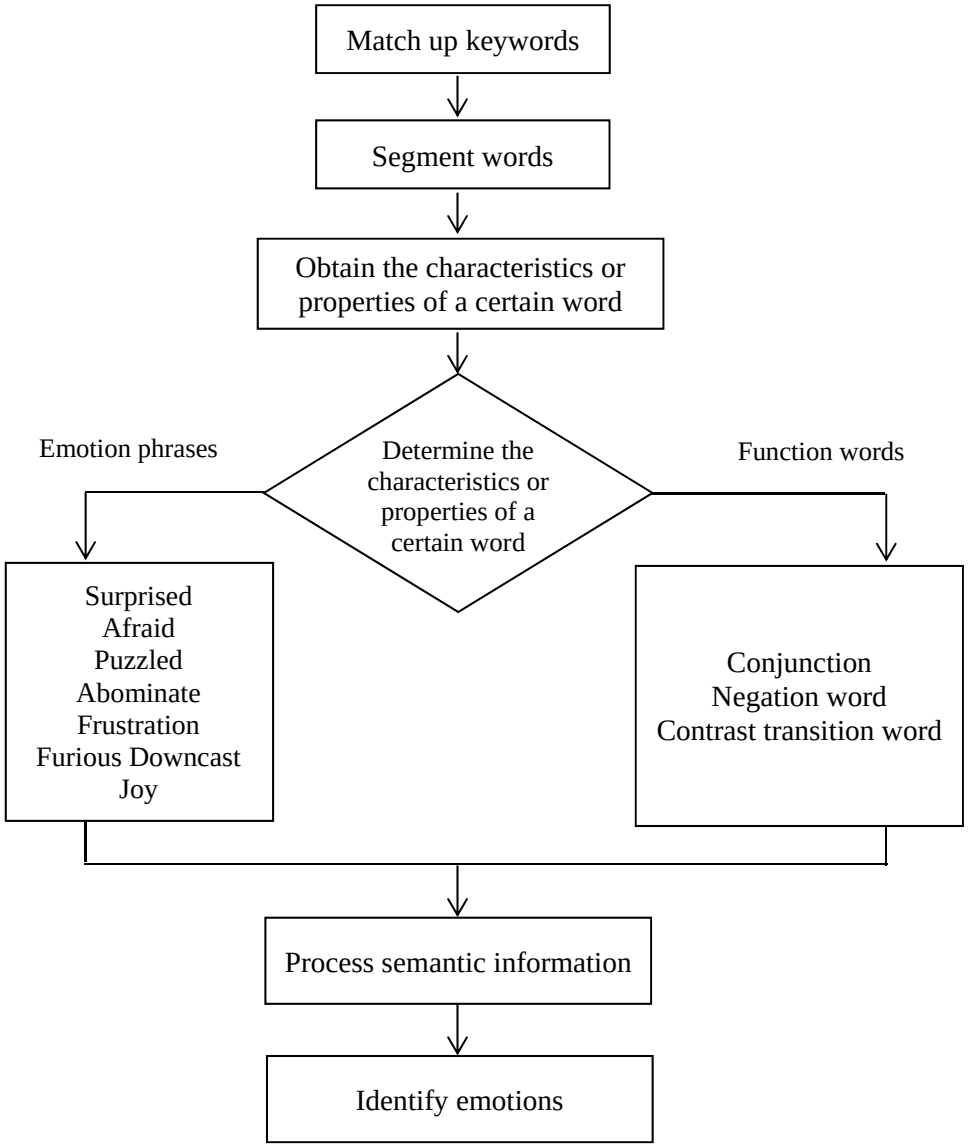

Figure 2 methods of how the semantic identification module was constructed and the operating procedures

Considering the similarity of categories of emotions and the system's promptness in perceiving learners' emotions and giving feedback, the six basic emotions proposed by Ekman (1972) and eight academic emotions proposed by Pekrun et al.(2009) were consolidated and classified to become this system's eight emotion categories derived from semantic identification. After giving definitions to each emotion, the collected emotion keywords were classified and the

characteristic or property of a certain word was marked next to the word. How the emotion keywords were consolidated is shown in Figure 3.

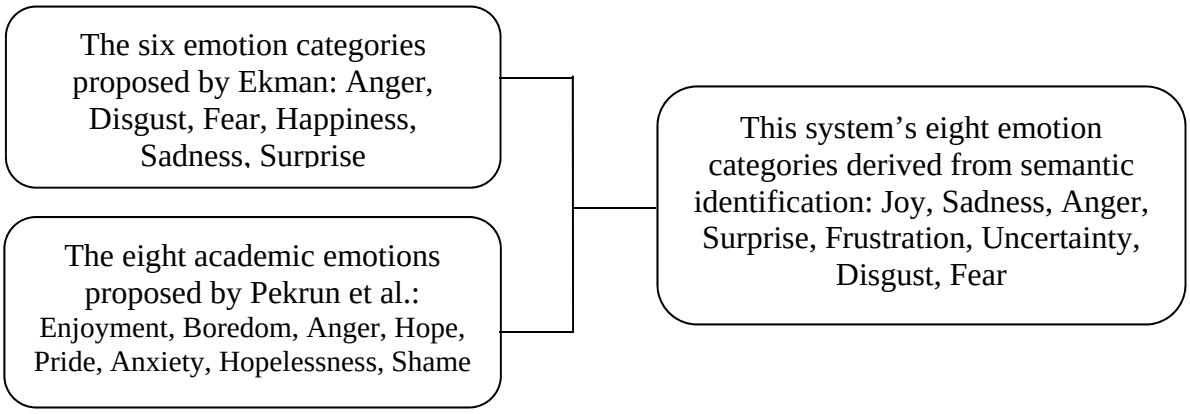

Figure 3 a flowchart of the integration of emotion keywords

(2) A pedagogical assistant agent module

A pedagogical agent, who acts as an intermediary between learners and messages from the system, could provide learners with opportune feedback through a two-way interactive mechanism which involves informing learners the system's current actions and understanding learners' needs. A screen shot showing the interaction between a learner and a pedagogical agent is shown in Figure 4.

Figure4 the interaction between a learner and a pedagogical agent

3.3 Experimental procedures

The one-group pretest-posttest research design is adopted for this study's experiment. Prior to using the affective tutoring system, students are instructed to fill out an information literacy questionnaire, take the dengue fever prevention knowledge pre-test, and receive a score from the pre-test. The same procedures are performed in each class for a total of four times. The next week, students are instructed to fill out a cognitive load assessment questionnaire, take the dengue fever prevention knowledge post-test in a computer classroom immediately after using the affective tutoring system, and receive a score from the post-test. The same procedures are also performed in each class for a total of four times, and the experiment lasts for two weeks in

total. Following the affective tutoring system-based course and questionnaires, students are divided into groups based on their information literacy. The top 27 % of students are allocated to the higher score group, the bottom 27% are allocated to the lower score group, and the remaining 46% are allocated to a new group. Further, three students are selected from each group and a total of nine students are selected to participate in a focus group interview. Also, the whole interview is recorded with a digital video camera instead of a sound recording device for better accuracy of recording. The experimental procedures are shown in Figure 5.

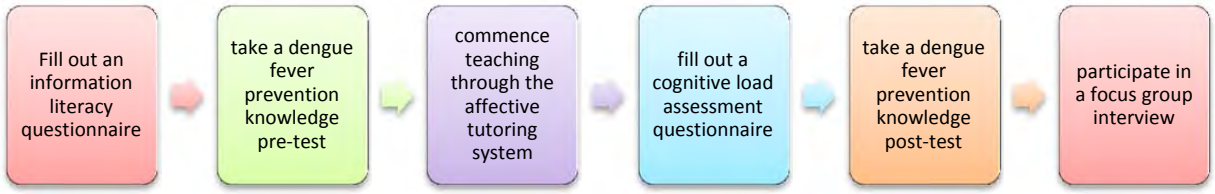

Figure5 Experimental procedures

4. Experimental results

This study aims to explore: 1. whether an affective tutoring system enhances students' learning outcomes; 2. difference in students' cognitive load in the process of using an affective tutoring system and students' learning outcomes afterwards due to students' varied information literacy; 3. the correlation between students' information literacy, cognitive load, and learning outcomes. T-test is employed to analyze students' scores at the pre-test and the post-test to compare students' learning outcomes before and after using the affective tutoring system and to test H1. Mean scores, standard deviation, and t-test results, which show students' learning outcomes before and after using the affective tutoring system, are shown in Table 1.

Table 1: Summarized statistics of students' learning outcomes

	Test	Number of students	Mean	Standard deviation	T value
Learning outcomes	Pre-test	66	76.73	14.50	-4.357***
	Post-test	66	84.73	11.38	

***p<.001

As shown in Table 1, "H1: teaching by means of an affective tutoring system can enhance students' learning outcomes" is supported as students' mean score on the post-test is higher than the mean score on the pre-test. Also, the quantitative data and results of qualitative data analysis validate each other as all students in the interview unanimously speak highly of the effectiveness of teaching by means of an affective tutoring system.

Independent sample t-test is employed to analyze the completed primary school students' information literacy questionnaire copies to find out difference in students' cognitive load and learning outcomes as well as to test "H1: teaching by means of an affective tutoring system can enhance students' learning outcomes" and "H2: students with varied information literacy would experience significantly different cognitive load while receiving teaching through an affective tutoring system." Mean scores, standard deviation, and t test results in relation to the two aspects of cognitive load and the overall cognitive load of students with varied information literacy are shown in Table 2.

As shown in Table 2, primary school students in the higher information literacy group and the lower information literacy group demonstrate significant difference of .05 on the interface operation aspect of cognitive load:. The t-value is -2.20, indicating that in comparison with students in the lower information literacy group, students in the higher information literacy group demonstrate significantly lower cognitive load on the interface operation aspect.

Nevertheless, the difference on content and overall cognitive load does not reach a level of significance, indicating primary school students' varied information literacy makes no significant difference on overall cognitive load and cognitive load on the content aspect. Further, mean scores, standard deviation, and t test results of learning outcomes of primary school students with varied information literacy are presented in Table 3. According to Table 13, difference on learning outcomes of students in the higher information literacy group and students in the lower information literacy group does not reach a level of significance, meaning that primary school students' varied information literacy does not make a significant difference on students' learning outcomes.

Table 2 Summarized statistics of the interplay between students' varied information literacy and students' cognitive load

Aspects in Relation to Cognitive Load	Information Literacy Group	Number of Students	Mean	Standard deviation	T value
Content	higher information literacy group	18	12.94	3.50	1.42
	lower information literacy group	19	11.11	4.29	
Interface Operation	higher information literacy group	18	15.06	6.88	*
	lower information literacy group	19	20.16	7.21	
Overall Cognitive Load	higher information literacy group	18	28.00	8.04	-1.25
	lower information literacy group	19	31.26	7.91	

* $p<.05$

Table 3 Summarized statistics of the interplay between students' varied information literacy and students' learning outcomes

	Information Literacy Group	Number of Students	Mean	Standard deviation	T value
Learning Outcomes	higher information literacy group	18	90.22	9.33	1.78
	lower information literacy group	19	82.74	15.38	

5. Conclusions and implications

This study aims to explore the correlation between cognitive load and learning outcomes of primary school students with varied information literacy when an affective teaching system is used. According to results of this study, the current status of students' overall information literacy is relatively good and is at an upper - intermediate level. As for each aspect of students' information literacy, students receive the highest score in the "retrieving information" aspect and the lowest score in the "assessing and sharing information" aspect, indicating students' relative strength in retrieving information yet relative weakness in assessing and sharing information. While students are using the affective teaching system, the "content" aspect of students' perceived cognitive load receives a higher score while the "interface operation" aspect receives a lower score, indicating that content causes more cognitive load for students than interface operation does. With respect to whether teaching with an affective tutoring system could enhance students' learning outcomes, statistical analysis by means of t-tests is performed on students' scores before and after receiving the affective tutoring system-assisted teaching. Results of the analysis show that students' mean scores at the pre-test and the post-test have reached a level of significance, indicating that teaching by means of an affective tutoring system could effectively enhance students' learning outcomes. However, students with varied information literacy are only different in the interface operation aspect of cognitive load yet show no significant difference in overall cognitive load and the content aspect of cognitive load. Nevertheless, a multitude of factors, which include students' intelligence, motivation to learn, learning styles, leaning attitudes, learning anxiety, parents' attitudes, and many more, may affect outcomes of teaching by means of an affective tutoring system.

Therefore, these factors may be counted as research variables in future research which explores the influence or correlation between other variables and different aspects of learning outcomes. In this way, researchers may better understand the importance of different variables on different aspects of students' learning outcomes as well as provide a reference for teachers who use an affective tutoring system to teach.

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