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The Prediction of Academic Emotions on Cognitive Load in Hypermedia Learning Environment

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***Abstract*—The purpose of current study was to investigate the prediction of academic emotions (namely, happiness, sadness, anxiety, and angry) on each type of cognitive load (namely, intrinsic load, extraneous load, and germane load). Thirty university students were involved in the experiment which required them to study the circulatory topics in hypermedia learning environment with hierarchical navigation system. The findings showed that angry positively correlated with extraneous load, happiness positively correlated with germane load, and sadness positively correlated with fixation. Discussions of present findings were focused to understand the contribution of academic emotions on cognitive performance in hypermedia learning environment context.**

Keywords—Cognitive load, academic emotions, hypermedia learning environment

I. INTRODUCTION

The capacity of human cognitive performance, particularly working memory, is discussed in cognitive load theory [1]. In learning context, cognitive load was the most important contributor for learning and performance [2]. In term of extending the cognitive load theory, Brunken, Plass and Moreno [3] suggested that the construct of cognitive load needs to be investigated by involving the construct of motivation, affection, and learning process to enrich the discussion and application of cognitive load theory. In line with their suggestions, the present study intended to clarify the affect of academic emotions on cognitive load in hypermedia learning environment. Various formats of information and learning contents, such as texts, graphs, video, animation, and audio, were provided in hypermedia environment and were organized in a non-linear and dynamic ways [4].

Academic emotions were identified to predict cognitive load. The finding of a study from Chen and Chang [5] in English learning context showed that anxiety positively predicted cognitive load. The other studies from Fraser, Ma, Teteris, Baxter, Wright, and McLoughlin [6] indicated that positive emotions had negative prediction on cognitive load, whereas negative emotions had positive prediction on cognitive load. Unfortunately, those two findings assessed cognitive load as a single construct. Therefore, the following question needs to be explored further: "How academic emotions affect different types of cognitive load?" The present study was oriented to clarify the contribution of academic emotions to the three types of cognitive load.

Cognitive load theory focuses on performance of working memory or short therm memory in processing information. According to Paas, vanGog and Sweller [7: 116], cognitive load was defined as the number of element information which needs to be processed in working memory before commencing meaningful learning. Learners experience cognitive load when there is information to be processed in working memory. When there is high element-interactivity of information, working memory is unable to process the information. The higher element interactivity of information leads to higher cognitive load.

There are three types of cognitive load, namely, intrinsic load, extraneous load, and germane load [8, 9]. Intrinsic load is related to the complexity of information element that needs to be processed. Extraneous load is related to irrelevant element of information with learning activity which is processed in working memory. In hypermedia learning environment, irrelevant information comes from the hypermedia design, the format of information, and the organization of learning contents. Finally, germane load is related to learners' effort devoted to process the element of information so that the information becomes meaningful knowledges.

Intrinsic load and extraneous load are addictive [8] which means that when the level of intrinsic and extraneous load are high, the capacity of working memory decreases. In contrast, when the levels of intrinsic and extraneous load are low, working memory have higher capacity to be allocated to process the other information. In addition, when extraneous load is high, the capacity of working memory for processing intrinsic load decreases, but when intrinsic load is high the capacity of working memory to process extraneous load also decreases. As implication in learning context, the intrinsic load needs to be managed so that the complexity level of information can be effectively processed, the extraneous load needs to be reduced, and germane load needs to be encouraged.

Emotions interact with cognition and motivation factors affect learning process. Pekrun [10] defined emotion as multi-component, coordinated processes of psychological subsystems including affective, cognitive, motivational, expressive, and peripheral physiological processes. Further,

Pekrun divided emotions into two types, namely activity emotions and outcome emotions. Activity emotions are emotions which occurred during learning process, whereas outcome emotions are emotions which related with the prediction of learning outcomes (prospective outcome emotions) or emotions which related with the accomplished learning outcomes (retrospective outcome emotions). Including activity emotions are enjoyment, anger, frustration, and boredom. Prospective outcome emotions consist of anticipatory joy, hope, hopeless, and anxiety, whereas retrospective outcome emotions consists of joy, pride, sadness, shame, and anger.

The impacts of academic emotions on cognitive performance were found from some studies. A study from Marchan and Gutierrez [11] showed that academic emotion predict the use of learning strategies. Furthermore, hope and anxiety positively predict the use of learning strategies, whereas frustration negatively predict learning strategies both in traditional and online learning group. Academic emotion also affected academic achievement. Enjoyment positively predict academic emotions, but anxiety and boredom negatively predict academic achievement [12, 13]. Related to the cognitive load, positive emotions negatively predict cognitive load and positive emotions positively predict cognitive load [6]. Based on those findings, it can be predicted that academic emotions will affect all types of cognitive load as a part of cognitive performance.

II. METHODS

A. Participants

Thirty university students from Department of Guidance and Counseling, Semarang State University, were involved in this experiment. Their ages ranged from 18 to 24 years old (M = 19.67, SD = 1,713). Before conducting the experiment, participants were gathered in a class to inform the research procedure and to ask their written consent for participating to the experiment.

B. Instruments

There are two instruments for assessing the cognitive load, namely cognitive load scale and eye-tracking system. Meanwhile, the academic emotions during study hypermedia content were measured using the Computer Emotions Scales.

1) Cognitive load

a) Cognitive load scale

The subjective measurement of cognitive load were assessed by applying cognitive load scales which developed by Leppink, Paas, Gog, Vleuten, and Merrienboer [14]. The cognitive load scale had 13 items with an 11-point scale from *not at all the case* (0) to *completely the case* (10). The first four items are for measuring intrinsic cognitive load, the next four items were for assessing extraneous cognitive load and the last five items were for assessing germane cognitive load. This study showed that the alpha coefficient of reliability ranged between 0.808-0.891.

b) Eye-track measurement

The current study used fixation with the parameters of duration fixation and counted fixation as indicators of cognitive load [15]. The low cost eye tracker of GP3 Desktop Eye-tracker was implemented to study 2. The tool has accuracy 0.5-1 degree of visual angels, 60 Hz sampling rate, 25cm x 11 cm (H x V) movement, and ± 15 cm range of depth movement (http://gazept.com). The eye track data during study hypermedia materials were automatically recorded and analyzed by applying Gazepoint Analysis Professional Edition.

2) Emotions

Emotions during learning hypermedia learning were assessed using the computer emotions scale from Kay and Loverock [16]. A total 12 items were applied to assess happiness (3 items), sadness (2 items), anxiety (4 items) and anger (3 items). Participants responded each item on 4-point scale ranging from none of the time (0) to all of the time (3). The coefficient alpha of computer emotions scale in the present study ranged from .733 to .760.

C. Research design and procedures

The repeated measured design [17] was applied in five steps of experiment procedures. First, participants were required to express the written consent to participate to this experiment. Secondly, participants were given overview of the experiment procedures and instructions. The experiment instructions consisted of simple guidelines to operate hypermedia learning materials and the rules of experiment, such as prohibited to open other computer program except hypermedia learning materials. Thirdly, conducting eye-track calibration by using 5-point calibration. Before calibration process, participants were asked to sit by leaning and to pay attention the moving point at monitor. Fourthly, participants registered as a new participant. During register, participants were required to make a new account and respond the demographic questions. Finally, participants read the learning objectives, studied the hypermedia learning materials, and responded the scales.

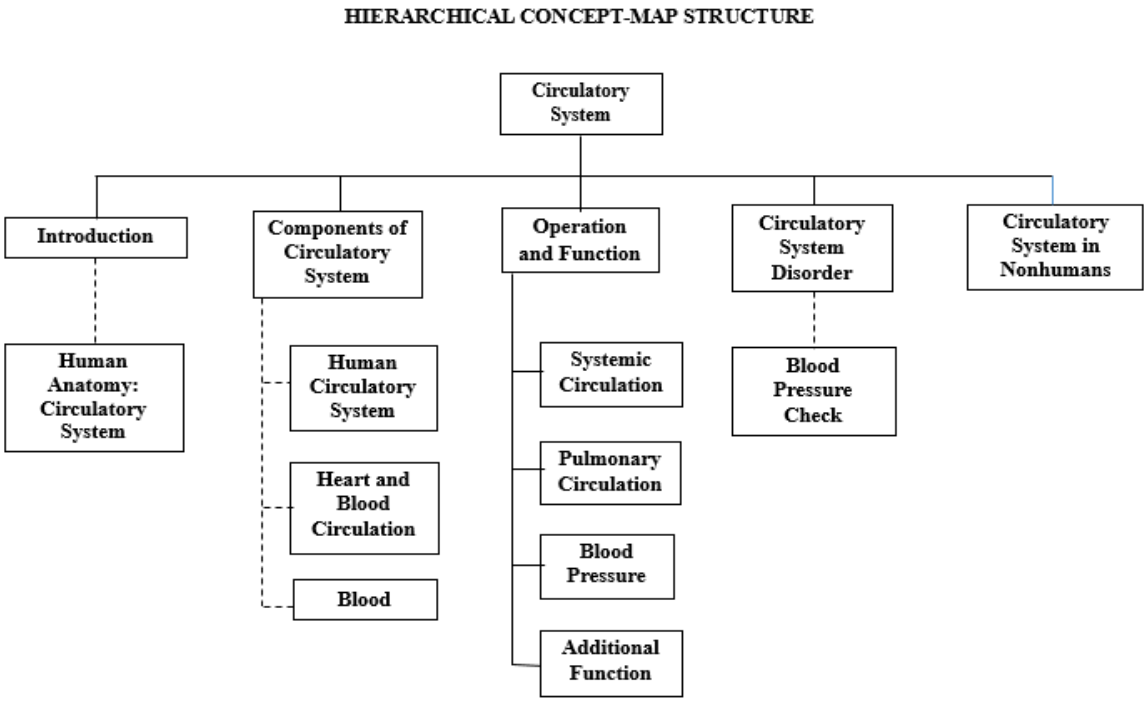

Figure 1 Hierarchical concept-map structure of navigation system

There were three learning objectives in this experiment which were shown in three steps of study period. Therefore, participants needed to mastery one learning objective for every single learning period. Before learning the hypermedia learning materials, participants were asked to read the learning objective. Participants can reread the learning objective when needed. They had enough time to study the hypermedia learning materials. When participants finished studying the hypermedia learning materials, they were asked to press the icon of "Responding Scale." Then the scale page appeared and participant can respond the cognitive load scales and emotions scale. These steps were repeated for three times.

Participants studied the hypermedia learning contents by using laptop with processor Intel i7 and 4 GB of RAM, keyboard, mouse, headset and 19 inch of LCD monitor as an external monitor. During experiment, participants sat 50 cm in front of external monitor which equipped with GP3 Destop Eyetrack System. In order to get the accurate data of eye movement, participants were required to minimalize the gaze movement during study periods, but during the responding scale periods they were allowed to make freely gaze movement. Fig. 2 showed the experimental environment.

D. The experiment materials

To conduct the experiment, researcher developed hypermedia learning materials with topics "Circulatory System." The hypermedia had hierarchical concept-map structure of navigation system (see Fig. 1) which refer to the navigation system from Amadeu, Tricot, and Marine [18]. The contents of hypermedia were adopted from Encarta Multimedia Encyclopedia [19] which was presented in English. Then, it was translated to Bahasa Indonesia. The hypermedia learning materials consist of 2793 Bahasa Indonesia words, 14 sub-topics, 1 animation video, and 7 figures.

E. Data analysis

The data were collected from three times assessment. Those data, then, were calculated the mean of each variables. This analysis produced a single data for each variable. All data analysis, namely descriptive analysis, correlation analysis, and multiple regression analysis, were implemented to the mean of each variable.

Figure 2. The experimental environment

III. Results and Discussion

A. Descriptive Data

Table 1 showed the descriptive and intercorrelation matrices. As seen on Table 1, germane load have a significantly positive correlation with happiness, but have a negative correlation with angry. Extraneous load have a significantly positive correlation with sadness and angry. Intrinsic load have a significantly positive correlation with germane load and counted fixation, but have no significantly correlation with all types of emotion. There are significantly positive correlations between all negative emotions, namely sadness, anxiety, and angry.

B. The contribution of academic emotions on cognitive load

The results of multiple regression analysis, as seen on Table 2, showed that only some emotions had significantly correlations with cognitive load. Extraneous load was positively predicted by angry ($r = .525$, $p < .01$), whereas germane load was positively predicted by happiness ($r = .502$, $p < .01$). The other findings of current study indicated that counted fixation and duration fixation were positively predicted by sadness ($r = .402$, $p < .05$; $r = .380$, $p < .05$, respectively). All types of emotions had no significant prediction on intrinsic load. Furthermore, emotions accounted explained 27.5%, variance of extraneous load, 25.2% variance of extraneous load, 16.1% variance of counted fixation, and 14.4% variance of duration fixation.

C. Discussion

The results of present study clarify the prediction of academic emotions on cognitive load. Specifically, happiness positively predicted germane load, whereas angry positively predicted extraneous load. The findings have succeeded to extend the finding of a study from Fraser et al [6]. Previously, they found that positive emotions negatively predicted cognitive load, but negative emotions positively predicted cognitive load. As cognitive load was assessed as a single construct, those findings did not provide information about impact emotions on each types of cognitive load. In contrast, present study showed the contribution of emotion on each types of cognitive load.

Findings of present study did not fully support the results of study from Chen and Chang [5]. In the study, Chen and Chang showed that anxiety positively predict cognitive load which was assessed as a single construct. However, findings of present study indicated that anxiety insignificantly predict intrinsic, extraneous, and germane load, whereas angry positively predict extraneous load. The positive prediction of angry on extraneous load reflected that angry encourage working memory to process irrelevant information with learning task.

Further, the negative impact of negative emotions, particularly angry, on extraneous load can be explained from concept of attention [20, 21, 22, 23] because angry requires working memory to process the source of information emotion [24]. Consequently, working memory performance decreased for processing learning task information.

Positive emotions, particularly happiness or enjoyment, had advantageous consequences than negative emotions. Positive emotions enable learners less distract so that they can implement the effective strategies for problem solving and information processing. The benefit impact of positive emotions on cognitive performance is relevance with the finding from a study from You and Kang [25], which showed that learners with positive emotions tend to implement various strategies, which enable them to process learning task information, and to ignore the irrelevant learning task information. In such situations, happiness facilitates optimal germane load.

TABLE 1 INTERCORRELATION METRICS, MEAN, STANDARD DEVIATION, AND ALPHA COEFFICIENTS

	1	2	3	4	5	6	7	8	9
1. Happiness									
2. Sadness	-.228								
3. Anxiety	-.046	.615**							
4. Anger	-.305	.742**	.439*						
5. Intrinsic load	.119	.211	.266	.218					
6. Extraneous load	-.348	.448*	.280	.525**	.273				
7. Germane load	.502**	-.332	-.083	-.435*	.462*	.109			
8. Counted fixation	-.110	.402*	.066	.182	.387*	.170	.198		
9. Duration fixation	-.137	-.380*	.124	.147	.331	.104	.165	.967**	
Mean	2.426	.111	.631	.112	2.426	.920	3.307	858.111	318.190
SD	.679	.206	1.168	.205	.679	.738	.687	343.992	136.534
Á	.736	.733	.742	.760	.829	.891	.808	-	-

** p < .05* *** p <.01*

TABLE 2 THE REGRESSION ANALYSIS RESULTS

	Intrinsic load	Extraneous load	Germane load	Counted fixation	Duration fixation
Happiness	-.105	-.232	.502**	-.021	-.056
Sadness	-.034	.103	-.258	.402*	.380*
Anxiety	.201	.065	-.122	-.251	-.151
Anger	.078	.525**	-.342	-.189	-.218
F (1,28)	.650	10.664**	9.416**	5.388*	4.727*
r^2	.094	.275	.252	.161	.144

** p < .05* *** p <.01*

The finding which showed that the insignificant correlation between academic emotions and intrinsic load was unsurprisingly because intrinsic load explain the complexity of information which come from information itself that need to be processed in working memory. Accordingly, academic emotions will not increase or decrease the complexity information.

The eye-track data and cognitive load scales showed that both counted fixation and duration fixation had significantly positive correlation with intrinsic load. However, the regression analysis showed that only sadness had significantly positive correlation with counted and duration fixation. Therefore, it is necessary to further investigate the validity of cognitive load by using eye-track techniques and scales.

IV. LIMITATION AND IMPLICATIONS

Present study succeeded to clarify correlation between academic emotions and cognitive load. Findings of present study specifically showed that happiness positively predict germane load, and angry positively predict extraneous load. Sadness have positive correlation with counted and duration fixation.

However, the current study had some limitations. First, participants' prior knowledge affect cognitive load, but it was not controlled. Therefore, further studies which explore the impact academic emotions on cognitive load should be conducted by controlling prior knowledge. Secondly, present study applied correlation study so that it is needed experimental study to demonstrate the effect of academic emotions on cognitive load. Finally, cognitive load predict learning performance and achievement, but it was not involved in current study. Further study should be oriented to explore the impact of academic emotions on cognitive load and students' learning performance simultaneously.

There are two practical implications from present findings. First, teachers need to consider and manage learners' emotions during learning so that students enjoy the learning process. Secondly, hypermedia design should attract learners to read hypermedia contents but less stimulate extraneous load.

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