J. Korean Earth Sci. Soc., v. 39, no. 4, p. 349−360, August 2018
https://doi.org/10.5467/JKESS.2018.39.4.349
ISSN 1225-6692 (printed edition)
ISSN 2287-4518 (electronic edition)

An Analysis of the Effects of Learning Stress for Inquiry Activities in College Earth Science Course

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Abstract: This study analyzed variations of learning stress by comparing the salivary cortisol levels of students who participated in Earth Science inquiry activities. The cortisol concentrations between the pre- and post-inquiries of the sample of 34 university students, who had taken the course of 'Basic Earth Science and Experiments', were analyzed. The Earth Science inquiries consisted of geology and astronomy activities. The observational geology activities consisted of a session of 'structure contours and map patterns' and the cognitive astronomy activities consisted of a session of 'representations of horizontal and equatorial coordinates'. These Earth Science inquiry activities were found to cause students to have anxiety, and the thought processes that these activities involved were found to cause learning stress. The variations in cortisol concentrations of students increased by 1.6±5.9 ng mL^{-1} after conducting observational activities in geology compared with 2.1±6.2 ng mL^{-1} after doing cognitive activities in astronomy. The analysis of the observational activities in the geology inquiry activities indicated that they were consistent with low levels of learning stress. Conversely, the analysis of the cognitive activities in the astronomy inquiry activities showed significant individual variations in cortisol concentrations. Furthermore, individual differences in cognitive ability were reflected in the astronomy inquiry activities. While students, who received high scores, exhibited low levels of stress in the geology inquiry activities, they showed high levels of stress in the astronomy inquiry activities. It was concluded that, in the case of students with high scores in the study, the level of learning stress increased due to the raised anxiety in cognitive inquiry activities. In contrast, students, who received low scores in the study, exhibited high levels of stress in the geology inquiry activities, and low levels of stress in the astronomy inquiry activities.

Keywords: learning stress, inquiry in Earth Science, cortisol, observational activity, cognitive activity

Introduction

Stress is a physical or psychological factor that causes bodily or mental tension. Stress manifests in various forms depending on internal and external environmental conditions or stressors (Pacak and Palkovits, 2001). Stress creates various physical and emotional conditions such as fatigue, depression, and anxiety. A moderate amount of stress may actually keep a person alert and motivated, allowing the person to accomplish more than they would otherwise. However, excessive stress disrupts performance and contributes to the development of negative symptoms on the body.

When a stressor has exceeded an individual's limit, symptoms of stress develop with physiological, psychological, and behavioral aspects. For example, stress can trigger physiological responses such as rapid breathing or an elevated heart rate. It can also cause cognitive functions to dull or cause one to feel anxious psychologically (Cohen, 1980; Kalman and Grahn, 2004). Additionally, stress symptoms may manifest in the form of behavioral aspects such as a lack of enthusiasm or an evasion of responsibility (Chandler and Shermis, 1985). Peer studies have mainly analyzed stress by simply viewing it as a

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physiological response to external conditions and have explained it from physiological perspectives such as heartbeat and blood pressure. However, stress is a set of complex symptoms which arise from a variety of causes. Stressors require a careful scrutiny of their physiological, psychological, and behavioral impact.

Additionally, stress often occurs in fields where people are exposed to the pressure to perform and succeed. It is not uncommon for both students and teachers to be exposed to stressful situations in educational settings (Glaser, 1982; Kudielka et al., 2009). An excessive amount of pressure builds up with the multitude of exams and evaluations that students undergo. Furthermore, stress may have a critical impact on learning processes, which are at the heart of the educational system (Joels et al, 2006; Vogel and Schwabe, 2016). Beyond their relevance in educational contexts, stress-induced alterations in learning are also thought to contribute to stress-related mental disorders, such as post-traumatic stress disorder (DuBois et al, 1992; MacGeorge et al., 2005). These stress-induced changes may explain some of the difficulties of learning under stress in the classroom.

In response, a large number of studies have been conducted to better understand how stress affects learning (Pritchard and Wilson, 2003; Schwabe et al., 2012). Recognizing and understanding students' learning stress is important in building an effective educational environment by incorporating the teaching and learning process (Sajaniemi et al., 2012). Considering a wide range of possible stress effects in educational settings, strategies are needed to deal with the issue of stress. While studies have been conducted on the relationship between learning stress and the level of scholastic achievement in the process of teaching and learning where cognitive activities are principally required, studies on learning stress in the field of Earth Science are few and far between.

Furthermore, while recent literature agrees on the relevance of high cognitive processes, there is disagreement on the relevance of behavioral processes. There are various arguments on whether behavioral processes should be high or low when acquiring knowledge in the process of teaching and learning (Mayer, 2009; Renkl and Atkinson, 2007). While studies have found that behavioral processes are required for successful knowledge acquisition (Chi, 2009; Peeck, 1993), studies have also found that behavioral processes interfere with learning when learners must participate in a simple cognitive process (Renkl and Atkinson, 2007). Additional studies have argued that both cognitive and behavioral processes promote learning equally (Mayer, 2009). Therefore, this study compared the degree of stress of cognitive processes plus behavioral processes.

The standardized stress influence on the reaction of biochemical parameters can be objectified as being especially relevant. Since stress and stress-related health impairments have become major concerns, investigations into the biological pathways in stress are of major importance. When the hypothalamus-pituitary-adrenal gland (HPA) system is activated in a physical response to a stressor exceeding an individual's limit, cortisol is released in the body (Goodyer et al., 2001; Hucklebridge et al., 2005). As cortisol is secreted, blood pressure and the blood sugar levels rise, and the levels of fatty acids and amino acids increase in the blood (Zhou et al., 2004). Cortisol in the blood is mostly composed of 'binding proteins' and some 'unbound free forms' to a lesser degree (Kurz et al., 1977). Since unbound free forms of cortisol enter the salivary glands in the form of diffusion in proportion to the amount used in other tissues, cortisol in the saliva reflects the degree to which it acts on the body (Read, 1993; Vittek, 1985).

Therefore, this study analyzed variations of learning stress for inquiry activities in the Earth Sciences by comparing salivary cortisol levels of learners. Learning stress attendant upon inquiry activities was analyzed, and the effects of learning stress were explained on achievements of inquiry activities in Earth Science. For this, the cortisol concentrations between pre- and post-inquiry activities of university students, and the effects of learning stress on the manipulative activities were analyzed. This study established research objectives and analyzed them as follows:

First, how do cortisol concentrations change due to learning stress in Earth Science inquiries?

Second, how does learning stress affect achievement levels in Earth Science inquiries?

Method and Materials

Participants

Thirty-four undergraduate students (17 females and 17 males), aged 20-26 years with a mean age of 21.6, participated in the study (Table 1). It was determined to be valid to analyze the results of adults who show a comparatively steady level of change in cortisol concentrations (Gunnar et al, 2009). Therefore, the participants were told to eat moderately and to not drink for two hours before the experiment. There were no smokers among the participants. Furthermore, experimentation was done on a day without course-work, when students were not stressed from academic requirements. As criteria for being part of the experiment, participants had taken a course on 'Basic Earth Science and Experiments' last semester. The full course is composed of lectures and experiments in Earth Science including geology, astronomy, the atmosphere, and the oceanography.

Table 1. Demographic information of participants (n=34)

Variable	Item	Frequency	Percent (%)
Gender	Male	17	50.0
	Female	17	50.0
Age	under 20	2	5.9
	21-25	28	82.3
	Over 26	4	11.8
Achievement in previous semester	A (91-100)	8	23.5
	B (81-90)	14	41.2
	C (71-80)	12	35.3

Sampling saliva and analyzing cortisol

The saliva samples of the students between the pre- and post-inquiries in geology and astronomy were collected in the course on 'Basic Earth Science and Experiments' (Fig. 1). Saliva was sampled after conducting experiments in geology and astronomy. Except for the time allotted to the analysis of cortisol, all conditions were maintained before and after the inquiry activities to minimize the impact of other variables. The remainder of the time was allotted to students to maintain a stable state of mind without external stimuli before collecting saliva samples. The inquiry activities were conducted for 60 minutes in geology and astronomy, respectively, so that each session would take 100 minutes.

Stress can be analyzed by means of self-reporting

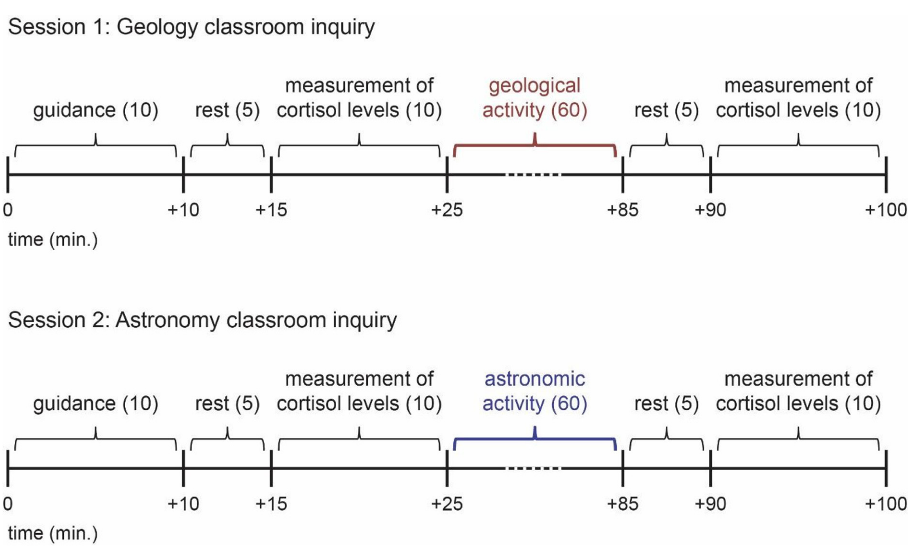

Fig. 1. Research procedure in geology and astronomy class inquiry.

and physiological measurements. Various questionnaires for self-reporting were developed so that they could be measured without special equipment. However, the results of the analysis of a self-report may be biased depending on the subject's intentions (Kopp et al., 2009). There are two recent reviews on workplace stressors and neuroendocrine responses. One focused on physiological changes in blood and urine while the other focused on the cortisol awakening responses (Chandola et al., 2010). The measurement of physiological changes in the blood has a disadvantage in that the process of collecting the samples could affect the subject.

In this study, to analyze the effects of learning stress on Earth Science inquiry activities, concentrations of cortisol were measured using Salivary Hormone Analysis (SHA), which analyzes stress by means of biochemical indicators. To accurately measure cortisol concentrations, saliva must be collected without the presence of blood. It is easy to collect saliva samples repeatedly regardless of place or equipment (Hellhammer et al., 2009; Clements and Parker, 1998). For the current study, approximately 2 mL of saliva were collected in sterilized tubes before and after the Earth Science inquiries. The saliva, stored at $-80.0^{o}C$ in a frozen state, was measured using an Enzyme-Linked ImmunoSorbent Assay (ELISA). A competitive ELISA method was used to adsorb a protein antibody on the surface of an ELISA plate and confirm the color development reaction. The optical density of the sample was measured at 450 nm and the average value was calculated by measuring 25 times per plate. The optical density value was substituted into the quantitative equation to calculate the cortisol concentrations.

Briefly, the ELISA plates were coated with monoclonal antibody against corticosterone (EastCoast Bio, North Berwick, ME) for 1hr. at a final concentration of 5 μg/mL in sodium carbonate/bicarbonate buffer adjusted to pH 9.6. The ELISA plates were blocked for 1hr. with 2% (w/v) bovine serum albumin dissolved in phosphate buffered saline (PBS). Plates were washed with PBS/Tween (0.5%) solution, 100 μL of standard Cortisol (Sigma-Aldrich Korea, Seoul) solutions and samples were added to the plates, then the 1/500-diluted cortisol-HRP conjugate (EastCoast Bio, North Berwick, ME) solution was added to each well immediately. The plates were incubated for 1 hr. at room temperature with shaking. The plates were washed, and then 0.1 mg/mL TMB solution in phosphate/citrate buffer were added to each well. The reactions were stopped with 2M H_2SO_4 solution. The O.D at 450 nm was measured using Infinite M200 (Tecan, Switzerland).

Consideration should be given to sampling cortisol in saliva at appropriate intervals after a stressful situation. Studies have reported that cortisol secretion reaches its peak after 10-20 minutes of stress (Levine, 2007). However, the time to reach the peak of cortisol secretion is different according to the stressor (Lopez-Duran, 2009). Therefore, it was very important to determine the sampling time for the stress. In this study, enough time was spent to secrete saliva in consideration of geology and astronomy inquiry activities.

Course context

The necessity of transforming a traditional approach of teaching Earth Science to an Earth Systems approach has been advocated by many Earth Science educators and reflected in the efforts to develop numerous system-oriented education projects (Nam, 2016). Through inquiry activities in Earth Science, students should learn how to conduct a scientific inquiry to develop a better understanding of the process (Shin, 2012). This process of learning would be useful for understanding Earth Science phenomena. Meaningful learning outcomes occur because of the learner's activity during learning. General activity processing can be characterized by behavioral and cognitive engagement. Figure 2 represents the two kinds of active learning in behavioral activity and cognitive activity (Mayer, 2009). It describes separate dimensions varying in intensity from low to high. A combination of behavioral and cognitive activity can be illustrated in a 2×2 cross tabulation with four

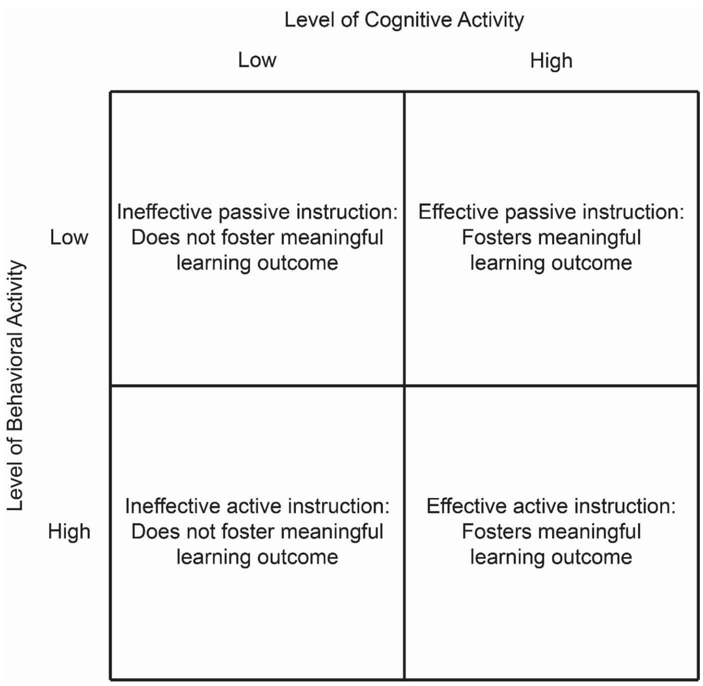

Fig. 2. Two kinds of meaningful learning (Mayer, 2009).

Table 2. Selection of pure cognitive processes and cognitive processes plus behavioral processes in Earth Science

Sessions	Processes	Topic
Solid Earth	Pure cognitive processes	Understanding the Earth using seismic waves
	Cognitive processes plus behavioral processes	Structure contours and map patterns*
Atmosphere and Ocean	Pure cognitive processes	Understanding Coriolis Effect
	Cognitive processes plus behavioral processes	Creation and analysis of weather chart
Space	Pure cognitive processes	Representations of horizontal and equatorial coordinates*
	Cognitive processes plus behavioral processes	Sun's azimuth and altitude change

*Selected topics

quadrants. Two scenarios are expected to encourage learning in pure cognitive engagement and cognitive engagement plus behavioral activity.

In this study, Earth Science inquiry activities included pure cognitive processes and cognitive processes plus behavioral processes were carried out. Topics with clear characteristics of pure cognitive processes and cognitive processes plus behavioral processes were selected in Solid Earth, Atmosphere and Ocean, Space from a course on 'Basic Earth Science and Experiments' at the first-grade level (Table 2). Topics of 'structure contours and map patterns' and 'representations of horizontal and equatorial coordinates' was selected from the processes listed in Table 2. One science education expert and three science teachers participated in setting the inquiry topic through discussions. The inquiry topic was characterized by pure cognitive processes and cognitive processes plus behavioral processes.

For the cognitive activity plus behavioral activity scenario, prompts required observational inquiry activities. Activities were composed of observational inquiries of mapping and interpreting a geological map in the classroom (Table 3). An understanding of the concept of structural contour lines made it possible to create and interpret a geological map. The geology activities consisted of the structure contours and appearance of planar beds on a geological map. The

Table 3. Inquiry Activities Overview

Sessions	Cognitive processes plus behavioral processes	Pure cognitive processes
Subject	Geology	Astronomy
Experimental topic	Structure contours and map patterns	Representations of horizontal and equatorial coordinates
Activities	1. Measuring strike and dip 2. Drawing boundary lines of bed and geological section 3. Making geological models	1. Understanding the celestial sphere 2. converting astronomical coordinates system 3. Calculate the movement of heavenly bodies
Outputs	Geological models of geological sections	Worksheets about the concept of celestial motion
Experiment method	Students make a geological model using various materials based on the geological section.	Students place the celestial body into absolute and relative coordinates to determine the position and motion of the celestial bodies.

Table 4. Scoring criteria by question

Rating	Standard
5 (exceptional performance)	Creative and above expectations
4 (highly effective performance)	Completely satisfies learning objectives
3 (effective performance)	Almost satisfies learning objectives
2 (partially effective performance)	Inadequate to achieve learning objectives
1 (ineffective performance)	Unable to achieve learning objectives

*Effective is the expected level of performance.

main topic of geology session is ‘structure contours and map patterns’. In the geology inquiry of this study, students measured strike and dip and constructed structure contours from outcrop patterns. They drew boundary lines of bed and geological sections, and made a geological model using various materials based on the geological section. The output of geological inquiries were geological models of geological sections. The process of mapping the geological map using the structural contour lines involved observational inquiry activities.

For the cognitive activity scenario, prompts required cognitive inquiry activities that included cognitive thought. Astronomy inquiries require an understanding of coordinate systems for placing celestial bodies (Table 3). The main topic of the astronomy session was ‘representations of horizontal and equatorial coordinates’. In the astronomy inquiry of this study, students understood the celestial sphere, converted astronomical coordinates system. Students placed the celestial body into horizontal and equatorial coordinates to determine the position and motion of the celestial bodies. Additionally, they calculated the movement of heavenly bodies. The output of astronomy inquiries were worksheets about the concept of celestial motion. Specifying positions of celestial objects involved cognitive activities to recognize and use wide patterns and spaces. The activities were composed of cognitive inquiries that set up the method of the experiment and obtained the results only by cognitive thought processes.

Scoring process

The process of deriving scores which emerged from the inquiries in geology and astronomy was as much a part of the method as the analysis of the effects of learning stress. Reasonable and reliable assessment methods are one of the most prominent issues in science education (Lee and Lim, 2002). A test was conducted for each of the two sessions of geology and astronomy inquiries. The scoring was done in 4 steps; set scoring criteria, criteria reviewed and revised, pre-applied and revised, main scoring, and comparison of scoring results. One science education expert and three science teachers participated in establishing the scoring criteria. Each session consisted of 5 questions. Each question was evaluated in 5 states as shown in Table 4. Five states were named as exceptional performance, highly effective performance, effective performance, partially effective performance, and ineffective performance. These states were based on textbooks and analysis of inquiry activities.

The scoring was conducted twice at intervals of one month. The second scoring result was used as the final scoring result. The scores in the geology and astronomy activities were marked by two Earth Science teachers. Inter-rater agreement was defined as the percentage of cases in which two reviewers classified a specific variable for a given proposition in the same way. The kappa coefficient will equal 1 if there is perfect agreement, whereas 0 is what would be expected by chance alone. The inter-rater agreement results were all relatively high for geology (κ=0.82, >0.05) and astronomy (κ=0.77, >0.05) activities in each variable.

Results

Learning stress involved in inquiry activities in Earth Science

The average cortisol concentration was 9.4±7.05 ng mL^{-1} before engaging in the inquiry activities, compared with 11.3±6.77 ng mL^{-1} after participating in the inquiry activities in geology and astronomy. As a rule, daily changes in cortisol concentrations show the highest value immediately after waking up in the morning, thereafter gradually decreasing to an all-time low before bedtime (Bergh et al., 2008; Ahn et al., 2007). The standard concentrations of cortisol for adults in their 20s stood at 6.07 ng mL^{-1} (1.4-23.5 ng mL^{-1}) for men and 3.03 ng mL^{-1} for women (1.4-8.0 ng mL^{-1}) at 4 p.m. at the time this study was conducted (Adrdal and Holm, 1995). The changes in cortisol concentrations of students were within the range of the mean. This study's research indicated that there were sensitive variations in learning stress for 60 minutes.

The difference in the average of cortisol concentrations before and after the inquiry activities significantly increased to 1.6±5.9 ng mL^{-1} in geology, and 2.1±6.2 ng mL^{-1} in astronomy, respectively (Table 5). The cortisol concentrations during the geology activities, typically student-directed observational inquiry activities, were found to stay lower than in the astronomy activities. The student-led observational inquiry activities could be interpreted as less stressful than thought experiments where experimental results were obtained solely by means of cognitive activities. Emotional stress has a negative effect on inquiry activities when only cognitive stimuli at a high level of difficulty given (Tae et al., 2016). The cortisol concentrations in geology were measured to be lower than those in astronomy because the activities consisted of more student-led observational inquiry activities than the cognitive inquiry activities. Student-led inquiry activities reduced learning stress and aroused interest in learning, thus reducing cortisol concentrations (Kwon et al., 2009).

In order to analyze variations in cortisol concentrations considering individual variables of the students, the difference between the pre- and post-inquiries was measured (Fig. 3). The difference of cortisol concentrations among individual students increased at the post-inquiry activities, compared with pre-inquiry. In particular, the differences in cortisol concentrations in astronomy were larger than the differences in geology. The standard deviation of cortisol concentrations in astronomy was measured at 6.2, which is higher than the standard deviation in geology measured at 5.9.

Table 5. Pre-post comparison of the cortisol concentration in Earth Science inquiry (*<0.05)

Sessions	Testing periods	Concentration (Mean±SD, ng mL^{-1})	t	p
Geology	Before	8.8±7.85	-2.293	.025*
	After	10.4±6.82		
Astronomy	Before	10.1±6.60	-2.763	.007*
	After	12.1±6.72		

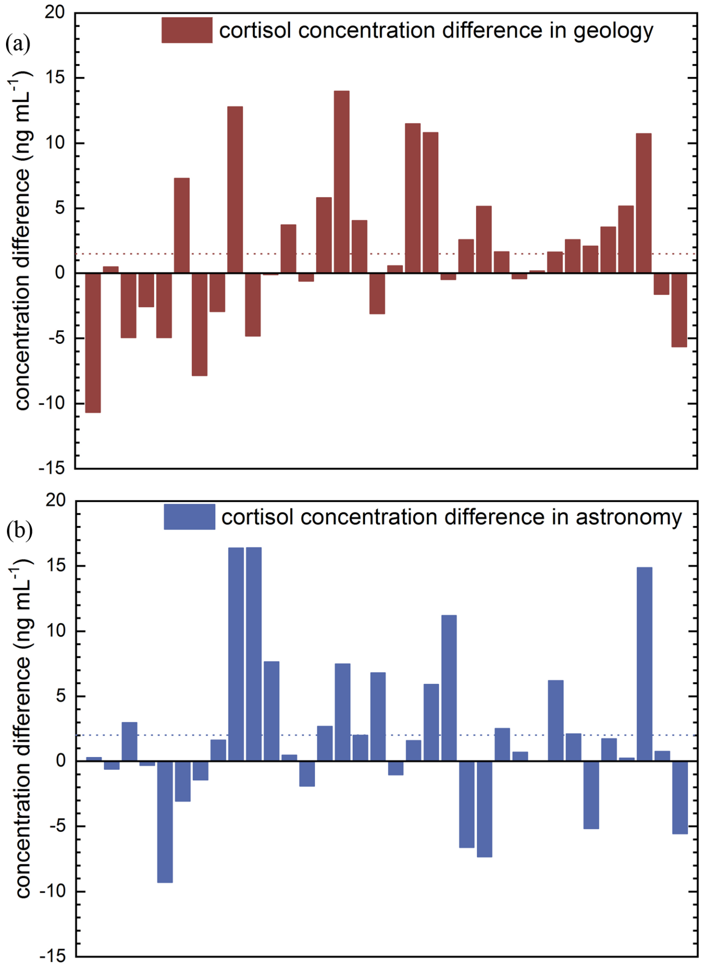

Fig. 3. Cortisol concentration difference in (a) geological activities, and (b) astronomic activities.

Effects of learning stress on achievements of inquiry activities in Earth Science

Inquiry activities in geology and astronomy were found to cause learning stress for students. Figure 4 shows the relationship between differences in cortisol concentrations and the percentile scores for the inquiry activities in geology and astronomy. The score in the geology inquiry activities registered 76.8±9.10 and the scores in the astronomy inquiry activities were 73.9±10.52. While the score had statistically positive correlations in geology, causing a relatively low level of learning stress, in astronomy, where high learning stress is involved, the stress showed statistically negative correlations. Cortisol concentrations generally manifest themselves in an inverted U-shaped curve that indicates a positive correlation up to a certain concentration, followed by a negative correlation during cognitive processes such as inquiry activities (Lupien et al., 2004). Increasing cortisol concentrations to a certain concentration point has a positive effect, but thereafter it has a negative effect on learning. Students with high levels of cortisol concentrations suffer memory and recall defects, and interference with achievements in the inquiry activities (Jegede, 1988). The cortisol concentrations of students may affect cognitive activities. The scores of students experiencing less learning stress scored higher on activities with a low level of difficulty. Conversely, they scored lower on activities with a high level of difficulty.

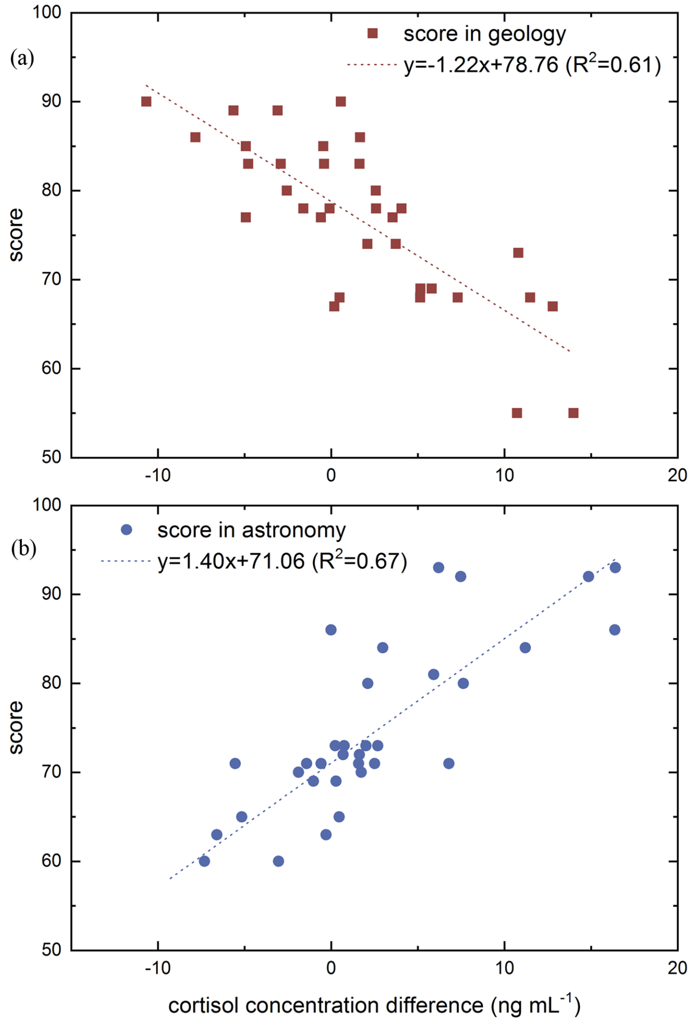

Fig. 4. Relations of the cortisol concentration difference with score in (a) geological activities, and (b) astronomic activities.

The astronomy inquiry activities were dominated by cognitive processes, but the geology inquiry activities were required cognitive processes plus behavioral processes. Behavioral processes consisted mainly of student-led inquiry activities. There was no significant correlation between gender, age, and achievement level. However, the correlation with activity type was meaningful (correlation coefficient of geology 0.61, astronomy 0.67). It was determined that the effect of stress is different according to activity types of similar difficulty (mean of geology score 76.8, astronomy score 73.9). The interviews were conducted with students whose scores differed significantly. Students were divided into high (upper 30%), moderate, low (lower 30%) according to the score of each session and interviews were conducted among the students of the upper and lower groups. Eight applicants were selected and classified into four groups according to the score of the sessions (Table 6). The A group had high scores and the D group was low in both sessions. B group had high astronomy scores, and C group had high geology scores.

The A and B groups both had high scores, the difference of cortisol concentrations was high, the C and D groups had low scores and the difference of cortisol concentrations was low in the astronomy inquiry activities. A and B groups reported that they had difficulty in understanding the motion of the sky

Table 6. Characteristics of scores and difference in cortisol concentrations in interview participants (n=8)

Sessions	A group (n=2)		B group (n=2)		C group (n=2)		D group (n=2)	
	Scores (points)	Difference in cortisol concentrations (ng mL^{-1})	Scores (points)	Difference in cortisol concentrations (ng mL^{-1})	Scores (points)	Difference in cortisol concentrations (ng mL^{-1})	Scores (points)	Difference in cortisol concentrations (ng mL^{-1})
Astronomy	89	13.8	89	15.7	69	-0.4	60	-5.2
Geology	84	-2.7	61	11.8	90	-5.1	68	6.2

at different latitudes in the astronomy inquiry activities. C and D groups also experienced difficulties in the same parts, but unlike A and B groups, they did not understand the concept. All groups experienced difficulties, but A and B groups fully understood the motion of the sky at different latitudes, whereas C and D groups did not. The A and C groups had high scores, the difference of cortisol concentrations was low, the B and D groups had low scores and the difference of cortisol concentrations was high in the geology inquiry activities. A and C groups reported that they were able to draw geological sections and able to compare the sequence of strata in the geology inquiry activities. B and D groups also understood the concept in the same parts, but unlike A and C groups, they were not interested. All groups understood the concept, but A, C groups were interested in drawing geological sections and comparing the sequence of strata, whereas B and D groups were not.

Conclusions

The effects of learning stress on Earth Science inquiry activities were analyzed through physiological measurements. The cortisol concentrations between the pre- and post-inquiries of the 34 university students majoring in science education during geology and astronomy inquiry activities were analyzed. The difference in cortisol concentrations between the pre- and post-inquiry activities was expressed as learning stress and the level of scores was analyzed as the results of observational and cognitive activities in Earth Science inquiry activities.

The average of cortisol concentrations of the pre- and post-inquiry activities increased significantly in geology and astronomy. The cortisol concentrations were found to be lower in the student-led observational inquiry activities in geology because they apparently caused less learning stress than the cognitive inquiries in astronomy that involved thought experiments. Emotional stress has a negative effect on inquiry activities when only cognitive activities with a high level of difficulty are involved. Student-led inquiry activities were shown to reduce cortisol concentrations by reducing stress while arousing interest in learning. Therefore, it can be concluded that the cognitive processes plus behavioral processes induce less learning stress in Earth Science inquiry activities than pure cognitive processes. Less learning stress enables effective knowledge acquisition. Wider individual differences in the cortisol concentrations were observed in astronomy than in geology. In astronomy, where student-led observational inquiry activities were involved to a lesser degree and learning stress was a significant factor, differences in cognitive ability were reflected on a person-to-person basis.

Lower scores in astronomy than in geology were attributed to the fact that astronomy inquiry requires more cognitive activities. The higher the scores rose in the geology inquiry activities, the lower the learning stress became. However, the more students sought to achieve higher scores in the astronomy inquiry activities, the more they exhibited learning stress. The students with high scores in the geology inquiry activities decreased cortisol concentrations because student-led observational activities reduced stress and aroused interest in learning. However, the students with low scores in the geology inquiry activities displayed increased cortisol concentrations due to the stress caused by cognitive activities. The students with high scores in the astronomy inquiry activities showed increases in cortisol concentrations due to higher task attachments and complicated cognitive processes. On the other hand, students with low scores in the astronomy inquiry activities showed decreases in cortisol concentrations due to a reluctance to perform inquiry activities which involve a complicated cognitive thinking process. The degree of learning stress varied according to the type of inquiry activity. Therefore, teaching and learning should be conducted considering the type of inquiry activity in Earth Science learning.

While stress had statistically positive correlations with scores in geology that involved a low level of learning stress, it had negative correlations with scores in astronomy that involved high learning stress. As cortisol concentrations increased, they had a positive effect on learning to a certain concentration. However, excessive cortisol concentrations caused defects in memory and recall in the process of conducting inquiry activities and interfered with achievements. The higher the learning stress, the higher the scores in the cognitive processes, whereas the lower the learning stress, the higher the scores in the cognitive processes plus behavioral processes. Stress is positively related to learning scores in the pure cognitive processes, but stress had a negative effect on learning scores in the cognitive process plus behavioral processes. Therefore, it is important to decide whether to include behavioral processes in the teaching and learning of Earth Science as learning stress changes depending on the behavioral processes.

Earth science has a variety of learning methods, including inquiry activities. This study analyzed variations of learning stress in Earth Science inquiry activities. Therefore, research for various types of teaching and learning methods is required. Also, it was difficult to control all the characteristics of students in this study. Research results can be interpreted differently depending on the characteristics of the students. And, further research is required to analyze the long-term learning stress because this study conducted only 2 sessions. The effects of learning stress on learning processes can be effectively analyzed by complementing the points indicated.

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Manuscript received: July 30, 2018
Revised manuscript received: August 20, 2018
Manuscript accepted: August 24, 2018