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Impact of open inquiry in science education on working memory, saliva cortisol and problem solving skill

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Abstract

The purpose of this study was to compare working memory, saliva cortisol hormone, and problem solving skill between students in two different contexts: Open Inquiry and Conventional Learning. The participants were consisted of two classes of 86 10th grade students, from one school during the 2011 academic year. A pretest -posttest control group design was used in the experiment. The tools were consisted of 1) salivary cortisol assay 2)The computerized assessment battery test 3)problem solving skill test. The collected data were analyzed by arithmetic mean, sd., t – test, and Hotelling T^2. The findings revealed that: after intervention 1) student's saliva cortisol hormone in Open Inquiry group was lower than Conventional group at .05 level of significance 2) student's working memory in Open Inquiry group were higher than students in Conventional group at .05 level of significance, but unable to proof about the difference of student's problem solving ability.

Keywords: Educational Neuroscience, Open inquiry, Stress, Working Memory, Problem Solving;

1. Introduction

Science education is very essential, the understanding about factors influencing on science achievement has gained much attention. Previous studies had demonstrated the strong relationship between working memory and science achievement (Danili and Reid, 2004; Gathercole et al., 2004; Tsaparlis, 2005). In addition, it has been reported that working memory also showed the positive correlation with chemistry problem test (Tsaparlis, 2005). Besides, working memory, problem solving skill is also playing a crucial role on science education in most countries (Lorenzo, 2005). Recent findings have demonstrated that working memory also influences on the problem solving capacity in science education (Solaz-Portoles, 2009). Based on the vital role of working memory both knowledge and problem solving skill in science education, numerous teaching method targeting at enhancing working memory including the reduction of stress and cognitive loaded is considered (Yuan et al., 2006).

Inquiry based teaching is an interactive process that actively engages students in learning in meaningful ways. Based on the student centered activity, we hypothesized that open inquiry could enhance working memory, decreased stress and enhanced problem solving skill. To date less scientific evidence is available. Therefore, this study aimed to determine the effect of open inquiry on the working memory, stress hormone or cortisol and problem

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solving skill. Our research question was "Will a traditional versus open-inquiry approach of the same physics topic have different outcomes on working memory, saliva cortisol, and problem solving ability for the students?"

2. Materials and Method

2.1. Participants

The participants were 86 10th grade students in two classrooms, simple random selection from three classrooms in one school in Loei Province in Thailand during the 2011 academic year. Using a simple random assignment, one class (42 students, male = 17) was treated to be an experiment group and another (44 students, male = 12) was treated to be a control group. All gave informed consent to participate in the study. For the limit of budget, we can only select 20 students from each group by simple random selection to be collected the saliva to calculate the amount of cortisol hormone.

2.2. Design

A randomized control group pretest posttest was used in the experiment. Both groups were taught the same topics (work and energy) for 3 weeks (14 hours) from the same teacher. The teacher was female, had a bachelor degree in Physics, had a science teaching license, and had an experience in teaching this subject at this level in this school for six years. The teaching strategy for the experimental group was designed in the open inquiry form (Bruck, Bretz, & Towns ,2009), while the teaching strategy for the control group was the traditional approach following the national curriculum teacher guide.

According to Bruck, Bretz, & Towns (2009), there are six characteristics represent areas of students' activities in doing science laboratory : the "problem/question" characteristic which refers to the topic of investigation, the "theory/background" characteristic which refers to all prior knowledge necessary to the investigation, the "procedures/design" characteristic refers to the experimental procedures student execute, the "results analysis" characteristic refers to how data are interpreted and analyzed, the "results communication" characterizes the manner by which data and experimental results are presented and the "conclusions" addresses whether the manual provides a summary or list of observations and results that should have been obtained in the laboratory. From these characteristics, we can determine the level of inquiry in the laboratory. The level denotes the extent to which a laboratory investigation provides guidance in term of the six characteristics. There are 5 levels of inquiry. Each level denotes a specific form of inquiry : 1) Level 0 - Confirmation level , an activity where all six characteristics are provided for students, all are in the student's manual, 2) Level ½ - Structured Inquiry, the laboratory manual provides the problem, background, procedures, and analysis by which students can discover relationships or reach conclusions that are not already known from the manual, 3) Level 1 - Guided Inquiry, the laboratory manual provides the problem, background and procedures but the methods of analysis, communication, and conclusions are for the student to design 4) Level 2 - Open Inquiry, the problem and background are provided but the procedures/design/methodology are for the student to design, as are the analysis and conclusions, 5) Level 3 – Authentic Inquiry, all the six characteristics are for the student to design.

In this experiment, both groups were taught via the 5E Learning Cycle, the teaching method recommended for teaching science by The Institute for the Promotion of Teaching Science and Technology (IPST) of Thailand, comprised of 5 steps : 1) engagement(teacher try to motivate students to be interested in the topic s/he want to teach, using some techniques until can go to the question/problem that is pre- planned and tell the students how to do the experiment or how to find the solution), 2) exploration(the students do the experiment, collect the data following the manual in textbook or worksheet and answer the guided question), 3) explanation(the students analyst the data using the method guided in the manual, make a graph or tables as designed in the manual to communicate their results, interpret the data, and make a conclusion) 4) elaboration(the teacher ask the students to relate their conclusion to previous knowledge or to other situation), and 5)evaluation (the teacher find out whether the students' understanding and abilities meet the standards or not). We use Level 2 - Open Inquiry in the exploration step so there are some contrast in other steps too. For the example, in traditional approach, after motivating the students' interest by some techniques, the teacher has to pre-lab, describe how to do lab and then bring them to the exploration step, doing the experiment following the manual, analyzing the data as guided in the manual to answer the fixed question, and then make their own conclusion (which can be found some hints in textbook). But when we use the open inquiry in the exploration step, the teacher starts like the traditional approach until they can go to the problem/question they want to find the answer, not pre lab but allow them to work in their subgroup to find or to initiate how to solve their problems by themselves so they have to design how to analyst their data and how to communicate too.

Before doing the experiment, we collected some background data to confirm the equality of participants in each group : gender, age, weight and height to calculate the body mass index (BMI),the science grade in previous semester, and IQ test raw scores, and found that there were no difference between groups.

2.3. Materials and Measures

As a tool to estimate the amount of cortisol hormone, working memory, and problem solving skill, we used the saliva cortisol assay , the working memory test, and the problem solving test, respectively.

We collected saliva (10 cc.) from each of 20 participants in each group at 7.30-8.00, freezed and sent to the Neuroscience laboratory Unit, Department of Physiology, Faculty of Medicine, Khon Kaen University for analyzing the amount of cortisol hormone.

The working memory test is comprised of four tasks from the computerized battery test which uses in clinical research at Khon Kaen University.(Wattanathorn,2008), which measures 4 components : the power of attention, the continuity of attention, the quality of memory, and the speed of memory. The tasks we selected were used in the Neuroscience laboratory Unit, Department of Physiology, Faculty of Medicine, Khon Kaen University. They are simple reaction time task, digit vigilance task , word recognition task, and picture recognition task. The students had to do these tasks via the computer. The simple reaction time task can measure the students's speed in reacting on the stimuli on the screen and it can indicate the students' attention too. The digit vigilance task can indicate the power of attention and the continuity of attention. Both the word recognition task and picture recognition task can measure the quality and speed of memory.

The problem solving test is a paper – pencil test based on Weir(1974) 4 steps of problem solving process : Statement of the Problem, Defining the Problem or Distinguishing Essential Features, Searching for and Formulating a Hypothesis, and Verifying the Solution. We used a 4 choices, 28 items, measure the ability in solving problems about work and energy, constructed by Khunprom(1991), the reliability(KR20)=0.85. We modified the test and verified it, using 48 students and found that the reliability(KR20)=0.82

We collected the data before and after intervention using the same three materials and measures above.

The collected data were analyzed by arithmetic mean, standard deviation, t – test, and Hotelling T^2 test.

3. Results

Measures were screened for missing values, outliers, and normality of distribution.

The arithmetic mean, standard deviation, and statistics t – test of cortisol hormone and problem solving ability between experimental and control group and between before and after intervention were shown in Table 1

Table 1 Mean and standard deviation of cortisol hormone and problem solving ability ; t statistics and p-value between experimental and control group and between before and after intervention

	before		after		Pair t-test	P
	$\bar{x}$	S.D	$\bar{x}$	S.D		
Cortisol hormone						
Control (n=20)	0.38	0.05	0.37	0.06	0.582	.282
Exp. (n=20)	0.39	0.04	0.26	0.04	9.468	.000*[b]
t- independent	0.280		6.837		-	
p	.391		.000*[a]		-	
Problem solving ability						
Control(n=44)	8.05	3.07	14.14	3.31	8.956	.000*[b]
Exp. (n=42)	7.50	2.08	15.38	3.64	12.184	.000* [b]

t- independent	0.970	1.660	-
p	.167	.050	-

*[a] p <.05 compared between experiment and control group
*[b] p <.05 compared between before and after intervention

. In Table 1, before the intervention, the means of the amount of cortisol hormone and the means of the problem solving ability of these two groups were not difference, but after intervention, the mean of the amount of cortisol hormone in the control group was highly than in the experimental group at .05 level of significance, but unable to proof about the difference of student's problem solving ability. However, if there were more subjects, it could have more probability to decide to have a significance difference, (p=.05).

The Hotelling T^2 test used in comparing the mean of working memory between experimental and control group before and after intervention and found that before intervention, there were no difference between group (T^2 = .089; F = .992; p = .443) but after intervention, students in experimental group had highly working memory than students in another group at .05 level of significance (T^2 = .814; F = 9.065; p = .000)
The comparison between group in each test (univariate test) were use to explore which test had the difference and found that there were difference in power of attention (from digit vigilance time : F=5.245, p= .025); Continuity of attention (from digit vigilance % of accuracy : F=4.702, p= .033); and speed of memory (from word recognition time : F=7.312, p= .008 , and picture recognition time : F=52.154, p= .000), but cannot proof the difference of quality of memory.

4. Discussion / Implication

Science learning under open inquiry approach can decreased students' learning stress, enhancing working memory, and has a tendency to promote problem solving skill. This experiment showed that after intervention, the students in experimental group who learned via the open inquiry approach had lower amount of saliva cortisol hormone from before intervention, and lower than another group. The result was in the same way as Kaewkraisorn et al.(2010) who found in their experiment that the students in experimental group who learned via the Project Based Learning in science had lower amount of saliva cortisol hormone from before intervention, and lower than students in control group, indicated that suitable learning approach had the potential to decrease students' learning stress. We used saliva cortisol as a biomarker for stress level. In this experiment, students in open inquiry group had the opportunity to decide what and how they want to inquire, while students in control group had to do lab experiment following lab manual. This may be influenced the stress level. And because stress is the essential factor in learning, if the teacher can reduce their students' stress, their students will get more learning. This experiment showed that open inquiry approach can enhancing working memory too, as we hypothesized. And it has a tendency to promote problem solving skill though we cannot proof it now.

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