The Effect of Constructivism, Metacognition and Neurocognitive-based Teaching Model to Enhance Veterinary Medicine Students' Learning Outcomes

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ABSTRACT

The purpose of this study was to examine the effects on the learning outcomes of veterinary medicine students after the intervention of constructivism, metacognitive, and neurocognitive based (CMEN) and traditional teaching models to the experimental and control groups respectively. The total participants were 84 students from Faculty of Veterinary Medicine, a public university in Khon Kaen province, Thailand. They were equally distributed to 42 students in each group on a voluntary basis. Researchers employed experimental research pre-test and post-test control group design. Results of this study showed that there was no significant difference between groups on the dependent variables before the intervention. However, all the dependent variables namely medical terminology and anatomical knowledge achievement, metacognitive ability, and working memory ability had significant differences between groups after the intervention. The developed teaching model has been proven to successfully promote students' learning outcomes. As a result, the CMEN teaching model can enhance students' abilities in understanding medical terminology, anatomical knowledge, raise their metacognitive ability, and promote their working memory ability.

Keywords: Anatomical knowledge, constructivism, metacognitive and neurocognitive-based teaching model, medical terminology, metacognitive ability, traditional teaching model, working memory ability

INTRODUCTION

Traditionally universities employ instructive forms of teaching such as lectures to convey much of the curriculum content in the pre-clinical courses of veterinary medicine and related disciplines (Lane, 2008). However, past researchers have found that the traditional teaching model not only encourages a superficial approach to learning (Canfield, 2002) but also many students are unable to effectively reason and their application of knowledge to real-life situations is less than optimal (Lane, 2008). In addition, it seems that advances in medical knowledge and biotechnology are escalating the curricular content of veterinary schools to massive sections, to the point that it could be considered impracticable to ensure that all students have a sufficient knowledge base (Doherty & Jones, 2006).

Veterinary medicine has increasingly embraced simulation and other teaching approaches as new veterinary teaching models to allow students to hone their skills on true-to-life models before moving on to live animals (Valliyate, Robinson, & Goodman, 2012). According to Englar (2017), there are a limited number of veterinary medicine teaching models in the market to train the next generation of veterinarians resulting in an unmet need and opportunity for new veterinary teaching models to be developed. In addition, the new teaching model, driven by a combination of constructivism, metacognition, and neurocognition, has become important in

veterinary education as a means to teach basic and advanced concepts along with aiding the development of cognitive and learning abilities.

Recently, researchers (Srikoon, Bunterm, Nethanomsak, & Tang, 2017; Sripongwiwat, Bunterm, Srisawat, & Tang, 2016; Tornee, Bunterm, Muchimapura, & Tang, 2017; Uopasai, Bunterm, Muchimapura, & Tang, 2017) have found that the constructivism, metacognitive and neurocognitive-based teaching model has the potential of making a significant contribution to students' learning outcomes. These researchers have successfully explored how the mechanisms of learning and cognitive development relate to educational attainment if the teaching model can be optimized. For example, Sripongwiwat et al. (2016) developed a teaching model based on constructionism which was rooted in constructivism and combined with neurocognitive learning approaches, and proved that the constructionism and neurocognitive-based teaching model had successfully promoted secondary school students' science learning outcomes, including nanotechnology content knowledge, science process skills, scientific attitudes, as well as creative thinking.

Srikoon et al. (2017) further supported the claim of effectiveness of the neurocognitive-based teaching model in enhancing students' attention, working memory, and mood. Besides, the findings of Uopasai et al. (2017) also reveal that the constructivism, metacognition and neurocognitive-based teaching model have

improved the veterinary medicine students' behavioral, electrophysiological, and achievement change in a Thailand public university. Finally, the findings of Tornee et al. (2017) indicate that the intervention of neurocognitive constructivist guided-inquiry based teaching model has made an improvement in the attention abilities of Grade 11 students. According to Nelson (2008), and Perkins and Wieman (2008), students should be helped to discover the value of evidence-based reasoning and higher-order cognitive skills, and taught to become innovative problem solvers. Thus, promoting the idea that students should be engaged in the excitement of science.

According to Akpan and Beard (2016), constructivism is a teaching model, not a theory. Instructors will constantly search for new strategies to assist their students to understand and connect to their past or present experiences when they are applying the constructivist teaching model. The constructivist philosophy of science teaching and learning is about students' mental models and their misconceptions which have important implications for instructors who wish to model scientific reasoning in an effective fashion for their students (Cakir, 2008). The growth of constructivism is an epistemological commitment and the teaching model includes aspects of Piaget's (1978), Ausubel's (1963), and Vygotsky's (1978) learning theories, namely the importance of establishing prior knowledge or existing cognitive frameworks as well as the use of relevant information to drive conceptual change.

According to Chauhan and Singh (2014), metacognition is the student's ability to use prior knowledge to plan a strategy for approaching a learning task, take necessary steps to solve the problem, reflect on and evaluate results, and modify his or her approach as needed. The metacognitive approach assists students to choose the appropriate tool for the task and plays a critical role in successful learning. In addition, metacognitive thinking is a key component in the transfer of learning. The student's development of metacognitive skills is defined as meta-learning. Meta-teaching strategies can help mediate the metacognitive skills of students and stimulate their metacognitive thinking. As a result, lecturers need to help student's metacognitive awareness and identify the factors that enhance metacognitive development.

The neurocognitive learning theory is a combination of three traditionally separate strands of inquiry, namely neurophysiology with an emphasis on the biological bases of brain and neural activity; cognitive science with a focus on information processing and internal representations of experience, and learning theory that explains how students cumulatively interact with, and adapt to, our environments (Anderson, 2009). Therefore, the fundamental principle of neurocognitive learning is that the brain actively constructs illustrations of experience at various levels through integrated 'action-reaction loop' mechanisms. Anderson further emphasized that the brain continuously engages in a constructive activity, either internally

instigating interactions among functional modules to self-regulate and initiate new internal states or assembling internal illustrations to actively perceive and incorporate incoming sensory experiences into existing systems of logic and knowledge networks.

The constructivism, metacognition and neurocognitive-based teaching model (CMEN) was developed by Uopasai (2015) by utilizing the three emerging fields, namely the constructivist philosophy of science teaching and learning, neurocognitive learning theory and metacognitive knowledge. Firstly, the idea of constructivism is to provide opportunity for students to construct knowledge by themselves. Therefore, lecturers have to focus on the student in thinking about learning (Srikoon et al., 2017). There is no knowledge independent of the meaning attributed to experience by the students. Secondly, the metacognition is another important component of the CMEN teaching model, highlighting students' inquiry and thinking (Uopasai et al., 2017). In short, lecturers' metacognitive knowledge in the context of teaching of higher order thinking skills will be the major concern. Finally, neurocognition emphasizes how the students' brains build cognitive systems from their sensory memory (Goswani, 2008).

The quality of teaching and learning in Thailand's higher education institutions are planned to support the implementation of the educational guidelines set out in the National Education Act, according to the Qualification Framework for Thailand's higher education system. This is to guarantee consistency in both standards and award titles for higher education qualifications as well as to make clear the correspondence of academic awards with those approved by any of the higher education institutions elsewhere in the world. The Thailand Quality Framework is a benchmark to assist in delivering appropriate ideas of comparison in academic standards for the institution in their planning and internal quality assurance processes (Thailand Ministry of Education, 2006). Consequently, higher education students' learning is categorized into five domains namely ethical and moral development, knowledge, cognitive skills, interpersonal skills and responsibility, and analytical and communicative skills. Meanwhile, students' achievements in the Faculty of Veterinary Medicine were found to be unsatisfactory for the past few years.

Effective teaching in learning medical terms or vocabulary in health sciences would assist veterinary medicine students to understand the origin of words, rules of creating words from etymology, memorization, radical, and finally connected words to ease the difficulties and complication of their learning. According to Veach and Holtsberry (2009), students have to understand the relationships between the terms with anatomy, physiology and clinical significance. This is further emphasized by Anderson (2009) where a process of restructuring of existing knowledge has to be sufficient in accordance with the penetration of new experience to give students an idea

of the occurring of terminology association. In short, the understanding of medical terms has to be actively created through interaction with sensory and be partly unique to the cultural and educational memorable events of the veterinary medicine students.

Pedagogical Manipulation

This study aimed to examine the learning outcomes of two teaching models, namely the CMEN and the traditional model (TM). The learning outcomes were an achievement on understanding the skeletal system of veterinary anatomy, metacognitive ability, and working memory ability (Figure 1). Both teaching models provided an equal opportunity for the instructor and students to learn how their knowledge, cognition, and emotions interact with the environment and how in both groups, change occurred through the learning process (Joyce, Weil & Calhoun, 2015).

The constructivist learning approach in this study means encouraging students to use active techniques, for example experiments, real-world problem-solving to create more knowledge and then reflect on and discuss about what they are doing and how their understanding is changing. The instructors have to understand the students' pre-existing conceptions and guides the learning activity so that they can teach their students based on the students' prior knowledge and experiences. The metacognitive learning theory is defined as the processes of planning, tracking, and assessing students' understanding or performance by facilitating their metacognitive development and

promoting the monitoring and regulation of one's own cognitive enterprises. The application of metacognitive strategies such as self-awareness and self-monitoring is to develop students who can control their own learning and learn how to learn for life. The fundamental principle of neurocognitive learning is that the brain actively constructs representations of experience at various levels through integrated 'action-reaction loop' mechanisms. Thus, the brain continuously engages in constructive activity (Anderson, 2009). Instructors have to provide the learning environment either internally initiating interactions among functional modules to self-regulate and initiate new internal states, or by mobilizing internal representations to actively perceive and incorporate incoming sensory experiences into existing systems of logic and knowledge networks.

Learning outcomes in this study are measured in three aspects namely medical terminology and anatomical knowledge, metacognitive ability, and working memory. A basic knowledge of medical terminology is an essential requirement of medical science students, namely medicine, dentistry, medical technology, nursing, and veterinary medicine. This is because they need to acquire the knowledge of medical terminology in order to proceed their studies in other subjects. Owing to the emergence of new diseases and technological advancement, medical terminology has kept on increasing adding to the students' already heavy learning load. As a result, veterinary medicine instructors need to improve their

teaching approaches to make students aware of the linkage of medical terminology and clinic (Veach & Holtsberry, 2009).

Metacognitive ability refers to the knowledge, awareness of students' ability to control and assess their own thinking processes to their intellectual thought processes and strategies (Brown, 1978; Flavell, 1979). Metacognitive ability comprises knowledge about cognition and regulation of cognition. Knowledge of cognition covers declarative, procedural, and conditional knowledge while regulation of cognition refers to a set of activities that help students to control their learning such as planning, monitoring, evaluating, information management, and debugging (Schraw & Dennison, 1994).

Working memory refers to the students' ability to process and remember information which is interconnected to a range of cognitive activities from cerebral tasks to verbal communication (Kane & Engle, 2002). Srikoon et al. (2017) defined working memory as an active system of storing information and information processing. As a result, the information must first be processed in working memory before students can remember the information (Cowan, 2005). Past researchers have proved that working memory is associated with academic attainment (Alloway & Alloway, 2010; Engel de Abreu, Conway, & Gathercole, 2010).

The CMEN model was used to teach the experimental group and the TM model was used for the control group. Both groups were taught the same content of the canine anatomy skeletal system, consisted of four chapters including a skull, fore limb bone, hind limb bones, and vertebrae. Both groups attended their lessons for a total of 20 hours. The CMEN model is an innovative teaching model which integrated the three major components of constructivism, metacognition, and educational neuroscience (Uopasai, 2015). Consequently, the CMEN model composed of six phases as follows: (i) perception and attention; (ii) objective of planning and monitoring; (iii) multisensory integration; (iv) linking; (v) rehearsal and practice, and (vi) summary and evaluation.

In the perception and attention phase, the instructor showed students a real canine skeleton along with a video projection displaying a dog's bone disorders, paralysis, walking with only two legs, and asked the students the cause of the disease. This phase could increase the students' perceptions and attention about the impact on the encoding of information in working memory (Dehn, 2008). This is followed by the planning and monitoring phase whereby the instructor informed students about the objectives of the lesson and students were expected to be able to describe the characteristics, relationship with adjacent bones, and clinical significance of the canine vertebral column. In addition, students were informed that every lesson will be accompanied by a test on the written medical terms the scores of which will in turn become part of their course evaluation. The instructor allowed them to analyze and evaluate the strategies for their own learning by handing out

written assignments and checklists which included items such as '*I set specific goals before I begin a lesson'*, '*I organize my time to be able to accomplish my goals*' etc. In the second phase, students are trained to set goals, plan, and monitor their learning strategies by themselves (Cheng, 2011; Schraw & Dennison, 1994).

The third phase is multisensory integration whereby students' polysensory cortices were stimulated with a consistent multimedia and tactile media, with real bone, simultaneously. This could cause the recognition and coding efficiency as indicated by Kim, Seitz, and Shams (2008), Alais, Newell, and Mamassian (2010), and Koelewijin, Bronkhorst, and Theeuwes (2010). In this phase, the instructor presented pictures of the various views of the vertebrae, such as cranial, caudal, dorsal, ventral, and lateral, on the screen and explained the important characteristics of each. This is coupled with an activity whereby students had to pick up the pieces of bone which they considered. The next phase is the linking phase which required students to use their prior knowledge to build medical terms with prefix, suffix, and root. The instructor presented the medical term that they learned from Phase 2 to mix the words, for example, cranial articular process. Cranial refers to the skull, articular refers to joints, and process means a bony projection of the vertebra. Therefore, cranial articular process refers to a process on the cranial side of a vertebra that serves the purpose of fitting with an adjacent vertebra. The instructor thus led the students to learn the etymology of the word combination.

The fifth phase is rehearsal and practice whereby students rehearsed and practiced the medical terms that they learned. The instructor allowed students to review a list of vocabulary by learning the different parts of the bone with their peers by taking turns within their own group either writing a post or checking the accuracy. Students' working memory was trained using provocation as a photo of the vertebrae in various perspective or orientation, and then they were randomly asked about the name of the final, semi-final, and quarter-final bones. The final phase is summary and evaluation. In this phase, students had to summarize and evaluate their content knowledge and strategies.

The traditional model (TM) is the teaching model used by the control group and is followed the TQF manual of Veterinary Medicine of this public university. The TM model composed of three phases namely introduction, instruction, and summary. The introduction phase of TM model is the same as the second phase of CMEN model. The instruction phase of TM model is divided into two sub-phases namely lecture and laboratory phase. At the lecture sub-phase, the instructor presented the picture of the various views of vertebrae such as cranial, caudal, dorsal, ventral, and lateral on the screen and explained the important characteristics. The instructor illustrated how to create new medical terms from prior ones. Likewise, in the laboratory sub-phase, the instructor distributed four to five students into each group and provided each group with a handbook titled '*Miller 's Guide to the Dissection of the Dog*' and

a box containing canine bones. They studied the vertebrae by themselves with the aid of the provided handbook.

Students were required to summarize the main idea of the gross anatomy of the vertebrae at the final phase of the TM model. The instructor gave each student a diagram thought (mind mapping) to link all the terminology. Students evaluated their understanding by matching the bones photos provided by the instructor with the picture shown on the screen. This was followed by the switching process whereby students have to evaluate their understanding by provoking other questions. Finally, students were required to write their learning planning, self-regulating learning, and self-assessment.
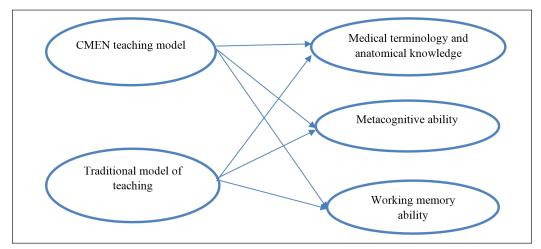

Figure 1. The effects of CMEN teaching model and traditional model of teaching on students' learning outcomes

Purposes of the Study

The purpose of this study was to examine the effect of using CMEN teaching model for promoting the learning outcomes of the students of veterinary medicine. Specifically, this study was aimed to achieve the following objectives:

1. To study the mean differences between the experimental and control groups' achievement on understanding the skeletal system of veterinary anatomy.

2. To study the mean differences between the experimental and control groups' metacognitive ability.

3. To study the mean differences between the experimental and control groups' working memory accuracy and reaction time while performing working memory tasks.

METHOD

Research Design and Study Samples

An experimental design of pretest-posttest control group was used to measure the effects of both CMEN and traditional models of teaching before and after the intervention. The design was chosen so that researchers were able to see the effects of each type of teaching model intervention on a group. However, researchers could not utilize randomization procedure to manage the groups for the intervention as it would obstruct the daily operation of the learning. Therefore, researchers had taken into consideration the confounding factors such as age, gender, and handedness to ensure the participants were equally distributed between the two groups.

A total of 84 second-year undergraduate students who enrolled in the Small Animal Anatomy course in the first semester of the academic year 2014-15 from Faculty of Veterinary Medicine in a public university located at Khon Kaen province were selected as participants. These 84 participants were equally distributed to experimental and control groups on a voluntary basis. A 2 (CMEN vs TM) x 2 (time of measure: pretest vs posttest) design was utilized in this study. Participants' learning outcomes namely achievement on understanding the skeletal system of veterinary anatomy, metacognitive ability, and working memory accuracy and reaction time were measured both before and after intervention in order to compare the effectiveness of the two teaching models.

Research Instrument

Research instruments were mainly used as tests to measure students' learning outcomes. A total of four types of instruments were utilized in this study, namely medical terminology test, anatomical knowledge test, metacognitive awareness inventory (MAI), and working memory battery test. The medical terminology test was used to measure the understanding of the medical terminology terms used to describe the dog skeletal system accurately. It was comprised of 30 items selected from the item bank of Department of Anatomy, Faculty of Veterinary Medicine, Khon Kaen University, Thailand. The reliability (KR20) was 0.91; discrimination index was 0.27 to 0.61, and difficulty index was 0.27 to 0.79. The anatomical knowledge test was used to measure the understanding of the canine skeletal anatomy which consisted of 30 multiple choice items selected from the Department of Anatomy, Faculty of Medicine, Khon Kaen University, Thailand. The reliability (KR20) was 0.86; discrimination index was 0.22 to 0.46, and difficulty index was 0.26 to 0.79.

The Metacognitive Awareness Inventory (MAI) is a rating scale used to measure two components, metacognitive knowledge (declarative, procedural, and conditional knowledge) and metacognitive regulation (planning, monitoring, evaluating, information management, and debugging) which consisted of 52 items. This instrument was adapted from Schraw & Dennison (1994) and translated from English to the

Thai language to ensure that the participants were clear about the statements. The reliability (KR20) was 0.95.

The working memory battery test was originally in Thai version and adopted from Bunterm et al. (2015) which comprised 10 tasks. The10 tasks covered: i) left-right; ii) up-down; iii) switching; iv) flanker; v) 2-words span; vi) 3-words span; vii) 4-words span; viii) o-back; ix) 1-back, and x) 2-back. This working memory battery test allowed the researchers to measure working memory accuracy and reaction time. Students were given 10 trials for each task, adding up to a total of 100 trials. The reaction time below 200 milliseconds was excluded, and data was analyzed in the range of $\overline{X}\pm3S.D.$

The 'left-right' and 'up-down' tasks are considered as binary choice reaction time tasks (CRTs) which required the participants to respond as fast as possible without errors by pressing one of the two keys. The 'switching' task required the participants to meet the stimulus of left-right and up-down tasks. The 'flanker' task is an inhibition test used to assess the ability to suppress responses which are inappropriate in a particular context. The stimulus of 'flanker' task consisted of a set of five arrows, with the target stimulus placed at the central position. The test of memory span is the Thai word span comprised 2-, 3-, and 4- words span. In the 2-, 3-, and 4- words span, Thai semantic words are presented sequentially at a rate of one per second in the center of the screen. The n-back task is a continuous performance task that comprised 0-, 1-, and 2- back tasks. Pictures of the characters in the Ramayana such as Rama, Lakshmana, Sita, and Hanuman are used as the stimulus to match the one from n-steps earlier in the sequence. Again, all the 10 tasks of the working memory battery test were in the Thai language and the goodness of fit test for construct validity purpose had been evaluated by Bunterm et al. (2015). The test-retest reliability values of these tasks were ranged from 0.822 to 0.979.

Data Analysis

Repeated measures multivariate analysis of variance (Repeated MANOVA) was used in analyzing the effect of time, teaching model, and interaction between time and teaching model on three dependent variables: medical terminology and anatomical knowledge achievement, metacognitive ability, and working memory ability. The purpose of using MANOVA is to test whether the vectors of means for the two groups are sampled from the same sampling distribution (Hair, Back, Babin, & Anderson, 2013). Wilks' lambda, a direct measure of the proportion of variance in the combination of dependent variables that is unaccounted for the group variable (Everitt & Dunn, 1991), is used to test whether there are differences between the means of identified groups of students on a combination of dependent variables.

RESULTS AND DATA ANALYSIS

Results are presented according to the purposes of the study as indicated above. The outcomes of the tests showed that there were no age ($t_{(82)} = 0.267$, $p = p>.05$),

gender (χ^2= 1.248, df = 1, p> 0.05), and handedness (χ^2 = 0.553, df = 1, p > 0.05) differences between the experimental and control groups. Thus, the experimental and control groups were identified as the same sampling distribution and appropriate to follow up with the intervention.

The results are presented in two sections namely descriptive and inferential findings. The initial findings highlight the medical terminology and anatomical knowledge achievement, metacognitive ability, and working memory ability of veterinary medicine students before and after using the CMEN and traditional models of teaching in their educational instruction. This is followed by evaluating the impact of these two teaching models on the learning outcomes of the students. Finally, the different impacts of the two teaching models are measured.

Findings of Medical Terminology and Anatomical Knowledge

A 2 x 2 multivariate analysis of variance (MANOVA) was used to examine the effects of the two teaching models on the learning outcomes of veterinary students. Results indicated that pretest vs. post-test of learning outcomes on the skeletal system of canine anatomy which consisted of achievement in medical terminology and anatomical knowledge of both the experimental and control groups are presented in Table 1. All post-test results show an increment compared to the pre-test results after the intervention any of the two teaching models.

The Box's M test for equality of variance-covariance matrices was not significant (p>0.05) and implied that the assumption of homogeneity across the group was met. Repeated-measures MANOVA analysis confirmed that there was a significant multivariate effect of the interaction between the groups and reaction time: Wilks' λ =0 .89, $F_{(2, 81)}$ = 18.53, (p<.05), partial η^2 = 0.10. In addition, findings indicated that there was a significant multivariate effect between learning outcomes which encompassed the abilities in understanding medical terminology and anatomical knowledge across the groups regardless of their reaction time: Wilks' λ = 0.81, $F_{(2, 81)}$= 9.68, p< 0.01, partial η^2 = 0.19. There was a significant multivariate effect across within-subjects time point (regardless of student group): Wilks' λ = 0 .03, $F_{(2, 81)}$ = 1426.05, p < 0.01, partial η^2 = 0.97.

When univariate tests were performed on the dependent variables, results indicated that the ability in understanding medical terminology score of an experimental group was higher than control group (regardless of time point), $F_{(1,82)}$= 7.18, p < 0.01, partial η^2 = 0.08; while anatomical knowledge score was also higher than control group, $F_{(1,82)}$= 10.53, p < 0.01, partial η^2= 0.11.

Before intervention, there is no mean difference of both dependent variables (ability in medical terminology and anatomical knowledge) between groups, Wilks' λ = 0.09, $F_{(2,81)}$ =0.24, p =.79, partial η^2= 0.01. After intervention, findings indicated that there was a significant mean difference between groups, Wilks' λ = 0.71,

$F_{(2,81)}$ =15.94, $p < 0.01$, partial η^2= 0.28. The experimental group scored higher in medical terminology ($F_{(2,81)}$ =18.36, $p < 0.01$, partial η^2= 0.28) as well as anatomical knowledge ($F_{(2,81)}$ =10. 64, $p < 0.01$, partial η^2 = 0.12) than the control group. The mean scores and standard deviation of the second-year veterinary medicine students in both medical terminology and anatomical knowledge tests, before and after intervention, are shown in Table 1.

Table 1
Pre-test vs post-test of skeletal system of veterinary anatomy achievement

Dependent variables	Experimental group (N=42)				Control group (N=42)				
	Pre-test		Post-test		t-value before intervention	Pre-test		Post-test		t-value after intervention
	M	SD	M	SD		M	SD	M	SD	
Medical terminology	7.05	3.09	22.51	1.97	0.63	6.64	2.81	20.84	1.69	4.29**
Anatomical knowledge	6.48	2.39	22.69	2.35	0.21	6.36	7.83	20.36	4.16	6.26**

**$p<0.01$

Findings of Metacognitive Ability

A 2x2 repeated MANOVA was utilized to examine the effect of the two teaching models on the metacognitive ability of the veterinary medicine students. The analysis was conducted with the repeated measure of time (before and after intervention) as the independent variables and mean score for declarative knowledge, procedural knowledge, condition knowledge, planning, monitoring, evaluating, information management, and debugging, as the dependent variables. Results revealed that there was a significant multivariate effect across the interaction between student group and time point: Wilks' λ = 0.56, $F_{(8, 75)}$ = 7.28, $p < 0.01$, partial η^2 = 0.44. There was a significant multivariate effect for between-subjects (of the combined mean score of eight components) across student group (regardless of time point): Wilks' λ = 0.86, $F_{(8, 75)}$ = 1.49, $p < 0.05$, partial η^2 = 0.14. There was also a significant multivariate effect across within-subjects time point (regardless of student group): Wilks' λ = 0.46, $F_{(8, 75)}$ = 11.25, $p < 0.01$, partial η^2 = 0.55.

When univariate tests were performed on the dependent variables, results indicated that all the components of a metacognitive ability of the experimental group were significantly higher than the control group (regardless of time point) at 0.05 significant level, except procedural knowledge of experimental group was significantly higher than control group at 0.01 significant level. Before intervention, there was no mean difference of all dependent variables

between the groups, Wilks' $\lambda = 0.97$, $F_{(8,75)}$ = 0.24, $p > 0.05$, partial $\eta^2 = 0.03$. After intervention, there was a significant mean difference between groups, Wilks' $\lambda = 0.56$, $F_{(8,75)} = 7.49$, $p < 0.01$, partial $\eta^2 = 0.44$. The mean scores and standard deviation of the metacognitive ability before and after intervention were shown in Table 2. Before the intervention, the result showed that there was no difference between the groups in all components. After the intervention, the experimental group had performed significantly better in all components of metacognitive ability than the control group.

Table 2
Pre-test vs post-test of metacognitive ability

Dependent variables	Experimental group (N=42)								Control group (N=42)							
	Pre-test		Post-test		t-value before intervention	Pre-test		Post-test		t-value after intervention
	M	*SD*	*M*	*SD*		M	SD	M	SD	
Procedural knowledge	12.88	2.06	14.98	1.55	0.10	12.93	2.18	12.81	2.16	5.28**
Conditional knowledge	17.24	2.07	19.43	1.63	0.14	17.17	2.52	17.64	2.48	3.91**
Planning	22.40	3.22	25.83	2.34	0.69	22.86	2.79	23.12	3.19	4.28**
Monitoring	21.31	3.85	25.17	2.65	0.29	21.07	3.51	22.57	2.90	4.45**
Evaluating	18.57	3.75	22.02	2.51	0.23	18.74	2.73	19.5	3.21	4.01**
Information management	34.12	5.03	39.17	3.53	0.46	34.62	4.89	34.86	5.62	4.21**
Debugging	18.21	2.93	20.81	2.28	0.45	18.48	2.36	18.24	3.54	3.96**

**$p<.01$

Findings of Working Memory Ability

Working memory was measured based on accuracy and reaction time. The mean score and standard deviation of accuracy and reaction time measured by each working memory tasks between experimental group and control group is shown in Table 3 and 4.

Accuracy. A repeated measure of time (before and after intervention) as the independent variables and the accuracy percentage of performing the working memory tasks including left-right, up-down, switching, flanker, 2-word span, 3-word span, 4-word span, 0-back, 1-back, and 2-back task as dependent variables. A 2x2 multivariate analysis of variance (MANOVA) findings confirmed that there was a significant multivariate effect for between-subjects (of the combined accuracy of 10 tasks) across student groups (regardless of time point): Wilks' $\lambda = 0.68$, $F_{(10, 73)} = 3.50$, $p < 0.01$, partial $\eta^2 = 0.32$. There was also a significant multivariate effect across within-subjects time point (regardless of student group): Wilks' $\lambda = 078$, $F_{(10, 73)} = 25.51$, $p < 0.01$, partial $\eta^2 = 0.78$. Findings also showed that a significant multivariate

effect across the interaction between student groups and time point: Wilks' $\lambda = 0.44$, $F_{(10, 73)} = 9.35$, $p < 0.01$, partial $\eta^2 = 0.56$.

When univariate tests were performed on the dependent variables, results indicated that the accuracy percentage of performing working memory tasks such as, up-down, switching, flanker, 2-word span, and 3-word span, had significantly higher accuracy than control group (regardless of time point) at $p < 0.05$. On the other hand, working memory tasks such as, left-right, 4-word span, 0-back and 1-back, were found to have higher accuracy than the control group at $p < 0.01$. Before intervention, there was no mean difference of all dependent variables (reaction time of 10 working memory tasks) between groups, Wilks' $\lambda = 0.86$, $F_{(10,73)} = 1.19$, $p = 0.31$, partial $\eta^2 = 0.140$. After

intervention, there was a significant mean difference between groups, Wilks' $\lambda = 0.47$, $F_{(10,73)} = 8.20$, $p < 0.01$, partial $\eta^2 = 0.53$. The experimental group was found to obtain higher accuracy level than the control group in almost all the tasks except flanker task. The mean scores and standard deviation of the accuracy percentage of the 10 working memory tasks before and after intervention are shown in Table 3.

Reaction Time. To order for the reaction time of performing the working memory tasks including left-right, up-down, switching, flanker, 2-word span, 3-word span, 4-word span, 0-back, 1-back, and 2-back task as dependent variables, a repeated measure of time (before and after intervention) is the independent variables.

Table 3
Pre-test vs post-test of working memory ability (accuracy)

Dependent variables	Experimental group (N=42)					Control group (N=42)				
	Pre-test		Post-test		t-value before intervention	Pre-test		Post-test		t-value after intervention
	M	SD	M	SD		M	SD	M	SD	
Left-right	91.00	5.63	95.71	4.04	0.324	90.48	8.84	88.29	7.72	5.53**
Up-down	86.81	5.73	94.14	5.08	0.057	86.71	9.13	87.62	7.41	4.71**
Switching	86.76	5.84	93.43	5.32	0.361	86.14	9.44	86.57	8.03	4.61**
Flanker	89.83	4.25	93.14	3.88	0.153	91.90	4.56	92.76	4.10	0.44
2-word span	68.45	13.87	85.42	12.32	0.186	69.05	15.43	70.24	16.55	4.77**
3-word span	73.81	21.44	84.97	10.06	0.681	70.68	20.59	76.64	14.35	3.08**
4-word span	62.86	23.19	68.10	19.28	1.653	54.76	21.67	56.67	22.92	2.47*
0-back	70.57	16.51	86.81	7.15	0.191	71.29	15.38	71.62	15.34	5.70**
1-back	66.29	17.96	81.38	11.65	0.404	66.10	15.64	65.81	16.37	5.67**
2-back	40.00	15.46	60.24	17.46	0.210	40.71	17.31	45.00	19.29	3.85**

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

A 2x2 multivariate analysis of variance (MANOVA) findings confirmed there was a significant multivariate effect across the interaction between student group and time point: Wilks' $\lambda = 0.38$, $F_{(10, 73)} = 11.79$, $p < 0.01$, partial $\eta^2 = 0.67$. There was a significant multivariate effect for between-subjects (of the combined reaction time of 10 tasks) across student group (regardless of time point): Wilks' $\lambda = 0.69$, $F_{(10, 73)} = 3.15$, $p < 0.01$, partial $\eta^2 = 0.30$. There was also a significant multivariate effect across within-subjects time point (regardless of student group): Wilks' $\lambda = 0.321$, $F_{(10, 73)} = 15.47$, $p < 0.01$, partial $\eta^2 = 0.68$.

When univariate tests were performed on the dependent variables, results indicated that the reaction times of the experimental group when performing left-right, up-down, switching, flanker, and 4-word span tasks of working memory were significantly shorter than the control group (regardless of time point) at $p < 0.05$, while 2-word span, 3-word span and n-back tasks were shorter than control group at $p < 0.01$. Before intervention, there was no mean difference of all dependent variables (reaction time of 10 working memory tasks) between groups, Wilks' $\lambda = 0.90$, $F_{(10,73)} = 0.24$, $p < 0.05$, partial $\eta^2 = 0.10$. After intervention, there was a significant mean difference between groups, Wilks' $\lambda = 0.54$, $F_{(10,73)} = 6.15$, $p < 0.01$, partial $\eta^2 = 0.46$. The experimental group had shorter reaction time in performing all the tasks compared to the control group. The mean scores and

Table 4
Pre-test vs post-test of working memory ability (reaction time)

Dependent variables	Experimental group (N=42)					Control group (N=42)				
	Pre-test		Post-test		t-value before inter-vention	Pre-test		Post-test		t-value after inter-vention
	M	*SD*	*M*	*SD*		M	SD	M	SD	
Left-right	535.79	75.00	482.43	59.20	0.015	539.58	61.44	533.03	61.92	2.33**
Up-down	596.76	79.87	535.58	66.92	0.223	596.33	71.61	598.05	73.67	2.48*
Switching	863.24	111.72	751.96	91.85	0.033	868.10	104.90	831.69	123.46	3.13**
Flanker	616.19	64.60	554.34	49.47	0.656	607.41	57.97	610.63	62.25	2.40*
2-word span	4014.69	456.72	3345.98	598.65	1.529	4238.69	832.01	4272.86	928.85	5.43**
3-word span	6431.67	1545.75	5376.05	1388.57	1.654	6911.47	1070.95	6577.94	416.44	3.93**
4-word span	9561.54	3082.16	7587.42	1758.10	0.467	9927.93	4043.74	9532.00	2743.93	3.87*
0-back	478.27	76.53	408.70	63.25	0.503	477.31	81.10	488.75	83.71	3.01**
1-back	510.14	91.96	421.04	74.44	0.056	503.77	103.11	496.08	90.99	2.84**
2-back	554.93	131.44	501.89	122.29	0.657	588.59	144.40	582.24	142.82	2.68**

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

standard deviation of the reaction time of 10 working memory tasks before and after intervention are shown in Table 4.

DISCUSSION AND CONCLUSION

The results of this study show that there is no significant difference between groups on the dependent variables before the intervention. However, all the dependent variables namely the learning outcomes such as achievement on understanding the skeletal system of veterinary anatomy, metacognitive ability, and working memory accuracy and reaction time have significant differences between groups after the intervention. On this line of reasoning, both the teaching models (CMEN and TM) are found to have a significant effect on the overall learning outcomes of second-year veterinary medicine students.

Results of this study indicate that the two teaching models have significantly different effects. As a result, great emphasis has been laid on the instructors to use effective teaching models for improving the learning outcomes of students. The results have revealed a greater understanding of the causal mechanism of the CMEN teaching model on the improvement of the learning outcomes of students. The results are supported by Uopasai et al. (2017). Uopasai (2017) found that CMEN teaching model had affected the 40 veterinary medicine students' behavioral, electrophysiological, and achievement change in a Thailand public university. With the passage of time, the importance of the teaching style of university instructors is being realized

and they are taking initiative to improve their teaching strategies using appropriate teaching models for the improved learning skills of the students (Jalbani, 2014).

The results of this study are found to be consistent with several previous findings of constructivism (Lin, 2015; Srikoon et al., 2017; Tanner, 2012). Lin used constructivism for vocabulary teaching to undergraduate students in Dalian University to make their own meanings and found it to be a more effective teaching model compared to the traditional approach. Moreover, findings also reinforced the concept of metacognition as emphasized by Tanner (2012). Tanner found that metacognitive based teaching enables students to discover their own strengths and weaknesses thus making them know how to learn, being able to monitor their own understanding and strategizing to resolve their confusions. In addition, Srikoon et al. (2017) revealed that the neurocognitive-based teaching model intervention had more effect on the attention, working memory, and mood of Grade 9 students than the conventional teaching model.

Tornee et al. (2017) had developed their constructivism and neurocognitive-based teaching model which was based on the theoretical foundation of neurocognitive learning theory and constructivist learning approaches. Their results are found to be parallel with the results of this study. Sripongwiwat et al. (2016) found that the constructivism and neurocognitive-based teaching model was able to enhance the science learning outcomes and creative

thinking of Grade 11 students in a secondary school in northeast Thailand. Tornee et al. (2017) found that there was a greater improvement in Grade 11 students' attention abilities after the intervention of neurocognitive constructivist guided-inquiry based teaching model compared to the conventional structured inquiry-based teaching model.

With a wealth of effective CMEN teaching models, veterinary medicine students, instructors, and the profession as a whole will likely benefit as they become more widely adopted. Ideally, newly developed teaching models will capture better educational achievement and learning abilities and expand on it by providing additional learning outcomes and benefits. It must be noted that even if this CMEN teaching model does not provide every benefit of learning outcome that the traditional model of teaching provided, it may still be superior overall. This is because the overall improvement from CMEN teaching model is found to be greater than traditional model of teaching although the traditional model of teaching still has its own significant effect. That the traditional model of teaching is entrenched and familiar is no reason for retaining them when other teaching models are shown to be more effective. Furthermore, we should not expect the CMEN teaching model to replace the traditional model of teaching as a total without further investigation on other aspects of learning outcomes. The CMEN teaching model will only allow instructors to re-conceptualize curricula and meet their learning objectives while placing greater emphasis on constructivism, metacognitive and neurocognitive approaches.

Finally, the results of this study would provide further evidence in support of the need to develop the abilities of university instructors to deliver and guide students using constructivism, metacognitive approach as well as the application of neurocognitition with educational practice as a new concept. An effective training program that relates to constructivism, metacognition and neurocognition is suggested to the Ministry of Higher Education, Thailand.

ACKNOWLEDGEMENT

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