

## Physics Teachers' Constructing Knowledge Base for Physics Teaching Regarding Constructivism in Thai Contexts

Chokchai Yuenyong\*

Kongsak Thathong

Science Education Program, Faculty of Education, Khon Kaen University, Thailand  
Email: ychok@kku.ac.th

Doi:10.5901/mjss.2015.v6n2p546

### Abstract

*This research aimed to clarify 5 physics teachers' constructing knowledge base for teaching regarding constructivism. The participants were 5 physics teachers who studying Master degree in science education in Khon Kaen University, Thailand. Three participants applied science, technology, and (STS) approach for developing their teaching regarding constructivism. Other 2 participants applied teaching strategies of Predict Observe Explain (POE). This qualitative research regarded interpretive paradigm for physics teachers' constructing knowledge base for teaching regarding constructivism during applying STS approach and POE for 2 months of physics teaching. Research instruments include teachers' lesson plan, observation, teachers' journal writing, and interviewing. The study explicates such a knowledge base. It is demonstrated what kind of pedagogical content knowledge (PCK) originates from our cooperation with six participating teachers. The pathway of teachers' constructing PCK will be discussed for provide information of enhancing physics teaching regarding constructivism. This study has implications for science teacher professional development.*

**Keywords:** pedagogical content knowledge, constructivism, STS, POE, and professional development

## 1. Introduction

Attempting of moving traditional teaching and learning into regarding constructivism still on the way of pushing teachers to improve after the recent wave of Thailand educational reform began in 1997. However, it seems to be on the right track, the majority of teachers perceived that the key concept of education reform is learner-centred. Learner-centred education evolved out of the constructivist paradigm of learning. Thai learning reform is based on the philosophy of constructivism (ADB, 2002: 14). The ONEC (2002a) provided the meaning of learner-centered approach for all Thai teachers. The learner-centred approach is learning processes aimed at development of the person and the enrichment of their lives. Learners should be offered learning experiences to develop to their highest potential and in line with their aptitude, interests and needs. Learning activities should be organized with regard to individual differences. They should provide learners to interact and relevant to their learning environment in everyday life such as people, nature and technology (ONEC, 2002a: 26 - 27). The goal of Thai science education was addressed along with these crucial aspects of educational reform. The goal of science education aims students to think by considers the relationship between science, technology and society. This goal requires people who held high level of scientific literacy in order to find agreement about local and global issues of science, technology and society (IPST, 2002; Yuenyong and Narjaikaew, 2009).

Teachers need to be enhanced to become professional practitioners who have the ability to recognize the most appropriate strategy and design learning experiences for specific learning situations regarding constructivism. Constructivism is described as two basic principles including psychological and epistemological knowledge. It emphasizes that these two kinds of knowledge cannot be separated from knowing (Treagust, Duit, and Fraser, 1996).

## 2. Literature Review

### 2.1 Constructivism and Pedagogical Content Knowledge

Constructivist psychology is based on the view that knowledge is a human construction (von Glasserfeld, 1992). Piaget's view is considered as a constructivist because he argues that learners actively participate in the process of construction

of meaning. Radical or personal constructivism regards knowledge as being in the head of individual who constructs what they know on the basis of their own experience (von Glasserfeld, 1995: 1).

Unlike traditional epistemology, constructivism epistemology will not be concerned on absolute truth. But, constructivist educators consider something where are representation of the world (Osborne, 1996). For example, von Glaserfeld (1993) proposed that knowledge has to be a representation of reality. He used the notion of viability in order to refer to the truth. The viability may provide some explanation which fit to person experiences, life or acceptable reason. This could be said that knowledge was the result of knower construction and therefore cannot be transferred to others (von Glasserfeld, 1995). Thus knowledge exists only in mind of cognizing beings where it is constructed. We cannot found the knowledge in books, texts, or other traditional repositories of human knowledge but we found the representation of symbols as a range of interpretation. Therefore, there is no knowledge without knower. Tobin suggests that "We construct a model of gravity that is viable in that the model fits experience, but no matter how elegant, that model cannot claim to be an absolute truth" (Tobin & Tippins, 1993: 2). According their epistemology, knowledge is viable because of its coherence with other understandings and its fit with experience. Viability is therefore determined with respect to those actions which facilitate the attainment of goals in the social contexts of action. This argument extends the notion that ideas must be personally viable to encompass the idea that they must be viable within a social context. Therefore, science learning may relate to construct meanings and concepts which process from socially negotiated understandings and not evolve from examining whether such inventions are supported when tested against the real world (Osborne, 1996).

Unfortunately, teachers' taking action regarding constructivism hardly appeared in classroom. It seems that there are many constraints for teachers' constructing knowledge to provide their teaching. As professionals, they could be expected to understand both the theoretical and the practical nature of theories (ADB, 2002: 10 – 12). To become professionals, a practice-based 'know how' may allow teachers to benefit from when trying out theoretical or more abstract ideas and ideals in daily practice. A practice-based 'know how' is usually depicted as pedagogical content knowledge. Although scholars differ with respect to their definitions of pedagogical content knowledge, it in general can be seen as knowledge needed to teach a particular topic. Furthermore all scholars agree on Shulman's (1986) two key elements (van Driel, Verloop, & de Vos, 1998):

- knowledge of representations of subject matter, that is "ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9) or as de Jong, Veal and van Driel (2002) put it: "knowledge of instructional strategies incorporating such representations" (p. 371);
- understanding of specific learning difficulties and students' conceptions with respect to that subject matter.

Pedagogical content knowledge specific for (teaching materials incorporating) science teaching regarding constructivism, and for the principle 'need to know' in particular, means knowing how to act – e.g. the kind of questions to be asked or remarks to be made – so that (all) students experience a 'need to know':

- through working within a context;
- and keeping in mind possible differences between the knowledge need as put forward by students and the knowledge need as will be fulfilled in subsequent activities.

Magnusson Krajcik, & Borko (1999) conceptualize PCK for science teaching as consisting of five knowledge components. These include orientations toward teaching science; knowledge of science curriculum; knowledge of students' understanding of specific science topics; knowledge of assessment in science; and knowledge of instructional strategies for teaching science. The knowledge components of PCK are highly integrated and the interactions among them are highly complex. Even though knowledge components of PCK function as parts of a whole, the integration of all components is needed because "the lack of coherence between components can be problematic in developing and using PCK, and increased knowledge of a single component may not be sufficient to effect change in practice.

PCK is not knowledge for all teachers can apply directly to given subject area. But, it is a particular expertise with individual idiosyncrasies and important differences that are influenced by teaching contest, content, and experiences. PCK is the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhanced student understanding (Loughran, Berry, & Mulhall, 2006). There are several ways that were used as assessment and capturing and portraying science teachers' PCK. These approaches, for example, include multi method evaluation (Baxter & Lederman, 1994), using PCK rubric score (Jang, 2011), lesson preparation method (Kapyła, Heikkinen, & Asunta, 2009), and story-line method (Drechsler & Van Driel, 2008). An interesting approach is Content Representation (CoRe) of PCK that developed by Loughran et.al (2001). CoRe is tool that attempt to portray, holistic overviews of teachers' PCK. CoRe engage groups of expert science teacher in activities about what they consider to be the "big ideas" associated with teaching a given topic for a particular grade level based on

their experience of teaching science topic. CoRe, therefore, provides theoretical framework to examine holistic overview of science teachers' PCK. The CoRe provided the aspects to ask teachers as following (Loughran, Berry, and Mullhall, 2006):

- Big Ideas: refers to the science concepts that teacher consider as importances for students to develop their understanding of the topic.
- What you intend the students to learn about this idea
- Why it is important for students to know this
- What else you might know about this idea (that you don't intend students to know yet)
- Difficulties / limitations connected with teaching this idea
- Knowledge about students' thinking which influences your teaching of this idea
- Other factors that influence your teaching of this idea
- Teaching procedures (and particular reasons for using these to engage with this idea)
- Specific ways of ascertaining students' understanding or confusion around this idea

## 2.2 Constructivist Teaching Strategies

Study teachers who trying to practice about science teaching regarding constructivism may have implications for science teacher professional development for Thailand education reform. This study aimed to study teachers' constructing PCK during adopting some teaching approaches regarding constructivism to practice in their class for doing a research. These approaches include science technology and society (STS) approach and Predict-Observe-Explain (POE) strategy. Influences of teachers' constructing PCK during the taking theory of constructivism into practice may provide the information for improving teacher development.

### STS approach

According to the different goals of STS there are several ways of attaining STS objectives. In this research, participants developed the STS unit regarding Yuenyong (2006)'s STS approach. The societal issues are employed to engage students to learn. Then, the unit will be moved to require technological concepts and science concepts and skills. Finally, students need to have chance to communicate their solution or act in society. Yuenyong (2006) proposed STS approach for science learning. His approach consisted of five stages.

- (1) Identification of social issues stage. This stage was planned to provide student attention and attitudes on science. Teachers have to provide societal or/and technological issues that related to science into the classroom. These issues need to be found solutions by students as good citizens. The issues also have to give students chance to participate in public decision-making; seeing social problem by taking field trip.
- (2) Identification of potential solutions stage. This stage was designed to focus student planning how to solve the societal or/and technological issues related to scientific concepts. The technological aspects need to be enhanced while students try to find the possible solutions. Regarding to technological aspects, students have to carefully think of what knowledge, skills and value to support student decision making. Students need to think of what, why, and how ideas, design, systems, volition of application scientific knowledge work for that social problems. Teaching strategies may be used discussion among students' group, role-play brain storming, searching information via internet, and discussion with expert (e.g. engineers or scientists).
- (3) Need for knowledge stage. This stage aimed to develop students' scientific knowledge related to the proposing the societal or/and technological issues. Students' planning in the second stage may require some scientific concepts in order to provide chance students to come to the best solution. Scientific concepts were constructed meaning in many strategies to students to understand the technology and social issues. The formative assessment should be also taken into account to give feedback students' understanding about scientific concept and enhance further learning.
- (4) Decision-making stage. This stage was designed students to apply scientific knowledge and other knowledge (e.g. art, economics, mathematics, value, culture, politics, and so on) in making a decision to do the best solution for societal or/and technological issues. Students have to discuss to dominate the issues becoming dichotomies like 'chances and problem', 'advantages and disadvantages', or uses and abuses'. Students will be supported to learn to select between alternatives and in a thoughtful way systematically comparing as many relevant pro's and con's as possible. Students' group discussion, role play, and brain storming may be used as teaching strategies.
- (5) Socialization stage. The stage allows students to communicate or act their best solution to the society.

Students may do exhibition, write a newspaper article, present science project, propose the plan to local government, post the solution in social media, and so on. This activity will give students to validate their ideas into the community. They may learn something from their sharing to. And, then, they may get the ideas to adjust their solution.

Using Predict–Observe–Explain (POE) strategy

The POE strategy focuses on examining students' ideas to clarify what existing idea and belief are relevant to a situation. These existing ideas will be challenged for explanation the phenomena. White and Gunstone (1992) proposed the POE to elicit students' understanding by carrying out three tasks including predict, observe, and explain. First, students have to predict the outcome of some event, and must justify their prediction. Then, they need to describe what they see happen. Finally, they must bring together any conflict between prediction and observation.

**Predict:** Students will be presented with an event, situation or set-up of equipment. Then, students were asked to predict what will happen and give a brief explanation of their reason. These explanations will be categorized and compiled to make the list of explanations. Students need to vote an explanation to determine the popularity of the theory.

**Observe:** Students will be asked to design how to prove their explanation. Teacher fosters them to think around possible way to do for observing the event or situation. Then, students do experiment or demonstration to observe the result. One of the predicted outcomes may have turned out to be correct. However, it happens that either more than one predicted outcome was correct, or none of them were right.

**Explain:** Students need to reconcile any disagreement between prediction and observation. They have to try construct the explanation why things happened the way they did.

### 3. Methodology

This research regarded the interpretive paradigm. The research will describe and interpret human behavior based on their natural setting. Clear description of how data also was obtained and open acknowledge of context should be provided in order to show the issue of dependability (Marriam, 1998; Cohen et al., 2011). As the process of interpretation, this research aims to interpret participating physics teachers' perception and actions that emerged or occurred during their adopting some teaching approaches regarding constructivism (i.e. STS approach and POE strategy) to practice in their class for doing a research. These interpret would be viewed as the influences of constructing pedagogical content knowledge (PCK) for science teaching regarding constructivism.

#### 3.1 Participants

The participants were 6 physics teachers who teach in Province of Khon Kaen, Yasothron, and Roi-et, Thailand, the first semester of 2009 academic year. All participants are studying master degree in science education.

#### 3.2 Backgrounds of participants

Pseudonyms were used to represent the participating physics teachers' names including Da, Mon, Wan, Kwan, and Rat. Backgrounds of participants were provided in the table 1.

**Table 1:** Backgrounds of Participants

Pseudonyms	Age	Qualification	Teaching Experiences	Teaching level	Content and Teaching Approach	School District
Da	26	B.Sc. (Physics) Dip. (Teaching)	2 years	Grade 10	Teaching about Newton laws through STS approach	Saimoon, Yasothron
Mon	27	B.Sc. (Physics) Dip. (Teaching)	2 years	Grade 11	Teaching about fluid density and pressure through STS approach	Meawadee, Roi-et
Wan	27	B.Sc. (Physics) Dip. (Teaching)	2 years	Grade 6	Teaching about moon phase through STS approach	Sila, Muang, Khon Kaen
Rat	30	B.Sc. (Physics) Dip. (Teaching)	4 years	Grade 5	Teaching about force and motion through POE strategy	Sila, Muang, Khon Kaen
Kwan	28	B.Sc. (Physics) Dip. (Teaching)	3 years	Grade 11	Teaching about Pascal law through POE strategy	Phuvieng, Khon Kaen

### 3.3 Methods of Inquiry

This qualitative research regarded interpretive paradigm for physics teachers' constructing knowledge base for teaching regarding constructivism during applying STS approach and POE for 2 months of physics teaching. The participants were 6 physics teachers who are studying master degree in science education. The influences of teachers' constructing PCK were examined during the taking theory of constructivism into practice in their doing a thesis. The arguments about constructing PCK for their specific were interpreted from teachers' lesson plan, classroom observation, teachers' journal writing, and interviewing.

### 3.4 Data analysis

This study interpreted participants words, meaning and actions that occurred during their teaching through STS approach and POE strategy. The interpretation would be viewed as influences of their constructing PCK for physics teaching through STS approach and POE strategy. Arguments about influences of constructing PCK for their teaching were categorized regarding Magnusson et.al (1999) and Loughran et.al (2006) PCK conceptualization. Peer debriefing was recognized for credibility of trustworthiness. Then, each argument categories of teachers' constructing PCK was validated through other lecturers in our team teaching.

## 4. Findings and Discussion

Study participant teachers' constructing knowledge reflected their developing PCK for taking teaching approach regarding constructivism (i.e. STS approach and POE strategy) into practice of their doing a research. The influences of constructing pedagogical content knowledge (PCK) for science teaching regarding constructivism could be viewed through the following arguments.

Keeping teaching approach (STS and POE) in mind enhanced teachers to realize students' prior knowledge and physics learning difficulties. Attempting of their carrying out research about science teaching through STS approach and POE strategy enhance them to understand their students' learning and constructing knowledge. All participants' journal writing indicated that they aware of probing students existing ideas during the teaching. For example, Rat's journal writing represented her awareness of probing students as below:

*"... Students have to find solution for the proposed situation. I expected them to make divert thinking, up to them. I tell them that "your ideas - no right or wrong". I would like to know how they think about this situation, how they give their reason. I expected them write down from their own ideas ..."* (Rat)

Teachers' action in the classroom also reflected how they pay attention to examine students' existing ideas. With regarding STS or POE, most of teachers tried to probe or challenge their students in order to build up physics concepts in social and technological issues or POE situations. Part of Mon's probing her students in classroom reflected this.

*"... Mon: Can you tell me why the dam broken? Students, give me your reasons.  
Student: many reasons. The wrong designing may be a reason of dam broking. Characteristics of geology, water in dam  
....  
Mon: If you know reasons of dam broking, how you will do to protect dam broking more.  
Student: Take some knowledge and limitations to design stronger dam and bigger volume, and more efficiency.  
Mon: Are you sure what you know will support you draw your designing? ...."*

Students' behavior, explaining the meaning of physics concepts and working on the teaching approach supported the developing teachers' roles for enhancing students' constructing meaning. These include fostering students construct what they know on the basis of their own experience and facilitating personally viable to encompass the idea within a social context.

Teachers who teach science regarding constructivism consider knowledge as a human construction. Students' behavior and working on the teaching approach reminded the participants to develop their role of teaching for enhancing students constructing meaning. Kwan's journal writing about pressure fluid teaching suggested that student behavior of explanation reminded her to reflect teacher role regarding constructivism as her reflection on the Predict and Explain stage of POE below.

Kwan's journal writing for lesson plan 1

### Lesson plan 1 Pressure fluid

Predict: Students discussed in group but they did not share many issues because it is the first period of learning through POE. I have tried to construct the atmosphere and relaxation for students' giving more ideas and explanation. Tell them that no right or wrong. It is just your existing ideas. ....

Explain: I found that students shy to give explanation although they have already done the experiment. I need to challenge them more. I need what they real ideas. However, because of the time limit, I have to hurry conclude the lesson. I think my role of teaching like this may not support some students to think by themselves.

Wan's journal writing also reflected how working on STS approach reminded teachers' role to support students presenting their ideas. She perceived that "identification social issues stage" could give students chance their constructing meaning.

*"... In the 1st stage – identification social issues, according to students' writing journal and interview, I found that students appreciated and proud because their ideas were shared in the class after physics learning related everyday life issues. ...." (Wan's journal writing)*

Teachers' role for facilitating personally viable to encompass the idea within a social context also gained from participants working on the teaching strategies. Regarding constructivism, knowledge has to be a representation of reality. Instead, truth is replaced by the notion of viability. According their epistemology, knowledge is viable because of its coherence with other understandings and its fit with experience. This suggests that learning in a social context is important for individual constructing meaning. Da' journal writing represents her developing knowledge of foster to construct meaning within social context.

*"... Teachers' role should support or challenge students sharing their ideas. I found that students could not link the relationship between STS and the philosophy of sufficiency economy (PSE). I tried to provide them STS and PSE. Teacher have to understand students' context, know how to challenge each student. ... Teachers could motivate students back to the lesson but it did not mean blocking their existing ideas. .... Normally, 70 percents of my class shy to share their reasons. After taking this intervention, particular 'decision making stage', students share more their ideas in group. Although their language was not perfect, they tried to share. ..." (Da' journal writing)*

Taking STS approach and POE strategy enhance participant teachers develop knowledge for provide their lesson plan appropriate for specific contents, teaching approach or strategies, students' prior knowledge, contexts, and so on. Practice science teaching regarding constructivism for their thesis allowed them knowing how to act and how to improve their teaching. Mon' s journal writing and Da's interviewing represented their PCK in principle 'need to know'. They reflected what they learn through working within a context and keeping in mind possible differences between the knowledge need as put forward by students and the knowledge need as will be fulfilled in subsequent activities.

Mon' journal writing reflected her rethinking about what they learn from teaching about fluid density and pressure through STS approach. She realized how to organize number of physics concepts for teaching through STS approach. She concluded that make the themes regarding social issues and physics concepts could allow her teaching physics through STS approach under the limit of time a semester as her idea in journal writing below.

*"... Physics teaching through STS approach, teachers should mix concepts. The concepts should be included into a theme because: 1) we can link between concepts in a theme, 2) we can efficiency manage the time for teaching STS approach. Teaching a concept through single 5 step of Yuenyong (2006) STS approach take time. Teachers have to select the appropriate social issue for covering concepts that will be taught in the "need for knowledge stage". Then, support students to apply all concepts in "decision making stage". .... (Mon)*

Da' s interviewing showed that she could identify some knowledge about pedagogy from working in a context. She argued that physics teaching through STS approach should provide from social and technological issues in students' communities. This may motivate students learn physics relating with their life. Her interviewing below:

*"... Interviewer: What is your impressive from practicing in your research?  
Da: I perceived that my students closed up their communities. They have chance to consult experts, local wisdom in the village. Those issues can take to the class as science and technology. I do believe that if I continuously teach physics through this approach, students will be happy to stay in their communities and reasonably survive. ...  
Interviewer: So, what you learn from?  
Da: Organizing physics teaching relating what students' taking part all the time may motivate students to learn. All*

*science related to life. We have to find the social issues for science teaching. ..”*

Attempting for applying science teaching through STS approach and POE suggested teachers to be appreciated the goal of science teaching. They considered how to enhance students to construct meaning of scientific knowledge regarding the relationship between science, technology, and society; and student contexts.

Da's journal writing reflected her appreciation about the goal of Thailand science education. She indicated that her students could learn science concepts in local context. She believed that if teachers could link students' context into the science classroom, science teaching and learning may obtain the goal of Thailand science education as her journal writing below.

*“... I feel that my students have chance to learn physics and close to their communities. They have chance to learn physics and validate their ideas with people in the village and local scholars. Students have chance to apply science knowledge in societal and technological context for their villages. I think I can provide students for surviving in the society and critical thinking.” (Da)*

Kwan's reflection in journal writing suggests that she appreciated students' explaining for predicting the given situation of POE. She thought that her students have chance to generate their own hypothesis and theory from explaining POE activities that related to student context. This could be claimed as Kwan's journal writing for lesson plan 4 of surface tension about the Predict stage of POE below.

Kwan's journal writing for lesson plan 4

*Predict: Students are interesting in the POE activity for force of surface tension. They were engaged by this activity. They tried to participate in activity, particularly force of surface tension in the soapsuds.... Students in each group want to explain their ideas without worrying about right or wrong reason. I think the activity related to their everyday life may allow them to share their ideas ...*

## 5. Conclusion

The paper indicates what teachers learn as base of knowledge for their teaching approach regarding constructivism (i.e. STS approach and POE strategy) into practice of their doing a research. Their applying new approach for them as STS approach and POE strategy allowed them to develop PCK for science teaching regarding constructivism. The component of knowledge base as PCK was considered during their applying STS approach and POE strategy. These included students' prior knowledge and physics learning difficulties for students' learning and constructing knowledge; the developing teachers' roles for enhancing students' constructing meaning; providing lesson plan appropriate for specific contents, teaching approach or strategies, students' prior knowledge, contexts, and so on; teaching science to reach the goal of science education. However, knowledge of assessment in science regarding constructivism should be taken in to account for developing science teacher professional development.

## 6. Acknowledgement

This work was supported by the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission, through the Cluster of Research to Enhance the Quality of Basic Education.

## References

- Asian Development Bank (ADB). 2002. *Teacher Development for Quality Learning: The Thailand Education Reform Project*, March 2002. Brisbane, Australia: Office of Commercial Services, Queensland University of Technology. Available: <http://www.worldedreform.com/pub/fulltext4.pdf>,
- Baxter, J. A. and Lederman, N. G. (1994). Assessment and measurement of pedagogical content knowledge. In J. Gess-Newsome and N. G. Lederman (Eds.), *Examining pedagogical content knowledge*. (p.147-161). Dordrecht, The Netherlands: Kluwer Academic Publisher.
- Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education*. (7th ed.). New York: Routledge.
- De Jong, O., Veal, W. R. & Van Driel, J. H. (2002). Exploring Chemistry Teachers' Knowledge Base. In J. K. Gilbert, et al. (Eds.), *Chemical Education: Towards Research based Practice* (pp. 369-390). Dordrecht: Kluwer.
- Drechsler, M. & Van Driel, J. 2008 Experienced Teachers' Pedagogical Content Knowledge of Teaching Acid-base Chemistry. *Research*

- in *Science Education*, 38(5): 611-631.
- Institute for the Promotion of Teaching Science and Technology (IPST). 2002. *The Manual of content of science learning*. Bangkok, Thailand: Curusapha ladphoa.
- Jang, S.J. (2011). Assessing college students' perceptions of a case teacher's pedagogical content knowledge using a newly developed instrument. *High Education*. 61 (6): 663 – 678.
- Kapyla, M., Heikkinen, J.P., & Asunta, T. (2009). Influence of Content Knowledge on Pedagogical Knowledge: The case of teaching photosynthesis and plant growth. *International Journal of Science Education*. 31 (10): 1395-1415.
- Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P)2001(. Documenting science teachers' pedagogical content knowledge through PaP-eRs. *Research in Science Education*, 31, 289-307
- Loughran, J., Berry, A., & Mulhall, P. (2006). *Understanding and Developing Science Teachers ,Pedagogical Content Knowledge*. The Netherland: Sense Publishers.
- Magnusson, S., Krajcik, J.S., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In Gess-Newsome, J., & Lederman, N. G. Eds. *PCK and Science Education*, (p. 95-132). The natureland: Kluwer Academic of Publishers.
- Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.
- Office of the National Education Commission (ONEC). 2000. *Learning Reform: A Learner-Centred Approach*. Bangkok, Thailand: Wattana Panit Printing & Publishing Company Limited.
- Osborne, J.F. 1996. Beyond Constructivism. *Science Education*. 80 (1): 53 – 82.
- Tobin, K. and Tippins, D. 1993. Constructivism as a referent for teaching and learning. In Tobin, k. (Eds.), *The practice of constructivism in science education*. Washington, DC: AAAS Press: 3 – 21.
- Treagust, D.F., Duit, R. & Fraser, B.J. (1996). *Teaching and learning of science and mathematics*. New York: Teachers College Press.
- Shulman, L.S. (1986) Those who understand knowledge growth in teaching. *Education research*. 15(2): 4 – 44.
- Van Driel, J.H., Verloop, N., & De Vos, W. (1998) Developing science teachers ,pedagogical content knowledge .*Journal of Research in Science Teaching*, 35(6): 673-695
- Von Glaserfeld, V. E. 1992. A Constructivist' s view of learning and teaching. In Duit, R.; Goldberg, F.; and Niedderer, H. (Eds.) *Research in Physics Learning: Theoretical Issues and Empirical Studies*. Keil, Germany: Institute furdie Padagogok der Naturwissenschaften an der Universitat, 29 -39.
- Von Glaserfeld, E. V. 1993. Questions and answers about radical constructivist. In Tobin, K. (Eds.) *The practice of constructivism in science education*. Washington, DC: AAAS Press: 23 – 38.
- White, R., and R. Gunstone. (1992). *Probing understanding*. London: The Falmer Press.
- Yuenyong. (2006). *Teaching and Learning about Energy: Using STS Approach*. Bangkok, Thailand: Thesis of Doctoral Degree in Science Education, Kasetsat University
- Yuenyong, C. and Narjaikaew, P. (2009). Scientific Literacy and Thailand Science Education. *International Journal of Environmental and Science Education*. 4(3): 335 – 349.