DEVELOPING A NEW TEACHING INTERVENTION TO PROMOTE GRADE 11 STUDENTS' LEARNING OF PHOTOSYNTHESIS IN THAILAND

This interpretive study aims to develop a new teaching intervention to promote an expanded range of objectives in Grade 11 students' learning about photosynthesis. The intervention was based on six principles: 1) correcting students' misconceptions, 2) taking account of the Thai National Science Content Standards, 3) applying photosynthesis knowledge to an environment issue, 4) using historical narratives to illuminate the nature of science, 5) recognizing Thai culture and society, and 6) encouraging active learning. Three biology teachers developed and implemented the intervention with 118 Grade 11 students. Two surveys consisting of multiple choice and open-ended questions were used to probe the learning, supported by individual interviews with twelve selected students. Also, twenty-four lesson observations and informal interviews with the teachers revealed their classroom practices and perspectives. The findings indicated that the students achieved an understanding of photosynthesis. Their better understanding of the concepts depended on how their teachers implemented the intervention. In some cases, the teacher was ready to change his or her teaching practices and believed that students could learn by themselves. This powerfully promoted the learning of photosynthesis, in particular the light independent phase.

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The Need to Study Photosynthesis

Photosynthesis is a very interesting field of knowledge. It is not only biology, but it is also directly related to all forms of life. "All the food we eat and all the fossil fuel we use is a product of photosynthesis, which is the process that converts energy in sunlight to chemical forms of energy that can be used by biological systems" (Vermaas, 1998: 158). Environmentally, photosynthesis can help reduce the level of pollution. It uses carbon dioxide, the major cause of "Global Warming" and an air pollutant, as a raw material for the synthesis of carbohydrates. The by-product of the process, oxygen, is also given off to the atmosphere to be used in normal metabolism of human and other aerobic organisms (Suzuki, 1997). In addition, it brings about the growth of plants which are important for nutrition, production of timber for building, paper, etc. Some of these plants may have medicinal properties which could help humans to fight disease (Julian, 2000).

Even though the promotion of photosynthesis knowledge has been the aim of Thai biology education for many years (Ministry of Education, 1991a; b; IPST, 2002), prior studies in 2002 (Kijkuakul, 2002; Kijkuakul and Yutakom, 2004) indicated that Thai

Grade 11 students still had difficulty learning about photosynthesis. One major cause was that the teaching had too much emphasis on transmitting knowledge to students and less emphasis on encouraging the students to understand the relationship between photosynthesis, the environment, and the nature of science.

Biology education research into students' learning of photosynthesis has mainly focused on three areas. The first research area was based on teaching and learning about photosynthesis itself as a single process topic, separated from other plant processes (Bell, 1981, 1985; Wandersee, 1983, 1985; Barker, 1985; Haslam and Treagust, 1987; Tregust, 1988, 1991; Amir and Tamir; 1989, 1994, 1995; Barker and Carr, 1989a, 1989b, 1989c; Anderson, Sheldon and Dubay, 1990; Eisen and Stavy, 1993; Hazel and Prosser, 1994; Lumpe and Staver, 1995; Griffard and Wandersee, 2001). The research indicated that students of all ages had conspicuously similar misconceptions about photosynthesis and the students' prior knowledge about plants significantly influenced their learning about photosynthesis. In the middle to late 1990s, the second research area focused on understanding photosynthesis in the context of other plant processes, i.e. on integrated knowledge (Waheed, 1992; Songer and Mintzes, 1994; Lavoie, 1997; Ozay and Oztas, 2003). However, the previous research argued that there was a need for more effective biology teaching. The third research area was focused on understanding photosynthesis in a broad environmental context, i.e. on the complex relationship between those integrated concepts, society, and environmental systems (Eskilsson and Holgersson, 1999; Carlsson, 2002; Eilam, 2002; Ekborg, 2003). The research expected that challenging students to understand aspects of science and the relationship between photosynthesis and the environment might be an effective way of teaching photosynthesis.

The Socio-Cultural Perspective

The socio-cultural perspective places less emphasis on *knowing*, and more on *being*. It holds that the individual's learning cannot be considered in any way to be context-free. The learning *always* relates to being part of a society and a culture (Cobb and Yackel, 1996; John-Steiner and Mahn, 1996; Marshall, 1996; Packer and Goicoechea, 2000; Alfred, 2002). In the case of Asian biology education, learning biology in classrooms is most commonly learning the biological knowledge of Western culture. So, this present study took a socio-cultural perspective on teaching and learning about biology, especially photosynthesis. The students learn by individual and social transformations based on the needs of Thai society and culture, in their classroom.

Some examples of Thai society and culture interacting with teaching and learning show that Thai students sometimes learn biology because they would like to succeed in the university entrance examination (Buranakarn, 2003); Thai students argue only with diffidence with their teachers about what they really think about teaching and learning because Thai culture seriously respects higher authority (Triolo and Lewis, 1998; Srivichit, 2004); and Thai people recognize that plants as essential for building and as valuable and spiritual substances (Buffalo villages, 2003). Also, having large numbers of students in a Thai classroom decreases their opportunities for participation in classroom activities.

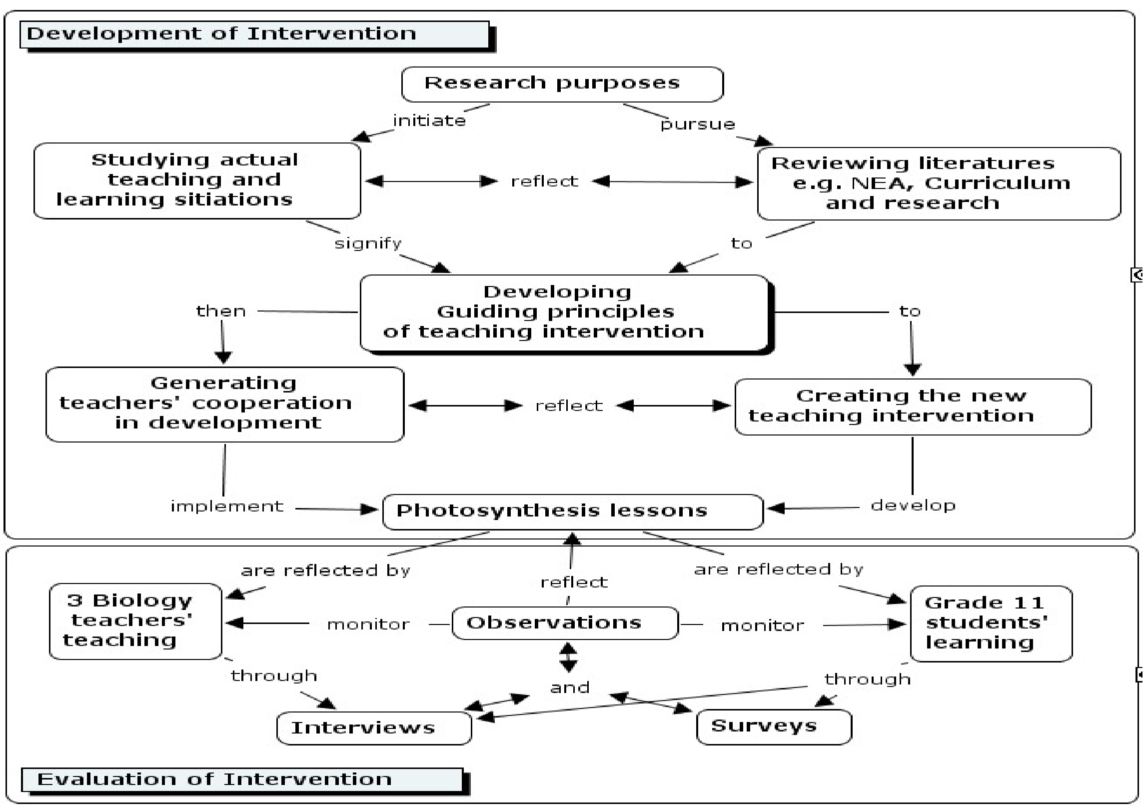
Due to the emergence of this socio-cultural perspective from the constructivist perspective, development of a teaching approach from constructivism to socio-culturalism was needed in this study. The generative teaching model (Osborne and Wittrock, 1985) was used to promote learning about photosynthesis. The model included three phases: focus, challenge, and application. The students would be focused on their prior knowledge of photosynthesis (Ministry of Education, 1991a); and be challenged to learn the current scientific ideas about photosynthesis and the nature of science (IPST, 2002). The scientific knowledge taught would then be applied to explore and develop the students' ideas about photosynthesis for the environment (Eisen and Stavy, 1993; Carlsson, 2002). In addition, the students would be encouraged to actively learn as a result of the classroom style of teaching (ONEC, 2000).

In brief, the purpose of the present study was the development of a new photosynthesis teaching intervention as a model to promote Grade 11 students' understanding of photosynthesis in the context of the culture and society of Thailand.

Research Design

Action research in three case studies was designed to develop the teaching intervention, to study how the teacher implemented the intervention, and the impacts of the intervention on students' learning. This study interpreted data from two surveys, classroom observations and interviews. Figure 1 shows the processes of the study.

Figure 1 Research Design



Research Participants

Three biology teachers and one hundred and eighteen students participated in this study. They were Mrs. Engka, Mr. Vyn, and Mrs. Amp, who taught at the 11th grade as well as the 7th – and/or 9th- grade levels in three different public high schools located in a Bangkok suburb. They had taught photosynthesis in Grade 11 for at least ten years. The teachers were selected on the basis of their personal interest in developing biology education.

Mrs. Engka, was head of her school's science department. Her love of nature was her initial motivation for teaching biology. Her formal education was a Bachelor of Education, with a major in biology and a minor in nutrition. She believed that teaching by lecturing alone could no longer adequately develop students' learning of biology, and it was her intention that her students learn happily and effectively in the classroom. She was thus enthusiastic about the importance of students' interactions in teaching activities, in particular, class discussion. She perceived her teaching role as monitoring student learning development, helping each student to learn by answering questions, and providing information as individual students recognized the need. However, she was not confident in her chemistry content knowledge of photosynthesis, and she wanted to learn more about the nature of science.

Mr. Vyn graduated with a Bachelor of Education (Biology Teaching) degree and a Master of Science (Botany) degree. He had the confident manner of a professional science teacher and he strongly emphasized the content of scientific knowledge. He taught biology because he preferred to study living things, nature as well as the environment. He perceived the nature of science as the scientific laws. However, he felt constrained by the school policy that assigned teachers to teach several periods at the school with a large number of students in each classroom. He focused on a teacher-centered approach. He thought that students learned directly from a teacher's lecture. Then, the students would be able to think and further their knowledge by inquiry on their own.

Mrs. Amp's teaching strongly emphasized good student discipline. The students should be quiet and not move around during the class. The role of teaching was perceived to be assessing students' work. The students needed to send assignments or homework to the teacher and then receive brief comments and their scores in return. Mrs. Amp would rarely appreciate students who argued with the teacher and the school. Mrs. Amp perceived the nature of science to be science content in general for everyday living. However, she was not confident in her chemistry content knowledge of photosynthesis. Also, she felt constrained by the government's educational policy which expected Thai teachers to change their traditional teaching methods from a teacher-centered approach to a student-centered approach.

A total of one hundred and eighteen students in the three classrooms were taught during the months of November and December 2004. Twelve of the students were purposively selected to monitor the learning arising from the three teachers' teaching. The selection was based on gender, age, biology achievement, and attitudes towards biology. Table 1 shows the information about the twelve students. -

Table 1 Information about students selected for in-depth study

Teachers/ Student Codes		Information Categories				
		Sex	Age	Biology Achievement	Career (Father/Mother)	Attitudes Towards Biology
Mrs. Engka	S01	M	16	3.0	A small business owner/ Tailor	I am sometimes interested in biology. It depends on the topic.
	S02	M	16	3.5	Lawyer/Nurse	I dislike biology.
	S03	F	17	3.5	Laborers	I dislike biology because it requires too much memory.
	S04	F	16	3.5	Engineer/ House wife	I study biology because I want to be a dentist.
Mr. Vyn	S05	M	18	4.0	Retirement/ Teacher	I like to study biology…because I want to be a doctor.
	S06	M	16	4.0	Irrigation officer/ Employee	I consider biology necessary for living…I even want to be an engineer.
	S07	F	16	3.5	Army officer/ Banking officer	I learn biology for everyday living.
	S08	F	16	3.0	Employees	I think that biology is too difficult to understand …there is too much information.
Mrs. Amp	S09	M	16	2.0	Private business	I do not like biology much when the teaching has an emphasis on lecturing.
	S10	M	17	3.5	Private business/ Language teacher	I consider biology necessary for taking the National Entrance Examination.
	S11	F	16	4.0	Engineer/ Housewife	I usually study biology by myself…when I am going to have the test.
	S12	F	16	4.0	Office worker/ Government officer	I am not motivated to study [biology] by myself, but I try to concentrate during study in class.

Methods

The Development of the Photosynthesis Teaching Intervention

The photosynthesis teaching intervention is comprised of a seven lesson teaching unit over twelve 50-minute teaching periods. The unit was created based on six guiding principles.

1) Correcting grade 11 students' misconceptions about introductory photosynthesis.
2) Enhancing grade 11 students' understanding about advanced photosynthesis concepts.
3) Encouraging students to apply photosynthesis knowledge to conserving the environment.
4) Using historical narratives to illuminate the nature of science based on the national science curriculum (IPST, 2002).
5) Having regard for culture and society as socio-cultural perspectives on teaching and learning.
6) Encouraging students to actively learn about photosynthesis.

The three biology teachers cooperated in the development of the teaching unit in the teacher preparation phase. It covered three sessions including introduction, validation, and development, as well as implementation and evaluation. During these sessions, the researcher took field notes, audio-recorded discussions, and interacted with the three biology teachers.

The first one-day teacher development session, early in September 2004, introduced the teaching unit to the three participating teachers. The research objectives, the six guiding principles of the teaching unit, and the data collection processes were revealed in parallel with promotion of social interactions among the teachers themselves. The researcher helped the teachers to appreciate why they needed to understand and investigate the students' prior knowledge based on the generative teaching model. The teachers discussed and shared ideas on the six guiding principles. After that, the data collection process was discussed to encourage the teachers' commitment to develop and implement the teaching unit in their three schools.

Because the teachers were unfamiliar with investigating the students' prior knowledge of photosynthesis, especially about plant food, the second teacher development session, in mid-October 2004, challenged the teachers to recognize their students' preconceptions by scrutinizing the empirical data of the survey, called the Introductory Photosynthesis Survey (IPS). Then, the teachers cooperatively validated and developed the teaching unit with this study. The validation concerned the learning outcomes, concepts, learning activities, teaching materials, media, and evaluation procedure in each photosynthesis lesson of the unit.

After the three teachers had implemented the teaching unit in their schools, the third teacher development session was conducted in mid November and mid December 2004. The session gave rise to the final development of the intervention. There were seven lesson plans in the teaching unit developed for the study. Table 2 shows the unit.

Table 2 Photosynthesis Teaching Unit

Phases	No. of Periods	Lessons and Objectives	Learning Activities	Materials and Evaluation
Focus	2.0	Lesson 1: Plant food Students would be able to: • Elicit their own existing ideas about plant food. • Develop a concept map about plant food. • Illustrate their ideas with each other.	1. Think pair share 2. Think pair square 3. Playing game by the post-box method 4. Concept mapping	1. Use the work sheet “What is Plant Food?” to elicit the existing ideas. 2. Use the booklet “Why do Plants Make Sugar?” to develop the understanding about plant food. 3. Use the game Circus of Misconceptions” (true or false) for students’ own evaluation of learning. 4. Use concept mapping to evaluate development of the students’ learning.
	0.5	Lesson 2: The nature of science and historical ideas of photosynthesis • Questions about the nature of science. • Summarize how knowledge of photosynthesis has been developed. • Give some examples representing the three aspects of the nature of science.	1. Questioning 2. Story telling using the student booklet 3. Cooperative learning 4. Classroom discussion	1. Use the booklet “History of the Word Photosynthesis” to probe the ideas about the nature of science covering three aspects: that scientific ideas are subject to change; science demands evidence; and science is a complex social activity. 2. Use the work sheet: Nature of science to evaluate the development of the students’ ideas.

Table 2 Cont'd

Phases	No. of Periods	Lessons and Objectives	Learning Activities	Materials and Evaluation
Challenge	2.0	Lesson 3: Structure and Functions of Chloroplasts • Identify where photosynthesis takes place. • Experiment to find pigmentation taking place in plant leaves. • Interpret, analyze, and describe the structure and function of chloroplasts. • Give some examples of photosynthetic pigments • Explain how photosynthesis was developed.	1. Playing the game: Historical jigsaw 2. Cooperative learning 3. Story telling using the student booklet 4. Experimentation using paper-chromatography	1. Use the game to elicit pre-conceptions about simple photosynthesis process. 2. Consider group discussion based on the booklet "Who Discovered the Chloroplast?", to evaluate understanding about chloroplasts. 3. Use the lab direction "Pigment of the Experimentation" to discuss, practice, and evaluate the students' conceptions about chloroplasts.
	1.5	Lesson 4: Light Dependent (Light) Phase • Identify the products of the light phase. • Explain the roles of light, pigment, water, and the electron transport system in the light phase. • Distinguish between the cyclic ETS and the non-cyclic ETS. • Explain the importance of the changing development of light phase.	1. Questioning 2. Cooperative learning 3. Story telling using pamphlet 4. Group discussion 5. Concept mapping	1. Use the pamphlet Van Neil, Arnon, and Hill to probe the students' ideas about the light phase. 2. Use concept mapping to evaluate the students' conceptions about the light phase.

Table 2 Cont'd

Phases	No. of Periods	Lessons and Objectives	Learning Activities	Materials and Evaluation
Challenge	3.0	Lesson 5: Light Independent (Dark) Phase • Explain how scientists worked out the process of photosynthesis. • Explain the process of the dark phase. • Distinguish between the dark phase of C3 plants and C4 plants. • Evaluate own learning about the dark phase.	1. Role play based on a historical story 2. Cooperative learning 3. Classroom discussion 4. Concept mapping	1. Use the dialogue to guide the role play activity and use discussion to evaluate the students' ideas about NOS as social enterprise. 2. Use the booklet "The Long Journey of the Light Independent Phase" to probe the ideas about the phase. 3. Use the work sheets "Photosynthesis of C3-and C4-plants and Matching Me" to evaluate understanding. 4. Use the concept map to correct the students' misconceptions about the phase.
Application	2.0	Lesson 6: Students' Own Demonstration of Photosynthesis • Theorize, plan, and design the experiment for studying light intensity. • Collect, analyze, and summarize the data. • Explain the advantage of the experimentation.	1. Problem solving 2. Experimentation 3. Group work	1. Use the booklet "Experiments of Photosynthesis" for students' own evaluation about the design of the problem solving. 2. Use the work sheet "Experimental design and observations" to evaluate the student group's understanding of photosynthesis factors.

Table 2 Cont'd

Phases	No. of Periods	Lessons and Objectives	Learning Activities	Materials and Evaluation
Application	1.0 plus Out side teach ing pe riod	Lesson 7: A Campaign: Photosynthesis for the Environment • Tell the story about the relationship between photosynthesis and the environment • Apply photosynthesis knowledge to the issue of conserving the environmental in school or community. • Explain the advantages of cooperative learning..	1. Science project 2. Students' personal story telling 3. Group work 4. Classroom discussion	1. Use the work sheet "A Campaign to Conserve the Environment by Photosynthesis" to elicit the students' ideas using accepted science knowledge to conserve the environment in the science project. 2. Use classroom discussion and observations to evaluate the students' practices on operating the science project.

After the development of the teaching intervention, this study used classroom observations and interviews with the teachers and the students to reveal effectiveness of the teachers' implementation of the intervention in their three classrooms. In parallel with the implementation, this study also revealed the impacts of the intervention on students' learning through the surveys, the interviews, and the observations.

Data Collection and Data Analysis

The process of participant observational fieldwork was used to collect data on the teachers' implementation and the students' learning. The three teachers were observed, noted on file, and audio-taped for twenty four teaching periods. Classroom observational data was organized into time, description, and comment columns. Overview reading of the three columns established the beginning ideas, questions, and thoughts about which data could be useful for this study. Coding based on the researcher's interpretation of the teaching and learning situations identified the elements of the situations. An additional column of the analysis described what the researcher thought of the coded situations in each of the three case studies and then described the analysis of each case study.

Interviews held in conjunction with the previous observational processes provided broader understanding of the teachers' implementation and the students' learning. The three teachers were informally interviewed before and after each observation. Teacher interview data, as an indication of the teachers' reflections, were transcribed verbatim. The transcripts were revised by the researcher and confirmed by the teachers. Data from the transcripts was selected, quoted, and acknowledged to support the findings of this study. In addition to student interviews, the twelve purposively selected students (Table 1) were individually interviewed before and after the implementation. The analysis of the interviews began by transcribing the audio-tapes verbatim. These transcripts were checked by the researcher listening to the audio recorder again. Important words or sentences were selected, highlighted, and interpreted. The student data was then analyzed thematically, in parallel with the surveys' responses.

Two surveys were developed and used to explain the relationships between the understanding about photosynthesis itself, photosynthesis in a broad environmental context, and the nature of science before and after implementation of the teaching intervention. The surveys consisted of multiple choice and open-ended questions, and were checked for validity, reliability, and practicability by scientists and science educators from New Zealand and Thailand. The first survey was called the Introductory Photosynthesis Survey and was used to explicate the students' prior-knowledge about photosynthesis. The second survey was called the Advanced Photosynthesis Survey and was used to probe the students' understanding of advanced photosynthesis concepts based on the curriculum (IPST, 2002). Content analysis was used to interpret the survey data. The analysis began with: 1) descriptions of student understanding; 2) categorization of the student's understanding of photosynthesis compared and contrasted with scientific conceptions; 3) coding the understanding and 4) calculating the percentage of responses in each category.

Results and Discussion

After the teaching unit was developed cooperatively, the teachers' teaching was monitored to reveal how far the teachers implemented the unit in their classrooms. Also, their students' learning was measured to indicate the impact of the unit. The findings showed that the three teachers implemented the unit differently. Mrs. Engka consistently implemented the unit, but Mr. Vyn and Mrs. Amp *in*consistently implemented the unit based on the six guiding principles. The findings also indicated that the implementation depended on the teachers' beliefs about learning, content knowledge, perceptions on the nature of science, and the teacher's role in the classroom.

The teachers' attempt at correcting the misconceptions using several learning activities depended on their beliefs about how students learn in the classroom. For example, Mrs. Engka, who believed that teaching only by lecturing, could not sufficiently develop the students' learning about biology, consistently attempted to correct her students' misconceptions using several learning activities, i.e. discussions, games, reading assignments, concept mapping, and collaborative learning. The findings indicated that her students could correct the misconceptions. For example, the misconception about plant food; "mineral, fertilizer, water and air are plant food..." was correctly substituted by the scientific concept; "glucose was plant food." Hazel and Prosser (1994) and Brown (2003) supported the notion that the learning activity, in particular concept mapping, powerfully helped teachers to explore and analyze the students' conceptions. The teachers would then facilitate the students learning through discussion to correct the misconceptions found.

It appears that lecturing and giving a particular reading assignment without discussion between the teacher and the students sometimes resulted in a further retention of the students' misconceptions and also generated new misconceptions about introductory photosynthesis. Mr. Vyn, who believed that students must learn from teachers, emphasized lecturing, and Mrs. Amp, who believed that students would learn if they often wrote all concept words and statements in their notebooks, preferred to emphasize the use of reading assignments to correct the misconceptions. The findings showed that their students could not correct the misconceptions. For example, a student in Mrs. Amp's classroom still held the misconception that "mineral, fertilizer, and water were plant food" and held new misconception that "CO_2 was also plant food".

Although the teachers had extensive knowledge of science, they might not have been convinced to use that knowledge to advance the students' understanding of photosynthesis. Mr. Vyn is an example of a teacher who had strong content knowledge in biology, but his belief very much emphasized a teacher-centered approach. In the classroom, his lectures often appeared to displace the intended learning activities in the unit, and focused on abstract photosynthesis concepts, definitions, and formulas to cover all of the contents for the end-of-topic examination. The students were expected to complete the activities and develop their understanding outside of the classroom teaching time. On the other hand, Mrs. Engka, the teacher who was not confident in her chemistry knowledge of photosynthesis concepts, but was enthusiastic about enhancing the teacher-student interactions, consistently developed her content knowledge and enhanced the students' understanding. Her teaching included cooperative learning, experimenting, questioning, discussing, role playing, and concept mapping. Mrs. Amp, the teacher who was not confident in her chemistry knowledge and also not enthusiastic about teacher-student interactions, mainly used reading assignments to enhance students' understanding.

The findings indicated that eighty percent of the students in Mrs. Engka's classroom and forty-three percent of those in Mr. Vyn's classroom developed adequate scientific understandings about the light independent (dark) phase compared with only twenty-four percent in Mrs. Amp's classroom. For example, a student in Mrs. Amp's classroom misunderstood that the dark phase was the process of producing food at night.

The teachers' personal perceptions of the nature of science (NOS) strongly affected the way they illuminated the three aspects of NOS: 1) that scientific ideas are subject to change; 2) that science demands evidence; and 3) that science is a complex social activity. Mrs. Engka, who perceived that understanding NOS is as important as understanding photosynthesis concepts, consistently initiated discussion about historical narratives involving earlier photosynthesis discoveries by scientists, and facilitated students' experimentation, role play, problem solving, and science projects. On the other hand, Mr. Vyn and Mrs. Amp, the teachers who perceived NOS as scientific ideas in science, taught NOS as similar to teaching the concepts. Mr. Vyn lectured about NOS prior to the experiment, and used role play and science projects based on the unit. Mrs. Amp informally used reading assignments and science projects without discussion to illuminate the students' understanding outside of teaching periods.

As for the results, a majority of the students (sixty-six, fifty-three and sixty percent in Mrs. Engka's, Mr. Vyn's, and Mrs. Amp's classrooms respectively) understood that science is a complex social activity. A student in Mrs. Engka's classroom showed the understanding that "…scientists worked by observing, hypothesizing, experimenting, summarizing, and *cooperating with others*... They needed to be patient doing many experiments with *loyalty*… They used scientific processes, *exchanged knowledge* with each other, and did experiments". Mrs. Engka's students also understood the two other aspects (that science demands evidence and that scientific ideas are subject to change), but Mrs. Amp's students did not understand these two aspects. Mr. Vyn's students were very unclear about the idea that scientific ideas are subject to change.

The teachers perceived that enabling students to undertake a science project which relates photosynthesis knowledge to conserving the environment, could be an intensive aspect of teaching about photosynthesis. The teachers often initially assigned the project to outside teaching periods. However, the teachers, e.g. Mrs. Engka, also perceived their teaching role in terms of monitoring student learning development and facilitating each student to learn by initiating the project through students' personal stories of the environment. The students then decided by themselves what they would like to engage in their environment. As for the results, the students appeared to use accepted photosynthesis concepts to operate the project for the environment. On the other hand, some students were not convinced about doing the project assigned. In one case, a student used incorrect photosynthesis concepts in the project.

The teacher who was enthusiastic about enhancing the teacher-student interactions had regard for the students' learning culture and society in the classroom. Mrs. Engka's teaching explicitly investigated the students' own views about plants as a basis for correcting the misconceptions; developed friendly relationships between the teacher and student and student to student, facilitated students' arguments in discussion; and promoted classroom participation to encourage students to value studying biology for everyday living, not only for taking the National Entrance Examination. On the other hand, Mr. Vyn and Mrs. Amp had less regard for culture and society; they taught to prepare students for the examination, introduced their students to unfamiliar material, and were not confident about participating in the teaching activities.

In addition, Mrs. Engka, who was ready to change her teaching practices, expected to develop her students' perspectives about learning belief values in studying science. Mrs. Engka noted that "I improved the launching strategy…, [because the students] were unconvinced by classroom discussion…they were convinced by listening and taking notes rather than talking with me…" As a result, the students enthusiastically participated in a new active learning style that suitably supported their learning about photosynthesis based on the unit. Some examples of observations and interviews illustrated that the students continued to read the booklets and revise the concept map after the discussion. They themselves were then willing to organize the group work to prepare learning materials and group responsibility to participate in classroom activity, e.g. role play. On the other hand, the two teachers who still believed in a teacher-centered approach and thought that classroom participation was time consuming, possibly caused their students to devalue the classroom study of biology and could not develop learning based on the unit. For example, a student in Mr. Vyn's classroom said that "It seemed to me that there was no problem-solving in our class…there was just the studying of dead knowledge…". Also, another student in Mrs. Amp's classroom perceived that the classroom teaching could not lead her to understand about photosynthesis, and the student was going to study biology with a private tutorial institute specifically to prepare for the National Entrance Examination.

Implications for Implementing a New Teaching Intervention

The results suggest that the development of student understanding about photosynthesis should be done in parallel with teacher development. Bell (1998) noted that teacher development should concern personal, professional, and social development. There are three recommendations for teachers' implementing a new teaching intervention.

1. Teachers should be challenged with up-to-date evidence of their students' learning difficulties in the context of their school society. Personally, this is to persuade teachers into a teaching practice based consistently on intervention in the real classroom and feeling more confident about changing their traditional teaching style.

2. The guiding principles of the new teaching intervention should be presented clearly and persuasively using the following steps:

- Initially, the teachers' beliefs about how students learn, the recognition of students' prior misconceptions, and the formative assessment of learning should be elicited through discussion, not only through pencil-and-paper responses.

- Then, the guiding principles should be presented.

- The teachers should reflect on the principles and organize their teaching roles in new teaching and learning activities to promote the students' learning based on the principles. Smith and Anderson (1984: 697) indicated that providing all lesson plans and teaching materials could not convince the teachers to develop their profession. Instead, promoting teachers to think about selecting and adapting teaching material based on their students' preconceptions should be emphasized.

3. The teaching experiences and the students' learning development with the new approach should be socially shared and discussed as the teachers cooperate in the development of the intervention. This is to support teachers who already recognize the need for a change in teaching traditions, and to motivate teachers who are waiting for an incentive to change.

This study suggests that the new teaching intervention has helped students to progress in their understanding of photosynthesis in schools where the teachers were not convinced of the effectiveness of the teacher-centered approach. Their interest in alternative teaching traditions enabled the teachers to value and trust in the teaching intervention. Then they were confident and ready to implement the intervention consistently. This consistency will possibly result in the students' improved learning of photosynthesis.

Reference

Alfred, M. (2002). The *promise* of sociocultural theory in democratizing adult education. *New Directions for Adult and Continuing Education* 96: 3-13.

Amir, R. and P. Tamir. (1989). When does a factor become a 'Limiting Factor'? –a study of students' misconceptions. *Journal of Biological Education* 23 (2): 129-134.

_____. (1994). In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The Case of photosynthesis. *The American Biology Teacher* 56 (2), p: 94. Retrieved August 7, 2003, from ProQuest database.

_____. (1995). Proposition generating task (PGT): a measure of meaningful learning and of conceptual change. *Journal of Biological Education* 29 (2): 111-118. Retrieved August 7, 2003, from EBSCOhost database.

Anderson, C., T. Sheldon, and J. Dubay. (1990). The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching* 27 (8): 761-776.

Barker, M. (1985). Teaching and learning about photosynthesis. *Working Papers No. 220-229*. Hamilton: University of Waikato.

Barker, M. and M. Carr. (1989a). Teaching and learning about photosynthesis, Part 1: an assessment in terms of students' prior knowledge. *International Journal of Science Education* 11 (1): 49-56.

_____. (1989b). Teaching and learning about photosynthesis, Part 2: a generative learning strategy. *International Journal of Science Education* 11 (2): 141-152.
_____. (1989c). Photosynthesis—Can our pupils see the wood for the trees. *Journal of Biological Education* 23 (1): 41-44.
Bell, B. (1981). Animal, plant and living: note for teachers. *Working paper No. 30*. Hamilton: University of Waikato.
Bell, B. (1985). Students' ideas about plant nutrition: What are they? *Journal of Biological Education* 19 (3): 213-218.
_____. (1998). Teacher development in science education. In Fraser, B and K. Tobin. (Eds.). *International Handbook of Science Education*. UK: Kluwer Academic Publishers, p. 681-693.
Brown, D. (2003). A Group approach to concept mapping. *The American Biology Teacher* 65 (3): 192-197.
Buffalo villages. (pseud.). (2003). *History of Thai Houses*. (Online). Available: http://www.buffalovillages.com/en/showbaan/songthai_his.htm, 24 Jan 2004
Buranakarn, V. (2003). Graduate experience influenced from elementary study: Thailand case study. In *Grade-Blueprint 2003* (Online). Available: http://www.grad.chula.ac.th/GRADBLUEPRINT/Fulltex/Vorasun.htm, 10 Jan 2004.
Carlsson, B. (2002). Ecological understanding 1: ways of experiencing photosynthesis. *International Journal of Science Education* 24 (7): 681-699.
Cobb, P. and E. Yackel. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist* 3 (3/4): 175-190.
Eilam, B. (2002). Strata of comprehending ecology: looking through the prism of feeding relations. *Science Education* 86: 645-671.
Eisen, Y. and R. Stavy. (1993). How to make the learning of photosynthesis more relevant. *International Journal of Science Education* 15 (2): 117-125.
Ekborg, M. (2003). How students teachers use scientific conceptions to discuss a complex environmental issue. *Journal of Biological Education* 37 (3): 126-132.
Eskilsson, O. and I. Holgersson. (1999). Everyday phenomena and teachers' training. *European Journal of Teacher Education* 20 (2/3): 231-245.
Griffard, P. and J. Wandersee. (2001). The Two-Tier instrument on photosynthesis: What does it diagnose? *International Journal of Science Education* 23 (10): 1039-1052.
Haslam, F. and D. Treagust. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education* 21 (3): 203-211.
Hazel, E. and M. Prosser. (1994). First-year university students' understanding of photosynthesis, their study strategies and learning context. *The American Biology Teacher* 56 (5): 274-279.
Institute for the Promotion of Teaching Science and Technology (IPST). (2002). *The National Science Curriculum*. Bangkok: IPST. (in Thai).
John-Steiner, V. and H. Mahn. (1996). Sociocultural approaches to learning and development: a Vygotskian framework. *Educational Psychologist* 3 (3/4): 191-206.
Julian (pseud.). (2000). The Value of trees. *WETlands* (Dec 2000): 7 (3). (Online). Available: http://www.sbwr.org.sg.wetlands.text/00-7-3-9.htm, 20 Dec 03.

Kijkuakul, S. (2002). Classroom Observations: Grade11 Photosynthesis Teaching. Aug 10, 2002. Bangkok.

Kijkuakul, S. and N. Yutakom. (2004). A study of level 4 students' photosynthesis conceptions. *Kasetsart Journal (Social Science):* 25 (2): 139-149.

Lavoie, D. (1997). *Using a Modified Concept Mapping Strategy to Identify Students' Alternative Scientific Understandings of Biology*. Paper presented at the 1997 Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, March 21-24, 1997.

Lumpe, A. and J. Staver. (1995). Peer collaboration and concept development: learning about photosynthesis. *Journal of Research in Science Teaching* 32 (1): 77-98.

Marshall, H. (1996). Implications of differentiating and understanding constructivist approaches. *Educational Psychologist* 31 (3/4): 235-240.

Ministry of Education. (1991a). *Junior High School Curriculum B.E. 2521 (Revised B.E.2533).* Bangkok: Karn-sat-sa-na printing. (in Thai).

_____. (1991b). *Senior High School Curriculum B.E.2524 (Revised B.E. 2533).* Bangkok: Karn-sat-sa-na printing. (in Thai).

Office of the National Education Commission (ONEC). (2000). *Learning Reform: A Learner-Centred Approach.* Bangkok: Watana Panit Printing and Publishing Company Limited.

Osborne, J., and M. Wittrock. (1985). The Generative learning model and its implications for science education. *Studies in Science Education* 12: 59-87.

Ozay, E. and H. Oztas. (2003). Case study: secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education* 37 (2): 68-70.

Packer, M. and J. Goicoechea. (2000). Sociocultural and constructivist theories of learning: ontology, not just epistemology. *Educational Psychologist* 35 (4): 227-241.

Smith, E. and C. Anderson. (1984). Plants as producers: a case study of elementary science teaching. *Journal of Research in Science Teaching* 21 (7): 685-698.

Songer, C. and J. Mintzes. (1994). Understanding cellular respiration: an analysis of conceptual change in college biology. *Journal of Research in Science Teaching* 31 (6): 621-637.

Srivichit, T. (2004). *Thailand in the 90s*. Available: http://www.thailandlife.com/thaifamily.html, 8 Jan 2004.

Suzuki, D. (1997). *The Sacred Balance: Rediscovering Our Place in Nature*. n.p. Allen and Unwin.

Treagust, D. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education* 10 (2): 159-169.

_____. (1991). Assessment of students' understanding of science concepts using diagnostic instruments. *The Australian Science Teachers Journal* 37 (4): 40-43.

Triolo, R. and R. Lewis. (1998). *A Thai Journey*. Australia: Curriculum Corporation.

Vermaas, W. (1998). An Introduction to photosynthesis and its applications. *The World and I* (March 1998): 158-165. (Online). Available: http://photoscience.la.asu.edu/photosyn/education/photointro.html, December 19, 2003.

Wandersee, J. (1983). Students' misconceptions about photosynthesis: a cross-age study. In H. Helm and J. Novak (Chairman), *Proceedings of the International*

Seminar on Misconceptions in Science and Mathematics. Cornell University, pp. 441-466.
_____. (1985). Can the history of science help science educators anticipate students' misconceptions? *Journal of Research in Science Teaching* 23 (7): 581-597.
Waheed, T. (1992). Understanding interrelated topics: photosynthesis at age 14. *Journal of Biological Education* 26 (3): 215-213.

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