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A Strategy for Productive Teachers' Questioning in Chemistry Class: Disassembly, Assembly and Interweave of Questions

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Abstract: Questioning forms an integral part of most strategies for effective teaching when the class consists of difficult content. Science including chemistry is usually content-rich, but difficult to understand without supporting lab experiments, subsidiary visual materials and model kits. Engaging the attention and interest of students in such a subject, therefore, is the key to the success of a daily lesson in the classroom. However, generating meaningful questions requires a certain level of information and metacognitive skills on the part of the teacher. The purpose of this study was to find out the framework of effective teachers' questioning with a large group in chemistry class: how teachers used questioning to engage their students in such a big class, to identify a variety of forms of feedback provided by students and to develop a model of question-inducing strategies. We investigated the teachers' recognition of their questioning and the students' recognition of teachers' questioning by surveying over 82 teachers and 434 students in Korea. The survey findings show that the questionnaire can be categorized into four elements: the theme of the teachers' questions (T), students' inquiries (I), methods of teachers' questioning (M) and encouragement of students (E). These elements can be analyzed and sub-categorized to find out which elements are effective in good questioning, even though the elements are interwoven tetrahedrally.

Key words: questioning, science teaching, TIME model, chemistry

I. Introduction

When students learn science in a class, the most important information comes from the teacher's verbal interactions with students (Park, 2004; Black & Harrison, 2001). Even though most of the subjects require empirical work, teaching in science classes in Korea have typically relied on a very limited number of experiments and field trips, and substantially teacher-led verbal lessons. Accordingly, the teacher's instruction has been the key to student success in a large class of a content-rich science subject, although the number of students in each secondary education class has been reduced from 60 to 35 over the last 40 years in Korea (KEDI, 2006). In teaching the content of science, teachers can explain the values of the subject and also, unwittingly, the 'mystique' of science (Lemke, 1990). This mystique describes the perception of science as being much more authoritarian and difficult than it actually is in reality, as well as the perception that scientists are "geniuses" with whom students cannot identify. Most of the students render 'chemistry' as 'chemystery' because, contrary to popular belief, the reaction inside the test tube or beaker seems to be mysterious (De Vos *et al*, 2002; Sutton, 1974). How do teachers reach out to students who have such an unwilling perception? Each chemistry lesson should open with the teacher's introduction that is designed to get rid of students' biased notions, and to attract students' curiosity or elicit students' ideas on what they are about to learn (Sutton, 1974). For a good instruction, it is very important for verbal interaction to be activated by the use of questions (Hunkins, 1989). Through questioning, teachers can attract students' attention and confirm that students are understanding well, while students can get the core of the content and direction of learning through teacher's questioning (Morgan & Saxton, 1991).

The introduction of each class may be composed of a question or questions which should be mutual and bilateral between the teacher and the students.

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Lemke (1990) and Wells (1993), similarly, pointed out that typical teaching consists of triadic dialogue composed of three moves: initiation (teacher question), response (student answer) and evaluation (teacher evaluation, sometimes, follow-up or feedback). However, this teaching-learning method has become somewhat disconnected from reality because it is perceived to have restrictive effects on students' thinking if students' responses remain brief and teacher-intended (Lemke, 1990). In addition, the actual class, with such a large group in Korea, is so didactical that students' participation is rather limited due to the difficult contents of scientific subjects and the restriction in class time. Unfortunately, the research of science teachers on questioning-inducing chemistry class have not yet fully recognized. Judging by past outcomes, if science, including chemistry, continues to be taught conventionally without systematic approaches including curiosity-induction about the heavy subject matter, many students in such a large group will be frustrated, and will fail to meet the daily class expectations.

Based on the above-mentioned research, this study investigated the impact of teacher-inducing questions on such a large group by surveying the teachers' recognition of their questioning and the students' recognition of teachers' questioning. In addition, we studied how to classify and arrange questions in terms of the function of the questions as well as how much sorted factors influence each other. Specifically, the following research questions were addressed.

(1) Which elements exist for effective questioning in a chemistry class and how can they be categorized and coded?
(2) What do students think about a science teacher's questions in class?
(3) What do science teachers think about their own questions of students in class?
(4) What's the difference between the cognition of teachers and students?
(5) Do science teachers in service present questions effectively in their class?

II. Theoretical Background

Teacher questioning has been the subject of interest of several researchers (Dantonio & Beisenherz, 2001; Dillon, 1988; Morgan & Saxton, 1991; Myhill, 2006; Zee *et al,* 1997 & 2001). According to Dillon (1988), the scheme for teacher questions could pedagogically include preparing, posing and pondering actions which consist of enacted answers to seven generic questions as follows: purpose, preparation, question, answer, reaction, assessment, and redesign. Morgan and Saxton (1991) classified teacher questions into three general functions: eliciting information, shaping understanding and pressing for reflection. Each category contains four to seven particular functions such as establishing the rule of the game, procedure and control of group discipline. Myhill (2006) classified teacher questions in terms of the four forms of the question (factual, procedural, speculative or process) and several functions of the question. According to Zee and Minstrell (1997), there are several kinds of questions to help students a) make their meanings clear by clarifying the meaning of what has just been said, bringing student knowledge into public view and prompting articulation of the focal issue by a student, b) consider a variety of views, and c) monitor the discussion and their own thinking. Zee *et al* (2001) also found that teachers elicited student thinking by asking questions that developed conceptual understanding, and by practicing quietness through long wait times, attentive silence, and reticence.

In Korea, questioning has been also a common theme of research. Most studies, however, have been focused on learning-teaching model encouraging the student to ask questions rather than the model of teachers' questioning strategies (Kim, Yeo & Woo, 1999; Kim & Pak, 2002; Chung & Bae, 2002; Lee, Jo & Song; Park *et al,* 2006). A few studies of teachers' questioning techniques have been reported in journals, but most are reported in the theses or books (Lee, 1999; Kim, 2003). For instance, Choi (1992) found that cognitive questions are efficient for students to obtain factual knowledge, and that diversified questions do help students to think variously and to participate positively in class. Lee (1999) classified questions as cognitive processes including directional process, empirical process, evaluative process and metaphysical process. Cognitive conflict process might not result in successful knowledge construction without continuous verbal interaction (Forman & Kraker, 1985). Thus, verbal interactions among peers can be essential in aiding students to detect cognitive gaps, transact meanings and modify their perspectives. Instruction mainly with cognitive memory questions is useful to improve the achievement in knowledge, while instruction mainly with diversified questions is useful to improve the achievement in inquiry skills and the level and type of questioning should be concerned with the contents and the goals of the class (Kim, 1996). Important functions of a teacher's questioning help students guide knowledge construction and enlargement of understanding, learn problem-solving and thinking ability and stimulate memory with the direction in the class (Lee, 1999). In addition to other functions that it can serve, questions have an effect the student's attention on related material, reducing the amount of learning in areas not related to the questions. Thus, a teacher's questions can determine the success of each class. If a teacher systematically prepares questions, students can scaffold productive thinking and understand the subject matter via constructing scientific knowledge (Chin, 2007).

Ⅲ. TIME Model for Effective Questioning

The results these researchers mentioned above in 'Introduction' and 'Theoretical Background' can be divided into two types: (a) the sequence, cycle, pattern and/or proceeding of recitation based on the teacher's questioning, (b) the function, purpose, type and/or effect of the teacher's questioning in class. Most of the models for effective questioning were based on one of each type.

A good teacher knows how to use questions for maximum impact on students (Myhill, 2006). Effective questions are those which accomplish their purpose as well as build a positive relationship between the teacher and students (Marqurdt, 2005). Every question has its content or *theme*. In other words, the teacher selects an issue of interest which can be the material of the questioning. After selecting it, the teacher will think how she can stimulate students to *inquire* by using the material, how (by which *methods*) she can make it a question, and what she can do in order to *encourage* students after presenting the question. This series of actions should be done in limited *time* because the teacher does not have infinite *time* to

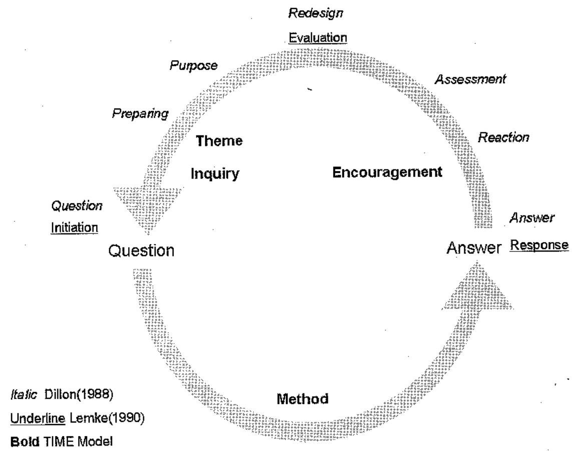

Fig. 1 Comparison of TIME model with other models in a question-answer cycle.

teach each session. Such a presentation of questioning can include both the sequence of recitation and the type of question.

The result of merging which we suggested is TIME elements which stand for the acronym of four categories of elements (theme of the teachers' questions (T), students' inquiry (I), methods of teachers' questioning (M), and the encouragement of students (E)) that good questioning could have. The teacher must first select the contents or the themes which she intends to teach students in each class. After that she should think how her students make inquiry about these themes or contents. If her idea is set for the theme, the teacher should also consider an appropriate questioning method and should present some questions converted from the theme. After the questioning, she should encourage the students with handling questions. Thus, the elements T, I, M, and E appear in a sequence.

Fig. 1 shows the schematic comparison our TIME model with previous patterns or cycles proposed by Dillon (1988) and Lemke (1990), respectively. Dillon's cycles are concentrated on actions switching from answer to question. Most actions take place before the right questions are asked. Lemke's triadic dialogue structure is more simple and also focused on evaluation after answer before question. In the TIME model, element M stands for questioning methods, which can be between initiative questions and students' answers, such as an addictive question. These four elements are linked with both teacher and students factor. When we think over these elements, we can find that element T and element M, out of the TIME elements, are relatively so more oriented and stressed by the teacher. Element I and element E are less oriented and less stressed by the teacher, comparing with element T and element M. When a teacher prepares the class, the teacher can select the theme of the class and the appropriate methods of class before the class. This means that the influence of students on element T and element M are relatively lower in class. The encouragement of students is dependent on the action of students. Therefore, the element T and the element M which teacher can use may be determined before the class and element I and element M are determined during the class because the response or the action of students can determine the action of the teacher. Thus, the element I and the element M are more influenced by the students than the other elements are. We suggest to depict these elements in terms of the function of the question as a tetrahedron in a cube rather than as a square to emphasize the flexibility of the questioning because four elements are not independent factors but variables to each other, even though each contribution to the whole picture could be different (see Fig. 2). Chin (2006) insisted that the teacher adjusts questioning to accommodate students' contributions and responds to students' thinking in a neutral manner. Each vertex of thetetrahedron stands for each element of TIME. The edges of the tetrahedron mean the mutual relation among elements. Every element has relations with every other element. The upper direction of a cube indicates the teacher's factor in the elements. Element T and element M are relatively influenced by the teacher rather than the students. The lower direction means the students' factor of elements. Element I and element E are relatively influenced by the students rather than the teacher. The distance between the vertex and the core of the tetrahedron/cube means the stress of specific element (s) in a certain context. The shape of four elements is not always necessary to be a regular tetrahedron. If in the context, these four elements are equally stressed, the shape can be the right tetrahedral. If any element is stressed or ignored, however, the shape can be distorted.

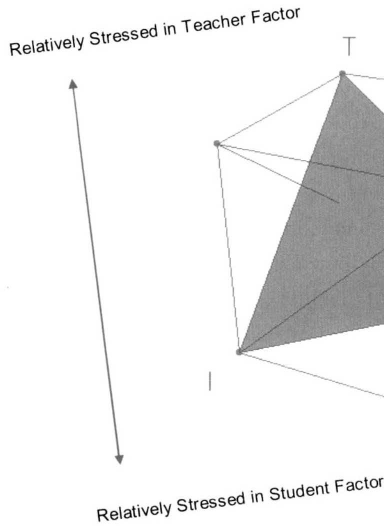

Fig. 2 Tetrahedral shape of TIME elements in cube for an effective questioning.

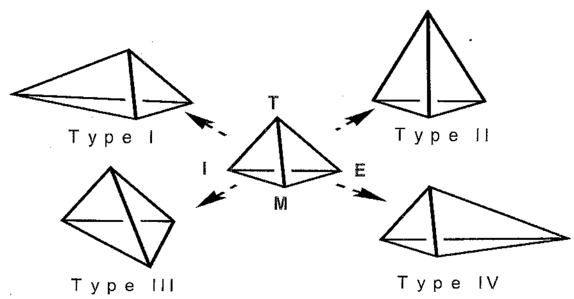

Fig. 3 An example of the flexibility of the question in the TIME tetrahedron where one element is more emphasized than the others.

In addition, flexibility of these elements is needed and is dependent upon the function or the type of questions. The teacher can adjust the questioning to accommodate students' contributions and responds to students' thinking in a neutral rather than an evaluative manner. Fig. 3 shows an example of the flexibility of elements in question; the context in which only the element is much more highlighted than the other elements if the class necessarily changes from time to time. When the teacher needs to nurture inquisitive minds in science class, questioning of Type I elements can help her to foster such a climate of inquiry. The flexibility and distortion of the tetrahedral shape, however, is generally dependent upon the number of stressed elements

Now, we describe the TIME elements in detail,

Table 1
TIME Elements and Selected Related-Items

Elements	Related Items
Theme (T)	Subject matter and main idea Goal and its presentation Teacher's presentation of content and its skill Materials of questioning and preparations for realizing it (Ask what?) Cognitive effects related to questioning
Inquiry (I)	Purpose of questioning (Ask why?) Levels of questioning Inquiry effects related to questioning Preference of questioning
Method (M)	Way of questioning (Ask how?) Frequency or number of questions (How many or how frequently?) Point of time (Ask when?) Media or devices of questioning (Ask with what?)
Encouragement (E)	Participation related to questioning Object of questioning (Ask whom?) Students' responses after questioning (What do students do after questioning?) Handling questions (What should the teacher do after questioning?) Affective effects related to questioning

which we suggest in the following text. Table 1 presents a summary of the TIME elements and its related items. It is noteworthy that sub-contents under each element can not be formulated but some of them are variable or often undistinguishable between elements.

1. Theme(T)

It is said that poor questioning from a teacher means he/she has limited knowledge and few ideas. A teacher can pose a good question only when he/she has enough knowledge and attainments. Classroom interviews and observations have revealed that students come to class with many disparate and often no ideas that apply to the same chemical problem. For example, whereas chemists agree that temperature is a measure of heat and that heat is the amount of energy that molecules could change, students have a variety of views including that heat is the higher temperature rather than the lower temperature on a thermometer (Linn & Hsi, 2000).

Questioning in chemistry class is one of the media between the chemical content and the students in a class; consequently, what should be taught needs to be considered and about what and how questions concerned with content knowledge should be asked. Therefore, themes for effective questioning mean content knowledge in a class, which can be the themes of an instruction and the goals in a class. Thus, theme (T) is concerned with the preparations of teacher for a class and it is the determinant of the quality of questions.

What should teachers do in order to present effective questions? Teachers ought to determine the content of the questions they want to present, in order to ask about the main idea, not to digress from the subject (Kim, 2003). Students will regard the content in a teacher's questions as important in class and they will learn and study mainly contents concerned with the teacher's questions. If a teacher asks an improvised question which digresses from the main idea, students may become confused over which idea is important in the class. In this context, it is better for the teacher to start with questions about phenomenon rather than questions about essence. If a teacher starts with question about essence, it is difficult for students to answer, and students may not understand why the teacher asked such a question.

2. Inquiry(I)

In a full inquiry, students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results (NRC, 1996). The instructional activities of a scientific inquiry should engage students in identifying and shaping an understanding of the question under inquiry (NRC, 1996). As we have seen, questions are important to inquiry-based learning. Students can formulate the questions by themselves and the teacher can also formulate the questions for the students and help them to develop an inquiry.

We are apt to imagine inquiry-based science learning as an experiment in the laboratory, but inquiry-based science learning is not performed just in a laboratory. If a student has a question or curiosity about his/her surroundings and he/she want to solve this question or curiosity, this is an inquiry-based activity.

Students' curiosity about some phenomena means that students are interested in a class and that they have a mind to engage actively in the class. In addition, teacher's questioning can be the determinant of students' engagement in class. Appropriate questions which coincide with students' needs, interests, and cognitive level makes students engage with the class. In other words, questioning which yields student's thinking and interests has the element inquiry(I). Thus, we can check this by confirming the purpose of the teacher's questions. The core of instruction is to develop student's thinking ability. Such questions to induce students' thinking can improve student's achievement. If a teacher intends to develope a student's creativity and application, the teacher should present questions to need not only the memorization of knowledge, but also the application, analysis, synthesis, and evaluation of the information.

3. Method(M)

Some desirable questioning methods (techniques) are known to us. For instance, questions should be presented without calling on a specific student (Blosser, 1973). After the questioning, the teacher finds a volunteer to answer the question and calls on any student to answer the question if no volunteer answers. When a teacher calls on a student before the question is asked, other students tend to ignore the question. Questions must not be repeated because repeated questions reduce students' attention in class.

Thus, questions which coincide with students' cognitive level through appropriate methods and assisting materials will get students to engage in class. Questioning is a verbal interaction, but the teacher can also use teaching devices such as overhead projectors, computers and so forth. Teacher's questioning using these devices can be more effective in stimulating students' curiosity.

4. Encouragement(E)

Through verbal interaction between teacher and student, the teacher can encourage student learning. In these interactions, the teacher's attitude to this interaction is the determinant of this element. Teacher can do something to students who answer teacher's question. When a student's answer isn't complete and partial, teacher can force the student to put together his/her partial knowledge into a more complete answer. To make science accessible, the first pragmatic pedagogical principle states that students should be encouraged to build on their scientific ideas as they develop more and more powerful and useful pragmatic scientific principles (Linn & Hsi, 2000). The teacher can also present leading questions to help the student to answer the initial question or to provide a more complete answer.

Predict-Observe-Explain (POE) may be useful in encouraging student learning. When a student answers a question, the teacher can use demonstration or experiment instead of verbally commenting on a students' answer. On the other hand, some teachers promptly commentate on students' answers without waiting time, or discourage the students who have given the wrong answer. Such teachers do not deliberate this element. The teacher can show his/her interest in the student's answer by showing his/her positive attitude toward the answer. The teacher should predict student answers, and handle unexpected answers well. Such behaviour can help students to solve the problem. Students can express their own emotions, affections and intentions, and satisfy their curiosity when they have the opportunity to request help. The teacher's actions in order to encourage students are more or less dependent on the students' actions when the students are asked questions.

IV. Research Methods

1. Subjects

82 secondary science teachers, 434 students (58 university students who major in natural science or engineering and 376 secondary students) a metropolitan area in Korea were sampled and surveyed to investigate the teachers' recognitions of their own questioning and students' recognitions of their teachers' questioning in class. In this sample, 36 teachers and 252 students are male, and 46 teachers and 182 students are female. Out of 434 students, 37 students attend in or graduate from a science high school, and the others are from a general high school.

2. Data Collection

The data were collected by means of survey. Questionnaires for teachers and for students were developed based on previous studies(Park, 2004) and pilot tests were taken to ten science teachers and 27 secondary students. After the pilot tests, the questionnaires were examined by two specialists with doctorates in pedagogy, and were subsequently modified.

The questionnaires for the teachers are made up of 23 items, and the questionnaires for the students are of composed 28 items. The questionnaires are also categorized into four categories according to TIME elements. The questionnaires include items on necessity, frequency, reasons, point of time, types, levels and effects of questioning and also include teacher's and students' attitudes after questioning, and teacher's effort for good questioning. Most of the questionnaires were developed in a multiple-choice format. Some items asked facts (teachers' or students' actual behaviors observed in class), and other items asked opinions(teacher or student behavior which they think is desirable). In these questionnaires, we tried not to use any difficult terms which may be difficult for secondary students. For instance, when we investigated if students mainly experienced deductive or inductive classes, we did not use the term "deductive" nor "inductive", and we described the context or the meaning in detail.

3. Data Analysis and Limitations of the Study

The frequency of each item in the questionnaire was calculated by percent. Cross analysis(chi-square) methods were used to analyse some factors. SPSS 12, a statistical software package, was used to analyse the data in this study. We also analysed and investigated the balance each elements in TIME elements. In the main text, we presented somewhat simple results, and detailed results were presented in the supplement.

Students may have met many teachers whose characteristics, teaching methods, *etc.* are different during their school days. The students were asked to base their answers on a 'typical' teacher they had met during their secondary school days. However, some of them may have provided answers based upon the teacher who "rings most in their heart", and this possibility may be a source of bias in this study. Another limitation is that the statistic analysis and interpretation was based on responses of individual members who participated in the surveying. It is not possible to know for sure the extent to which individual students could understand the question addressed. It is also worth noting that this model shows both the strengths and weaknesses of determining the quality of research in terms of the classification method of dividing the survey into four elements, the so-called "T. I. M. E. model", because the elements are interwoven with each other.

V. Results and Discussion

1. A Rationale of The Study

The research study described here set out to explore the framework of effective teachers' questioning with a large group in each chemistry class by surveying over 82 teachers and 434 students in Korea. We were curious about how chemistry teachers obtain productive questioning skills, and how they determine their efforts on student thinking and understanding. We also wondered how students respond to teachers' questions, and what they acquire from the questioning. Lemke (1990) examined classroom dialogue, and suggested that if you sit in on almost any classroom in the USA is characterized by whole-class interaction and repeated three-turn sequences that constitute a so-called 'triadic dialogue'. In Korea, unfortunately, we were continually frustrated when trying to gather sufficient meaningful data to analyze in terms of teacher-student interactions through question-response by recording, or video-taping class conversation. One of the reasons that is already known through several studies (for example, Lemke (1990); Myhill & Dunkin (2005)) is student-silence during the class. Dillon (1988) contrarily discussed the lack of student active engagement when teachers asked too many questions based on the triadic format. Even further students rarely asked questions, especially questions that could help them to elucidate their understanding of a chemical concept. Therefore, we reached the conclusion that it is difficult to elicit students' recognition of teachers' questioning from the chemistry classroom discourse. We rather switched to survey teachers and students in attempt to find out a teacher's strategy to awaken students by asking the same content questions to both teachers and students. The questionnaire attempted to evoke teachers' recognition of their questioning and the students' recognition of teachers' questioning. From statistical analysis of the survey, we could glance the difference and the interrelationship between responses of each side at some of the same questions. This was the reason why we compare the response with each other for the first time. We tried to list 32 content items, including 23 student-teacher interactive codes out of 23 teachers' responses and 28 students' responses to the questions. When these 32 content items were analyzed and combined into similar groups, most of these data could not clearly be sorted into two-dimensional arrangements in terms of their functional forms due to networking each other and finally itemized them into four elements three-dimensionally. None of the models for questioning have been pictured in three-dimension to correlate the factors of the model, even Myhill (2006) classified the questions used by the teachers into the form and the function of the question to provide a stereotype of whole class interaction. The categories for the coding of the questions were derived through an iterative process, where a teacher, a post-doc and a professor who had a different academic background coded the statistic data independently and then met to compare the categories which had been classified. The outcome of the data analysis was a grouping of questions into theme of the teachers' questions (T), students' inquiries (I), methods of teachers' questioning (M) and encouragement of students (E) in terms of function of the question as following.

2. Questionnaires on Element T

For effective questioning, the teacher should select appropriate contents and materials, and present the questions having some connection with the theme of the class. In the questionnaires, seven items were related to the element T (see Table 2). The first two items (T1-T2) were given only to teachers whose self-evaluation gave us information about their efforts in the development of questioning and the source of

Table 2

Summary of questionnaire on element T

Sub-categories	Items given to teachers(T) and students(S) in questionnaire	Code	
Teacher's efforts for questioning before/after class	Do you think that you make active efforts to choose the level or the types of the question suited to each students or to context?	T1	T
	Which do you mainly use as the main sources for getting clues to questioning?	T2	T
Way of presenting goal/contents and main type of questioning	How do you[does your teacher] present the goals of the class?	T3	TS
	By which way do you[does your teacher] present the themes of the class?	T4	TS
	Which is your[your teacher's] main type of questions in class?	T5	TS
Outcome effects of questioning	Do you think questioning is helpful to improving your students'[your] learning concepts and to acquire knowledge?	T6	TS
	Do you think questioning is helpful to improving your students'[your] achievements?	T7	TS
Teachers' and Students' ideas inferred from questionnaire	- Teachers insist that they make effort for good questioning(T1) and science textbooks are commonly used material when they prepare the question to be presented in class(T2). - Goals of the class are not presented concretely by teachers(T3). - Closed questions are more common than open questions(T5). - Questioning is helpful to students for concept learning(T6 & T7).		

questioning contents. Initial results showed that 43.9 % of teachers were active in sharpening the question in class, while 11.2% of them were passive. In terms of searching class materials, 55.3% of teachers generally obtained their clues for questioning in science textbooks.

The next five items (T3-T7) were questioned to both teachers and students. These items can be divided into two sub-categories. One is related to present the theme of the chemistry class (T3-T5) and the other is related to survey the cognitive effects of questioning on both teachers and students (T6-T7). More than half of the teachers answered that they did not present the goal of the class in concrete terms (T3). The students' answers were not inclined to specific items. It seems that students did not pay attention to the teachers' actions, or that they did not have a clear memory of these actions. Concerning the way of the presenting the themes of the class, 56.3% of teachers preferred inductive ways of teaching rather than deductive methods, while 41.2% of students ironically answered that they met teachers who taught with deductive methods (T4). These contradictive views may stem from different interests with each other. As shown in T3, teachers did not open the class with the specific subject at first. If students did not focus on the lecture at first, they likely listened to only the specific or interesting examples later. Thus, they can remember the process of the class as the inductive way. As far as the type of questions, both teachers and students chose that closed questions were more common than open questions (T5).

We investigated two items concerning the outcome of questioning strategy. Both teachers and students thought that the teacher's questioning in class was helpful to the students' learning conceptual thinking and obtaining more knowledge (73.2% for teachers & 66.1% for students in T6) as well as students' better achievements (86.6% for teachers & 68.3% for students in T7). In particular, there was only one teacher who thought negatively about the questioning concerning cognitive effects. However, 48 and 44 out of 428 students think questioning is unhelpful to students' conceptual thinking and knowledge and achievements, respectively. Some students and teachers indicate that questioning is less helpful to achievements than to learn chemical concepts or obtaining knowledge of chemistry. Ironically, it is noticeable that teachers have relatively more positive thoughts of the outcome than the students in both items because well-prepared teachers always have pride in their work.

3. Questionnaires on Element I

Teachers' questions create student interest and critical thinking, and also play a role in promoting students' thinking ability. To investigate what teachers should do in order to help students to inquire and take an interest in learning, we used ten items. The first two of these items were only given to teachers, the next two of these items were only given to students, and last six of these items were given to both teachers and students (see Table 3). The questions for Element I were made up of four subcategories: teachers' and students' opinions on the necessity of questioning (I1-I3); the level of questioning in class and its recognition (I4-I7); teachers' and students' recognition of relationships between questioning and inquiry (thinking) ability (I8); students' preferences for questioning and for science class (I9-I10).

Teachers and students were asked whether they thought the teacher's questioning was necessary in class (I1). Those who gave answers indicating that questions were not necessary were asked their reasons for this opinion. (I2). Teachers who did not ask too many questions in class, or students who encountered such teachers before, were asked why they or their teachers did not ask many questions (I3). All of teachers (100%) and most of students (86.6%) answered that questioning in class was necessary in I1. The aiming of the questionnaire I2 was originally intended for only teachers/students who thought that questioning itself is unnecessary. However, some of the respondents could not understand the purpose of I2, and marked their opinions over it, even though they preferred questioning in class. We do not delete or intentionally process Item I2. According to the result of the questionnaire, a few students (13.4%) also answered "unnecessary" in I2 due to various negative attitudes such as being afraid of giving an incorrect answer in class, or not being willing to

Table 3
Summary of questionnaire on element I

Sub-categories	Items given to teachers(T) and students(S) in questionnaire	Code	
Necessity of questioning	Do you think that teacher's questioning is necessary in class?	I1	TS
	Why do you think that teacher's questioning is unnecessary?	I2	TS
	Why do you think you[your teachers] don't present many questions?	I3	TS
Level of questioning and its recognitions	Why do you think you[your teachers] ask questions in class?	I4	TS
	Why do you present closed questions in class?	I5	T
	Why do you present open questions in class?	I6	T
	On which your[your teacher's] questioning mainly focuses?	I7	TS
Thinking ability and questioning	Do you think questioning is helpful in improving your students'[your] thinking ability?	I8	TS
Student's preference	Do you like teachers who present many questions in class or not?	I9	S
	Do you like science classes?	I10	S
Teachers' and Students' ideas inferred from questionnaire	- Questioning is necessary in science class (I1). - Some students don't want to answer the question (I2). - Some students have fear of incorrect answer (I2). - Some teachers don't ask many question because of limited time or of their students' unwillingness (I3). - Questioning is mainly for students' participation and attention (I4). - Closed questions are for confirming students' knowledge (I5). - Open questions are for problem solving (I6). - Teacher's expectations were higher than the student's acceptance of the questioning (I7). - Questioning is helpful in improving students' thinking (I8). - Many students don't care whether the teacher asks many questions or not (I9).		

answer the questions. This explains why the number of negative respondents in I1 and the number of respondents in I2 are not equal. Only two teachers answered that they did not ask many questions because of not having sufficient time or efficiency (I3).

To investigate the level of questioning in class and its recognition, we asked teachers and students to think of the reasons for the questioning. In addition, we gave other items only to the teachers. Teachers who mainly asked open/closed questions in class were asked why they did so. We also investigated which taxonomy of the cognitive domain (Bloom, 1956) teachers' questions generally belonged to. Many teachers (57.2%) and students (58.1%) thought that questions were asked to improve students' participation and attention (I4). It appears that both teachers and students considered participation and attention as the purposes of questioning. 42.7% of teachers mainly asked closed questions in class whereas 9.6% of teachers mainly asked open questions. Teachers who asked mainly closed questions expected students to remember the knowledge in class and apply it, while teachers who asked mainly open questions expected students to analyze the knowledge, to synthesize it, and to use it in making decisions (I5 and I6). Many teachers argued that their questions were mainly focused on 'analysis' in Bloom's taxonomy, but many students thought that the teacher's questions were mainly focused on 'knowledge' (I7) (Bloom, 1956). This implies that the teacher's expectations were higher than the student's acceptance of the questioning.

Concerning teachers' and students' recognition on relations between questioning and inquiry (thinking) ability, the answers were positive. 86.6% of the teachers and 61.3% of the students thought that the teacher's questions were helpful to students' thinking ability (I8). The ratio of teachers who thought their questions were helpful to students was a bit higher than the ratio of students who thought so. This irony was also observed in T6 and T7.

Students' preferences for questioning and for science class were also investigated. Students were asked whether they liked a teacher who likes to question in class or not. Many students answered that they did not like questioning. However, students who liked

Table 4
Summary of questionnaire on element M

Sub-categories	Items given to teachers(T) and students(S) in questionnaire	Code	
Number of questions per class	How many questions do you [does your teacher] ask per class?	M1	TS
	How many questions do you think are appropriate per class?	M2	TS
Main point of time of questioning	When you[your teacher] ask questions mainly in class?	M3	TS
	When do you think is appropriate when the teacher ask questions mainly in class?	M4	T
Teachers' interest in questioning or teaching methods	Are you deeply interested in developing or improving your questioning skills or teaching method?	M5	T
Media for questioning	What's your [your teacher's] main media or ways for questioning or explaining in class?	M6	S
Teachers' and Students' ideas inferred from questionnaire	- Teachers think of their questions in class as many, while students do not agree (M1). - Appropriate number of questions per class that the teachers think is necessary is more than the number that the students think is necessary (M2). - Appropriate timing of questioning is not specific (M4). - Teachers and students think differently about the point of time of questioning in an actual class (M3). - Teachers are interested in improving questioning methods and teaching methods (M5). - Verbal method dominates the media of presenting the main idea of the class (M6).		

teachers that asked more questions participated more often in class than students who preferred teachers that asked fewer questions (I9). Students were also asked if they liked science class. 68.1% of the students answered that they liked science class. Many students have attended or graduated from the science school and were majoring or planning to major in schools of natural science or engineering in accordance with the results of survey (I10).

4. Questionnaires on Element M

No matter how good the questions are that the teacher has prepared, such as questions with a good theme or content to encourage the students, the effect of questioning may be reduced when the teacher does not have good questioning methods. We included six items about Element M, five of which were given both to teachers and students and one of which was given only to teachers (see Table 4). These items were related to the average number of teachers' questions per class (50-60 minutes, M1 and M2), the timing of questioning (M3 and M4), the teacher's endeavor to develop or improve his/her questioning skills or teaching methods (M5), and the main tool used in questioning or explaining in class (M6).

Concerning the average number of questions actually presented per class, 3-5 (38 teachers, 46.3%) or 6-9 (28 teachers, 34.1%) questions per class were given in the class. Two teachers responded that they did not need to ask the question in class (see I3). Some students (44.2%) answered that their teacher asked 3-5 questions per class, but others (30.4%) answered that their teacher did not ask any questions. Noticeably, teachers thought that they asked many questions in class, but the students did not agree with this opinion (M1). Concerning the appropriate number of questions per class, many teachers thought that 6-9 questions was the best, while students thought that 3-5 questions was the best. Teachers needed to ask more questions than the students did (M2). We can suggest that the appropriate number of questions for teachers and students is 3-5 per class by results of the questionnaire M1 and M2.

Concerning the timing of questioning, we surveyed when the teacher actually asked questions in class and which time was best for the teacher to ask questions in class. Teachers and students gave us different answers (M3). Many teachers responded that they asked a question mainly to motivate a student at the beginning of the class (28.4%) or when they explained the main idea of the class (27.2%). Other teachers (24.7%) asked questions at any time during the class. 41.6% of the students answered that their teacher mainly asked questions when they explained the main idea of the class. A minority of the teachers and students answered that the right time of teacher's questioning should be at the end of the course. Many teachers (45.1%) and students (30.5%), however, thought that questions should be presented at any time in the class (M4).

As for the teachers' endeavors to develope or improve their questioning skills or teaching methods, 56.1% of the teachers answered that they had an interest to make an effort to improve their questioning skills and teaching methods. Only 13.4% of the teachers answered that they did not have such an interest (M5).With regard to the main tools for questioning or explaining in class, most of teachers (81.4%) responded that they used mainly verbal methods and that they explained the facts using words. Unfortunately, there were not many teachers who mainly used test-experiments or audio-visual media. Most students also answered that their teachers used mainly verbal methods in questioning (M6). From these questionnaires, we can conclude that subsidiary teaching ways such as model-kits and power points should be developed in the chemistry class.

5. Questionnaires on Element E

In order to investigate how teachers improve students' confidence level and students' participation and how teachers maintain a good atmosphere in the class, we surveyed the teachers and students. Seven items were given to both the teachers and students and three items were given to just the students (see Table 5). These items were related to the teacher's calling on students (E1-E2), students' reactions after questioning (E3-E6), the teacher's handling of the questions (E7-E8), the affectional effect of the questioning (E9), and students' views about the teacher's enthusiasm in class (E10). Most of teachers (70.4%)

Table 5
Summary of questionnaire on Element E

Sub-categories	Items given to teachers(T) and students(S) in questionnaire	Code	
Teacher's calling on students	What's the way of your [your teacher's] calling on students?	E1	TS
	Which students do you [does your teacher] mainly call on when you [your teacher] present a question?	E2	TS
Students' reactions after questioning	Do your students [you] react in active or in passive when you [your teacher] present questions?	E3	TS
	Why do you think students are so passive?	E4	TS
	Is your teacher's expectation level for students' answers high or low?	E5	S
	How correctly do you answer when your teacher ask you questions?	E6	S
Teachers' handling of questions	How long do you [does your teacher] wait for students' answer and what do you [does your teacher] do after questioning?	E7	TS
	What do you [does your teacher] act when students answer incorrectly or incompletely?	E8	TS
Affectional effect of questioning	Do you think questioning is helpful in maintaining good atmosphere in classroom?	E9	TS
Teachers' enthusiasm from students' viewpoint	Do you think your teacher has passion or enthusiasm in classroom?	E10	S
Teachers' and Students' ideas inferred from questionnaire	- Teachers generally call on the whole class rather than individual student when questioning (E1) and when they call on someone they generally don't select specific students (E2). - Some students in class are passive because of various reason such as low achievements, passive attitudes, difficult content and so forth (E3 and E4). - Teacher's expectation level for students' answers is high and students think they themselves have answered contently (E5 and E6). - Teachers try to have enough wait time (E7). - About incorrect or incomplete answers of students, many teachers help and guide students to get the correct or complete answers (E8). - Questioning is helpful to students for affectional effect (E9). - Students know that their teachers have passion to teach themselves hard (E10).		

and students (69.5%) answered that the teacher generally calls on the whole class rather than on an individual student when questioning. There were some teachers who called on an individual student if no answer was given when the whole class was called on. Some (20.9% of the teachers and 11.3% of the students) answered that this differed from time to time. 19.2% of the students answered that their teacher called on individual students, while 8.6% of the teachers believed this, too. Students might be afraid of being called on (E1). Furthermore, when a teacher calls on individual students, there are various ways to do so. 42.7% of the teachers and 46.5% of the students answered that random students were called on in class during questioning. There were, however, some teachers who mainly called on students who were attentive or active in class participation regardless of achievement. Other teachers called on students who were inattentive in class (E2).

As far as students' reaction after being calling on, students (45.1% for teachers' opinion & 30.4% for students' one) were active when being questioned (E3). A low motivation for achievement (62.5% of the teachers and 31.1% of students) was the main reason for students' passive attitudes when questioned (E4). Some students (20.2%) said the reason for passive attitudes was because the content of science was difficult. A relative minority of students answered that the teacher's method or attitude in questioning was not satisfactory. As for the expectation on the part of teachers of their students, students whose teachers had high expectations of their students were major (40.1%) (E5) and most of students (87.7%) answered the questions correctly (E6).

Another investigation dealt with the teacher's handling of the questions in class, such as wait time and handling incorrect or incomplete answers. Both teachers (90.1%) and students (74.1%) thought the teacher had enough wait time, but minor students (2.2%) thought that the teacher wanted the students to answer immediately (E7). Concerning incorrect or incomplete answers of students, many teachers (90%) helped and guided students to obtain the correct or complete answer (E8).

On the other hand, both teachers and students thought the teacher's questioning in class was helpful in achieving a good atmosphere in class. 95.1% of the teachers and 68.8% of the students agreed with this opinion. From the students' answers, it is clear that questioning is less helpful on the affective side than on the cognitive side (E9). Most students thought that their science teacher showed enthusiasm in class: many more students (68.6%) agreed than disagreed (E10).

6. Analysis of Relationships between Elements

As we mentioned above, each element (T, I, M & E) can be influenced by each other as featured in the vertices or edges of the TIME tetrahedron (see Fig. 3 and Table 6-9), and we speculate such influences inferred from questionnaires. The purpose of these analysis is not to miss the important facts which cannot be seen in terms of an independent element. We introduce some items with statistical significance. These items can see why teacher should ask many questions in class and they are not seen well without seeing inter-element relationships. Specifically, teachers' self-evaluations on endeavors for effective questioning (T1) and number of questions per class (M1) had a significant relationship (p=.006). It is clear that a teacher who asks more questions in class tends to regard himself or herself as endeavoring to question. In addition, such teachers thought that their students responded to their questions actively (E3). This means that many teachers thought that if they made an effort to question effectively, students would respond to their questions actively (see Table 6). The number of teachers' questions per class (M1 of students) also has significant correlation(p=.000) with teacher's enthusiasm viewed from students (E10). Students think teachers with more enthusiasm presents more questions in class (see Table 8). Students also answered the more enthusiasm teacher has, the more helpful teacher's question is to students' learning concept or getting knowledge (T6 of students), students' achievements (T7 of students), and students' thinking ability (I8 of students) and the atmosphere in classroom (E9 of students).

As we described above (Table 6-8), we can say that the more questions the teachers ask students in order to engage the class and to induce thinking well, teachers and students think that the more efforts the

Table 6
Relations between endeavors for effective questioning (T1) and number of questions per class (M1) / students' activeness or passiveness to questioning viewed from teachers (E3)

	Value	df	p
N of Valid Cases	82		
Pearson Chi-Square (T1-M1)	27.782	12	.006
Gamma (T1-M1)	-.309		.035
Pearson Chi-Square (T1-E3)	29.122	16	.023
Gamma (T1-E3)	.345		.016

Table 7
Relations between number of question and teacher's enthusiasm viewed from students

	Value	df	p
Pearson Chi-Square	69.173	12	.000
N of Valid Cases	430		
Gamma	-.471		.000

Table 8
Relations between the enthusiasm of teacher and effect of question on knowledge, achievements, thinking ability, and atmosphere in classroom

	Value	df	p
Pearson Chi-Square (E10-T6)	109.58	16	.000
Gamma	.488		.000
Pearson Chi-Square (E10 -T7)	79.770	16	.000
Gamma	.461		.000
Pearson Chi-Square (E10-I8)	73.461	16	.000
Gamma	.427		.000
Pearson Chi-Square (E10-E9)	62.050	16	.000
Gamma	.346		.000

Table 9
Correlations among the influence of questioning according to teachers' / students' opinions

Teachers	T6	T7	I8	E9
T6	1	.520	.518	.395
T7	.520	1	.635	.526
I8	.518	.635	1	.423
E9	.395	.526	.423	1
Students	T6	T7	I8	E9
T6	1	.674	.622	.352
T7	.674	1	.644	.434
I8	.622	.644	1	.367
E9	.352	.434	.367	1

All correlations are significant at the 0.01 level (2-tailed)

teachers make and the more passion or the more enthusiasm in class the teachers have. Furthermore, students feel that more the questioning is helpful when they meet more enthusiastic teachers in class. According to these results, many questions can be the scale of measuring the teacher's efforts or passion for good instruction. The findings suggest the reason why teachers ask productive questions in class and that the students who are asked by such questions feel the more usefulness of questioning.

The correlations among the influence of questioning on students' learning concept or getting knowledge (T6), students' achievements (T7), students' thinking ability(I8) and the atmosphere in classroom (E9) were also speculated (see Table 7). We identified high correlations among them, but the correlations between atmosphere in classroom and others are relatively lower than others. In addition, we could see that the results from teachers' opinions and students' are not different. We could find that the correlations among T6, T7 and I8 from students were higher than that from teachers and we also could find that the correlation between E9 and others from students were lower than that from teachers (See Table 9).

VI. Implications and Conclusions

Very recent studies in teachers' questioning have concentrated on the characterizing questions that promote effective thinking in students in terms of diagnosis of dialogue during science instruction (Chin, 2007; Myhill, 2007). Most of results have been based on the classroom discourse in rather a small class in USA (Lemke, 1990). If there are too many students to allow an opportunity to respond to a question, or if the students are too silent or shy to talk due to the a variety of reasons, the outcome of the classroom talk might not always be meaningful. Questioning is one of the integral tools of effective teaching. Despite its importance, fine analytical studies of questioners and students are rare, especially with such a large group in science class. The characterization of questionnaire approaches in this study excludes such problems and contributes to an understanding of rather genuine nature of the questioning-response from both sides.

Based on the above-mentioned research, this study investigated the effects of teacher-student questions on generation of an effective class and improvement of teaching for such a large group. We also studied what kinds of factors should be included in a good question and found out how these elements can be categorized into the four TIME elements: theme of the teachers' questions (T), students' inquiries (I), methods of teachers' questioning (M) and encouragement of students (E) in terms of function of the question. In addition, we explained what each element means and what we can infer from each element using tetrahedral schematic diagrams, which are flexible for the function or type of questions. Following is the summary of the questionnaires related to the TIME elements. From Element T, teachers insisted that they themselves were active in questioning in class and both teachers and students agreed that questioning was helpful in developing students' cognitive aspects. The outcome disclosed that teachers need to present their goals in each class concretely and such goals should be clear in teachers' questioning. As to the questionnaires on Element I, both teachers and students believed that questioning was indispensable in class and that questioning was helpful to students' thinking ability and inquiry. They coincided that teachers' questioning was mainly concentrated on lower cognitive level questions. The outcome showed that teachers should make effort to ask various types of questions. Regarding Element M, there were some differences between the appropriate number of questions per class viewed by teachers and students, but it is clear that teachers asked as many questions as possible. Both teachers and students thought it was appropriate that questions are asked throughout the whole class, not concentrated at a specific point of time in the class. The survey disclosed that teachers made efforts such as participating in in-service training, reading books on teaching methods, or questioning to improve their questioning. It also pointed out that teachers used too simple questioning method such as verbal methods. Finally, concerning the questionnaires on Element E, teachers mainly called on the whole class rather than on any specific students for questioning. When teachers called on a student, they generally did so on a random basis. In the interaction between teachers and students through questions and answers, teachers helped students to answer the questions and to solve the students' problems by feedback. Their questioning was also helpful to the atmosphere of the classroom. It is also noticeable that students tended to be passive when being questioned, whereas their teachers contrarily answered that their students were active when being questioned. This difference probably occurs when the teacher could not grasp their students' viewpoints or when they were generous in their self-evaluation.

From the statistical analyses, we found some items including teachers' self-evaluations on endeavors for effective questioning (T1) and number of questions per class (M1), the number of teachers' questions per class (M1 of students) and teacher's enthusiasm viewed from students (E10) with statistical significance. The correlations among the influence of questioning on students' learning concept or getting knowledge (T6), students' achievements (T7), students' thinking ability (I8) and the atmosphere in classroom (E9) were also confirmed. This means that each element (T, I, M & E) can be influenced by each other and that gives us to structure a tetrahedron of four elements. Therefore, teachers can create a good class by using question-inducing strategies. They can approach their students with an open attitude and through the use of well-thought-out questioning strategies with flexible TIME elements in tetrahedral shape.

In conclusion, this study provides the autonomy of teachers' recognition of their questioning and the students' recognition of teachers' questioning by surveying over 82 teachers and 434 students in Korea. The survey findings show that the questionnaire can be categorized into four elements that can be analyzed, sub-categorized and restructured to tetrahedral shape for easy applications to instant atmosphere during the class, even though elements are interwoven each other. This 3-D model for teachers' questioning may help us glimpse how teachers wrangle with students in large chemistry classes in order to teach difficult chemical knowledge effectively and achieve daily class productively.

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