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The Role of Cognitive Strategic Questioning in the Changes of Students' Conceptions about Heat and Temperature

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I. Introduction

Students' conceptions about heat and temperature have been the subject of a lot of research in many countries and as a result some general patterns are emerging. it is now clear that students have difficulty in understanding physical concepts about heat and temperature. Although questioning in the educational situation has been thought of as important since Socrates, students' questioning for learning was less investigated than teacher's questioning for teaching. Nevertheless, it has long been recognised for its importance to facilitate students' learning in science, but students seldom ask questions during school learning.

In the view of learning as conceptual change, it is important for students to ask questions about physical concepts and search for answers to those questions, since students' questioning may be the mark of their cognitive conflicts.

Therefore it is necessary to improve students' questioning in learning science. The purposes of this paper are to develop models for improving high school students' questioning and to investigate the role of models in the students' conceptual changes about heat and temperature.

II. Theoretical Considerations

Many studies on students' conceptions about heat and temperature have shown that there are general patterns in students' conceptions such as caloric idea, the idea that heat is the same as temperature, cold particle notion and so on(Erikson, 1977; Harris,1981; Tiberghien, 1983; Brook et al.,1983;Engel Clough and Driver,1985). It has been well known that many students bring their own conceptions about natural phenomena into science classroom and students' physical conceptions can not be changed after traditional science instruction such as presenting new correct concepts(Stavy and Berkorvitz, 1980; Ryu Jae Hyeok and Park Sung Jae, 1987; Kim Sang Myung, 1993). What are the reasons? One of the eminent phenomena during school learning is that students seldom ask questions. Questions from the teacher to the student are a common feature of classrooms in many parts of the world. The steady interest that researchers have maintained in the role of questions in science teaching may be indicative of a belief that questioning is an essential ingredient of inquiry and discovery and consequently should be emphasized in science education.

The research on questions in science teaching is largely of three types. First, the effect of questions in science texts, second, the improvement of teachers' questioning skills and the effects of new questioning skills on pupils' achievement, critical thinking, and attitudes and third, the effect of lengths of pauses between questions, responses and reactions. All three types concern questions posed to the students.

But, students' questioning was less investigated than teacher's questioning. and studies on students' questioning were mainly focused on self-questioning. Brown, Campione and Day(1981) advocate that attention should be also paid to the role of students' questions and to improving their skills in framing them. Arzi(1986) studied exploratorily the sorts of students' questions which are content related with a focus on science. White(1988) said that students' questioning encourages their processing, gives the teacher new insights about their understanding and is a good training in the cognitive strategy of reflective thinking. Dillon(1988) suggested the model of student's questioning process. Dillon's model is composed of four steps. first, the experience of perplexity, second, asking, third, answering and fourth, sequelae. Learning occurs in the last step.

Current efforts to study the learning of cognitive strategies use the label of metacognition or metalearning and it is believed that cognitive strategies can play an important role in learning science(Weinstein and Mayer, 1986). In this paper models are proposed to provide students with their questioning as an cognitive strategy in learning science.

Teacher's questioning and student's answering to it are activities often found in the traditional instruction. However, it is important for students to ask questions on the constructivistic view of learning. Various studies on the conceptual change have shown that the notion of status is central to the process of conceptual change. So cognitive strategic questioning is defined as students' questioning as one cognitive strategy to make their status explicit. Two models were developed.

One model called as cognitive strategic questioning I (CSQ I) is to make student's comprehension status explicit because many students can not be aware of the difference between their own conceptions and scientific concepts in the text. This strategy is associated with the generative learning model of Osborne and Wittrock(1985) and the metacomprehension on reading of Koch and Eckstein(1991). Cognitive strategic questioning I is composed of three questioning categories, Q1, Q2, Q3 as follows.

Q1 : questions whose answers are in the text and which he/she understands.(Answers A1s to Q1s must be followed)

Q2 : questions whose answers are in the text and which he/she does not understand.

Q3 : questions which are related to the text, but are not discussed in it.

In Q1 category, there are questions whose answers are in the text and which he/she understands. Therefore answers A1s to Q1s must be followed. In Q2 category, there are questions whose answers are in the text and which he/she does not understand. In Q3 category, there are questions which are related to the text, but are not discussed in it. In the application of this model into the treatment, students are encouraged to ask as many clear questions as possible, and are directed to write the questions in their worksheets developed according to the model.

Another model called as cognitive strategic questioning II(CSQ II) is to make student's conceptual status explicit because students can not appreciate their own conceptual status on the new concepts. This strategy is associated with the conceptual change model of Posner, Strike, Hewson and Gertzog(1982). Their model suggests that a new concept should be intelligible, plausible and fruitful to students. Recently Hewson and Hennessey (1991) presented descriptors for the technical terms of the conceptual model. Cognitive strategic questioning II based on their research is also composed of three questioning categories, q1, q2, q3 as follows.

q1 for an concept to be intelligible to me

q11: Do I know what the words on heat mean?

q12: Can I describe the concept of heat in my own words?

q13: Can I give examples that belong or do not belong?

q14: Can I find ways of representing my ideas to others?(eg. drawings, illustrations, talking, explaining, concept mapping and so on)

q2 for an concept to be plausible to me

q21: Do I believe that the new meaning is true?

q22: Does it fit my picture of the world?

q23: Does it fit in with other ideas I know about?

q3 for an concept to be fruitful to me

q31: Do I see the idea as something useful?(eg. problem solving, new way of explanation and so on)

q32: Can I apply it to other ideas?

q33: Does it give me new explanation of things?

q34: Is it a better explanation of things?

q35: Does it give me new ideas for further investigation?

This model assumes that the above 12 questions to make conceptual status explicit may be important for students' conceptual changes. In the application of the model into the treatment, students are encouraged to ask as many questions as possible in their worksheets developed based on the model and answer questions if they can.

Ⅲ. Method

1. Development of instruments for inducing students' questioning about heat and temperature and the same pre-post test for investigating students' conceptions.

The key concepts related to heat and temperature in the Korean high school physics curriculum were selected as molecular motion, thermal equilibrium, change of state, heat conduction, convection, radiation, basic concepts of the 1st law of thermodynamics and the 2nd law of thermodynamics. Many physics texts written according to the curriculum contain the above concepts. Instruments for inducing students' questioning about selected concepts were developed, which were made as counter intuitive as possible. Developed teaching instruments are total fourteen qualitative items as follows.

1) 100 ℃ water is not hot to my sense of touch

2) Ancient people berried ice lump into the chaff for long storage

3) Iron bar changes its temperature at its own will

4) Temperature of the boiling water is not changed though we strengthen the heating power of the burner

5) Boiling is cooling process

6) We can boil water through cooling

7) Though the degree of warmness in hot water is similar to that of the saunar air, temperatures of the two are different by two or three times

8) The paper wrapped around a thick iron bar is not burned, but he paper in the air is well burned

9) Ice lump is not readily melting in the boiling water

10) We can know the precise temperature at the bottom of lake Baek Du on the morning of January 1st in 1901

11) We can calibrate directly the temperature of the Sun's surface

12) Is it possible for massless materials to exist?

13)Matter is cooling through friction

14)he so-called "thermal death "does not mean the death of heat

Counter intuitive contexts are considered as the phenomena that momentary predictions based on our intuition or common sense are not fit to the answer. Presentation forms were used such as teacher's oral suggestions, demonstrations, data and historical materials. For the face validity, developed models were discussed under the seminar group composed of the persons majonng in physics education. The same pre-post test for investigating students' conceptions about selected concepts was developed using items of the previous studies(Ryu et al.,1987; Duit et al.,1988; Kim,1993). The format of test items is explanation and questioning after choice with paper and pencil. Before and after the treatment, investigations on students' conceptions were carried out using this test.

2. Subjects and experimental design

Subjects were high school students in eleventh grade taking a first-year physics course. The number of subjects was 152 and they were randomly divided into three groups according to their scholastic achievements. One control group C was to have the traditional instruction and two experimental groups E1,E2 were to have instructions using developed models. The group C consisted of 53 students. The group E1 was treated with cognitive strategic questioning I in which 49 students were encouraged to ask questions in subjective form. The group E2 was treated with cognitive strategic questioning Ⅱ in which 50 students were encouraged to ask questions by selection in presented question list(Kim,1995).

3. Application of models into the instruction

The models of cognitive strategic questioning were applied for the experimental groups in which instructions on heat and temperature unit continued for nine hours, two hours per week. Before the application of the models, introductions on the cognitive strategic questioning activities were given to students in experimental groups during four hours.

4. Measurements of conceptual change

Student's conceptual score C is defined as the following equation .

$$C = Ox_1 + Sx_2 + \frac{Ox_1 + Sx_2}{3}$$

where C : score(integer)
O : right choice
S : right explanation

In the above equation, the first two terms mean the gained score in the test and last term means the weight value score for the coherence of thinking. So total conceptual score is the sum of these. Student' conceptual change CC was defined as Cf - Ci, where Ci and Cf are the scores gained in the pre and posttest, respectively. The above quantitative measurements were analyzed using the STAT view +512 program.

Ⅳ. Results

1. Students' cognitive strategic questioning in the treatment

During the treatment on the heat and temperature unit, the number of students' cognitive strategic questioning activities are in table 1&2. Table 1 presents the activities of students' cognitive strategic questioning I

Table 1. Number of students' cognitive strategic questioning I (n=49)

Treatment	1	2	3	4
Q1	185(75)	175(71)	169(62)	151(65)
Q2	52(21)	53(22)	82(30)	71(30)
Q3	11(4)	17(7)	22(8)	12(5)
Q4	248	245	273	234

*Treatment 1: Molecular motion & thermal equilibrium
2: Change of state
3: Heat transfer
4: Basic concepts of thermodynamics

According to table 1, it can not be said that activities of students' cognitive strategic questioning increase as the treatment is progressing because physical contents are different in each treatment. Q1 tends to be slowly decreasing. Though Q2 and Q3 appear to be increasing, they are decreasing in the last treatment 4. The reason is that the concepts of thermodynamics is difficult. Table 2 presents the number of students' cognitive strategic questioning Ⅱ.

Table 2. Number of students' cognitive strategic questioning Ⅱ (n=50)
N/n(N : No. of q , n : number per student)

Treatment	1	2	3	4
q1	0/0	82/1.64	60/1.2	107/2.14
q2	0/0	73/1.46	60/1.2	78/2.14
q3	0/0	61/1.22	37/0.74	63/1.26
sum	0/0	216/1.44	157/1.05	248/1.65

In table 2, T1 & T2 were treatments for temperature and T3 & T4 for heat. It appeared that at first treatment students could not do cognitive strategic questioning Ⅱ. So explanations on the activities were given to students. Figure 1 shows how the mean number of students' cognitive strategic questioning Ⅱ increases as treatments are progressing.

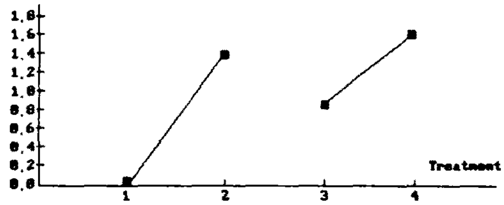

Figure 1. Mean number of CSQ II per student
T1, T2 : Temperature T3, T4 : Heat

Students' cognitive strategic questioning II tend to be increasing. According to table 2, it has been shown that there is increase in the frequency from 0 to 1.44 for the temperature concept and increase from 1.05 to 1.65 for the heat concept.

2. Students' conceptual changes

The mean conceptual scores for each group at pretest and posttest were measured. Table 3 presents the results.

Table 3. Mean scores for each group and ANOVA
Total score per student : 39

group	pre	post	t-test	p
C (n=53)	5.3	6.5	2.05	0.0454
E1(n=49)	5.5	10.3	5.09	0.0001
E2(n=50)	3.8	14.6	10.56	0.0001
f-test	2.204	18.199		
p	0.1139	0.0001		

To determine if there were any initial differences between the three groups, an ANOVA was carried out on the pretest scores. There is no significant difference (f=2.204,p=0.1139). A t-test was also carried out to check whether the differences in conceptual scores between the pre and post tests are significant. This was done for each of the three groups; C, E1, E2. The results are also shown in the table 3. There was no significant change in the scores of the control group C from the pretest to posttest(p=0.0454). But there were highly significant increases in the scores of the group E1 and the group E2 (p=0.0001).

Figure 2 presents the changes in the mean conceptual scores of each group between the pretest and the posttest.

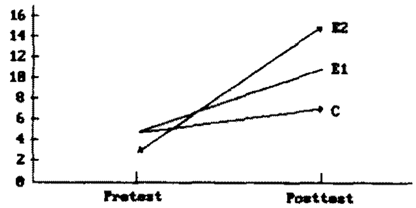

Figure 2. Changes in mean scores between the pre and posttest for each group

In the above figure 2, the experimental group E2 has shown the highest change in the mean conceptual scores.

3. Relationships between cognitive strategic questioning and conceptual changes

The correlation coefficients were carried out to determine which question categories Q1, Q2, Q3 in the group E1and q1, q2, q3 in the group E2 were correlated with the students' conceptual changes. These are presented in table 4 & 5.

Table 4. Correlation coefficients between CSQ I and CC

	CC	QN-1	QN-2	QN-3	QN-SUM
CC	1				
QN-1	.702	1			
QN-2	-.017	.596	1		
QN-3	.966	.695	.085	1	
QN-SUM	.738	.932	.637	.808	1

The third category Q3 in CSQ I was highly correlated with conceptual changes. This implies that though Q3 is relatively less than the Q2 and Q3 it is important for students' conceptual changes. Table 5 shows the correlation coefficients between CSQ Ⅱ and conceptual changes.

Table 5. Correlation coefficients between CSQⅡ and CC

	CC	qN-1	qN-2	qN-3	qN-SUM
CC	1				
qN-1	.884	1			
qN-2	.37	.662	1		
qN-3	.971	.893	.416	1	
qN-SUM	.914	.971	.668	.943	1

In table 5, the third category q3 in CSQ Ⅱ was also highly correlated with conceptual changes. This implies that though q3 was relatively less than the q2 and q3 it is important for students' conceptual changes.

Simple regression analysis for the correlation coefficients was carried out to determine what the regression line and the scatter diagram are. Figure 3 shows regression line and scatter diagram on CSQ I and conceptual changes.

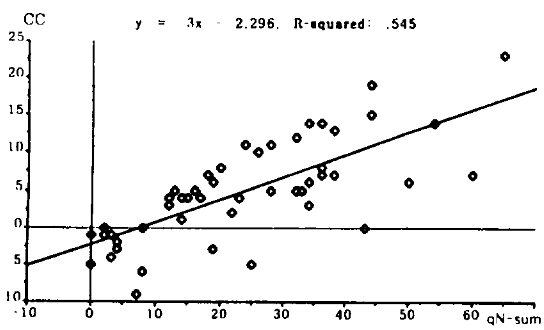

Figure 3. Regression line and scatter diagram on CSQ I and conceptual change

It has appeared that students' cognitive strategic questioning I is very positively correlated with the conceptual changes. Figure 4 shows the regression line and scatter diagram on CSQ Ⅱ and conceptual changes

It has appeared that students' cognitive strategic questioning Ⅱ is more positively correlated with the conceptual changes than students' cognitive strategic questioning Ⅰ. So cognitive strategic questioning Ⅱ is thought to be more effective in the students' conceptual changes.

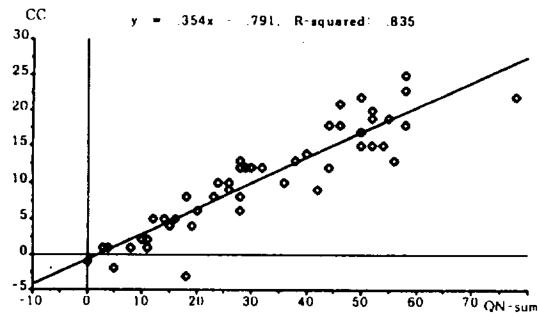

Figure 4. Regression line and scatter diagram on CSQⅡand conceptual change

V. Conclusion

The students' cognitive strategic questioning models were developed in order to make status explicit. In conclusion, it appears that, at least, in the case of conceptions about heat and temperature, developed models of students' cognitive strategic questioning could help change physical conceptions. In particular, Q3 in CSQ I and q3 in CSQ Ⅱ seem to be highly related to their conceptual change about heat and temperature. So the students should be given more various chances in order for them to ask their own cognitive strategic questions such as Q3 or q3, since this may be a good way to improve their learning and metacognitional knowledge. It is suggestive for further research to apply the cognitive strategic questioning to learning other physical concepts.

References

Arzi, H.J. & White, R.T.(1986). Questions on student's questions, *Research in Science*, 16 :82-91.

Brook, A., Briggs, H., Bell, B. & Driver, R.(1984). Aspects of secondary students' understanding of heat. Centre for studies in Science and Mathematics Education, University of Leeds.

Brown, A.L., Campione, J.C., & Day, J.D.(1981). Learning to learn: On training students to learn from texts, *Educational Researcher*, 10(2):14-21.

Dillon, J.T.(1988). Questioning and teaching: a manual of practice. London and Sydney: Croom Helm Ltd.

Duit, R. & Kesidou, S.(1988). Students' understanding of basic ideas of the second law of thermodynamics, *Research in Science Education*, 18 : 186-195.

Engel Clough, E. & Driver, R.(1985). Secondary students' conceptions of the conduction of heat: bringing together scientific and personal views, *Physics Education*, 20 : 176-82.

Erickson, G.(1977). Children's conceptions of heat and temperature phenomena. Paper presented as part of the symposium on 'Patterns of student's beliefs-implications for science teaching' at the CCSE convention, June, Frederiction.

Harris, W.F.(1981). Heat in undergraduate education, or isn't it time we abandoned the theory of caloric? *International Journal of Mechanical Engineering Education*, 9: 317-21.

Hewson, P.W. & Hennessey, M.G.(1991). Making status explicit: a case study of conceptual change. In Proceedings of an international workshop held at the University of Bremen, March 4-8, 1991, pp. 176-187.

Kim Jin Man(1995). The role of cognitive strategic questioning in the changes of student's conceptions about heat and temperature. Doctoral Dissertation, Seoul National University.

Kim Sang Myung(1993). An investigation of the students' concepts about heat/temperature and the effectiveness of the use of teaching models for decreasing misconceptions. Master's thesis, Lee Wha University, Korea.

Koch,A. & Eckstein,S.G.(1991). Improvement of reading comprehension of physics texts by students' question formulation, *International Journal of Science Education*, 13(4): 473-485

Posner, G.J., Strike, K.A., Hewson, P.W. & Gertzog, W.A. (1982). Accommodations of a science conception: towards a theory of conceptual change, Science Education, 66(2):211-227.

Ryu Jae Hyeok & Park Sung Jae(1987). An investigation of the secondary school students' concepts about thermal equilibrium, *Physics Teaching*, 5(2):169-179.

Stavy, R. & Berkovitz, B.(1980). Cognitive conflict as a basis for teaching quantitative aspects of the concept of temperature. Science Education, 64(5): 79-92.

Tiberghien.(1983). Critical review on the research aimed at elucidating the sense that the notions of temperature and heat have for students aged 10 to 16 years. Research on Physics Education, Proceedings of the first international workshop 26 June-13 July, La Londe les Maures, France, Editions du Centre National de la Recherche Scientifique, Paris,1984, pp.75-90.

Weinstein, C.F., & Mayer, R.E.(1986). The teaching of learning strategies. In M.C. Wittrock(Eds.), Handbook of research on teaching, 3rd ed., pp.315-327,New York:Macmillan.

White, R.T.(1988). Learning science. New York: Basil Black Ltd.

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(국문요약)

학생의 열과 온도 개념 변화에 있어서 인지 방략적 질문의 역할

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학생의 물리 개념 변화가 어려운 이유들 중의 하나는 학습자가 자신의 상태를 명확히 인식하지 못함으로써 자신이나 타인으로부터 되먹임을 받을 수 없다는 것이다.

본 논문은 학생이 자신의 학습 내용 이해 상태 또는 개념적 상태를 명확히 파악하여 드러내도록 하는 인지 방략적 질문 모형을 구안하고 이것이 고등 학생의 열과 온도의 개념 변화에 있어서 어떠한 역할을 할 수 있는가를 분석한 것이다. 이를 위하여 일반계 고등 학교 2학년 152명을 하나의 통제집단과 두 개의 실험집단으로 구성하였다.

학생의 개념 변화를 ANOVA 분석한 결과 세 집단은 모두 수업 처치 전과 후에 유의 수준 0.05 이내에서 의미 있는 차이가 있는 것으로 나타났으나 세 집단들 사이에도 유의한 차이가 있었다. 그러므로 학생이 지필로써 인지 방략적 질문 활동을 한 처치 수업은 전통적인 수업보다 열과 온도에 관한 학생의 개념 변화에 더욱 효과적인 것으로 나타났다.