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An analysis of Taiwanese eighth graders' science achievement, scientific epistemological beliefs and cognitive structure outcomes after learning basic atomic theory

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This study explored the interrelationships between students' general science achievement, scientific epistemological beliefs and their cognitive structure outcomes derived from instruction of basic atomic theory. Research data were mainly gathered from 48 Taiwanese eighth graders' questionnaire responses and their recalled scientific information about the atomic model, analysed by a flow map technique as evidence of their cognitive structures. This study revealed that students' science achievement was correlated with many of the students' cognitive structure outcomes; however, their scientific epistemological beliefs were also significantly related to the structure of knowledge recall, following their listening to a replay of their prior elicited recall. Students holding more constructivist-oriented views about science tended to recall more information, as well as show more richness, more flexibility and a higher precision of knowledge recall, indicating they had a better metacognitive ability when reconstructing their ideas than respondents having empiricist-aligned epistemological beliefs. However, those students having constructivist-oriented epistemological orientations tended to have a slower information retrieval rate.

Introduction

Most science educators agree that learners' prior knowledge highly influences how new knowledge is constructed (e.g. Ausubel *et al.* 1978). This study is an attempt to use two important indicators of students' prior knowledge, that is, students' past science achievement and students' scientific epistemological beliefs (SEB), to predict their cognitive structure outcomes after learning basic atomic theory. Students' past science achievement, at least, partially represents their general cognitive ability in science and prior performance, which strongly affect subsequent science learning and knowledge structures. Moreover, there is research evidence that students' SEB may influence their learning orientations (Edmondson 1989, Songer and Linn 1991, Hammer 1995), and science educators have identified a learner's SEB as an essential feature of his or her conceptual ecology (Posner *et al.* 1982, Hewson and Hewson 1984, Strike and Posner 1985, Demastes *et al.* 1995). These beliefs will very likely guide the student's metalearning assumptions. For example, Roth and Roychoudhury (1994) state that:

> [I]f science is presented to students as a body of knowledge, proven facts, and absolute truths, then they will focus on memorizing facts and think that all knowledge can be ascertained through specific proof procedures embedded in the scientific method. If, on the other hand, students experience science as a continuous process of concept

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> development, an interpretive effort to determine the meaning of data, and a process of negotiating these meanings among individuals, then students might focus on concepts and their variations. (p. 6)

Hence, students' SEB may shape their metalearning beliefs and consequently influence their learning strategies. Therefore, based on their epistemological orientations, students may learn science either as a collection of discrete facts, or as integrated knowledge. In other words, students' SEB may influence organization of scientific concepts they have learned as evidenced by their cognitive structures (West and Pines 1985). This study, which was conducted with 48 Taiwanese eighth graders, was intended to explore the interrelationships between students' science achievement, scientific epistemological beliefs and cognitive structure outcomes.

Methodology

Subjects

This research was conducted with an initial sample of 202 eighth graders from four different classes in a junior high school near Taipei City in Taiwan, ROC. In order to acquire more reliable findings for the research questions, a pool of students who met the following criteria were chosen: (1) they were above-average achievers and (2) they expressed a strong certainty or confidence about their epistemological beliefs based on questionnaire responses (Pomeroy 1993). This set of criteria were employed since the students would be expected not only to reconstruct what they had already learned and therefore needed to be articulate about what they had acquired, but also to be highly aware of their epistemological orientations toward science. Among those who met these criteria, a total of 48 students from the four participating classes were randomly selected for this study. This final sample included 18 female and 30 male students.

Measurement of students' science achievement

Students' science achievement was represented by their scores on two school-wide science examinations; hence, this is appropriate for cross-classes comparisons and analyses. These examinations were implemented before the instruction concerning atomic theory. The scores resulting from these tests could be viewed as students' prior science achievement in learning basic atomic theory.

Instrument for assessing students' scientific epistemological beliefs

A Chinese version of Pomeroy's (1993) questionnaire was administered to assess students' SEB. The questionnaire consists of bipolar agree–disagree statements on a 5-1 Likert scale, ranging from empiricist to constructivist views about science. The empiricist views about science, which imply a static perspective about the nature of science, tend to support that: (1) scientific knowledge is unproblematic and it provides *right* answers, (2) scientific knowledge is *discovered* by the *objective* data gathered from observing and experimenting or from a universal scientific method, (3) scientific knowledge is additive and bottom up, and evidence accumulated carefully will result in sure knowledge (Strike and Posner 1985, Carr *et al.*

1994, McComas 1996), whereas the constructivist views, which claim the dynamic nature of science, assert that scientific knowledge is *constructed* (or *invented*) by scientists, its status is tentative and its development experiences a series of revolutions or paradigm shifts (Kuhn 1970, Tsai 1996). The final questionnaire for this study was developed by selecting Pomeroy's items representing 'traditional views of science' (empiricist views) and 'nontraditional views of science' (constructivist views), a total of 17 items. Pomeroy (1993) reported that the internal consistency for these two parts of the questions was moderately high (Cronbach's alpha=0.651 and 0.591 respectively). The following two statements are sample items, cited from the questionnaire.

1. Science is the ideal knowledge in that it is a set of statements which are objective; i.e., their substance is determined entirely from observation. [identified as traditional or empiricist views]
2. Non-sequential thinking, i.e. taking conceptual leaps, is characteristic of many scientists. [identified as nontraditional or constructivist views]

To assess respondents' certainty or confidence about their SEB, after making a choice for each question, they were asked to answer the following question: 'Concerning this choice, I am: (1) guessing (2) uncertain (3) fairly certain (4) sure.' The questions that elicited responses of 'fairly certain' or 'sure' were viewed as *confident* items, and the students with over three-quarters of items in the questionnaire which were identified as *confident* were viewed as appropriate subjects for this study.

The translation of Pomeroy's (1993) questionnaire was validated by two Chinese-speaking researchers and the researchers tried to rephrase the questionnaire statements so that these eighth graders could understand the questions without any difficulty. The Chinese-version questionnaire showed adequate internal consistency from a pilot study conducted in the same junior high school.[1] In addition, further evidence of the questionnaire's validity was obtained by interviewing a subset of 20 students who took the questionnaire and it was concluded that their SEB as educed from interview questions basically were consistent with their responses on the questionnaire (Tsai 1996).

Students' responses of *confident* items on Pomeroy's questionnaire (i.e. showing students' strong certainty or confidence) were scored as follows. For the 'constructivist-perspective' items, a 'strongly agree' response was assigned 5 and a 'strongly disagree' response was assigned a score of 1. Items representing an empiricist view were scored in a reverse manner; that is, a 'strongly agree' response was assigned 1 and a 'strongly disagree' response was assigned a score of 5. Thus, on the total questionnaire, students having strong beliefs about constructivist views would have higher *average* scores. By and large, this study examined a one-dimensional assessment of students' SEB; namely, a continuum from empiricist to constructivist perspectives.

The exploration of students' cognitive structures after learning the atomic model

In order to determine students' cognitive structures of the atomic model, a two-period treatment lesson (a total of 100 min) on basic atomic structure, taught by the same science teacher (not the author), was presented to all students of four participating classes. Taiwan strictly uses a nationwide curriculum for every

course in elementary and secondary education. Thus, these students presumably had similar academic experiences. Eighth grade is the first time when they receive formal instruction about the atomic model. After the second period of the treatment lesson, every subject was interviewed to obtain an audiotaped record of what he or she had learned from the treatment lesson. The interview questions were as follows:

(1) Please tell me what are the main parts of the atomic model.
(2) Could you tell me more about the parts you have identified?
(3) Could you tell me the relationships among the ideas you have already told me?

As this part of the interview was used to elicit each respondent's recall as evidence of his or her cognitive structure, it was essential to analyse the data with sufficient precision and detail to allow as full an explication of the discourse structure as possible. Consequently, after the above tape-recorded interview, the tape was replayed for the student with the intent of finding out what additional ideas it would elicit, perhaps through metacognition. During this 'meta-listening' period, the tape could be paused after each major concept to allow the respondent to add, modify or even delete any information if he/she desired. This response was also tape-recorded by using a second tape recorder. In this way, the researcher could obtain a more complete picture of the learner's cognitive structure in a non-directive manner and also assess the student's metacognitive ability in reviewing his/her own ideas. The *total* interview narrative from the tape-recorded recall of each student was transcribed to yield a 'flow map' (Anderson and Demetrius 1993). A flow map is constructed by diagramming the respondent's verbalization of thought as it unfolds, and it is a convenient way to display the sequential and multirelational thought patterns expressed by the respondent without imposing a predetermined structure such as hierarchical organization or cross-linking of ideas. The flow of information and any cross-related ideation are mapped statement by statement as the narrative the respondent unfolds.

A flow map analysis is based on the theory that knowledge is not only constructed during its formation, but also during recall. That is, knowledge is reconstructed from prior experience based on the context of the recall situation, the available organizing epistemic structures in memory, and the expectations the respondent brings to the recall task. The flow map (see figure 1) captures the dynamics of this reconstruction process and was used as evidence for students' cognitive structures in this study.

Basically, the flow map is constructed by entering the ideas in sequence as they are uttered by the respondent and they are linked by a connecting arrow (both serially and then as cross-relations among revisited ideas). For example, the record of student recall, shown in figure 1, began with an introductory major idea that an atomic model included electrons, protons and neutrons. This was followed by statements about the location of these particles and their charge and mass and so on. All of the uttered statements were entered sequentially in the flow map diagram and then every statement was assigned a number consecutively throughout the stream of narrative presented by the respondent. The final three statements shown in the sample (figure 1) were added by the student after hearing the replay of the first part of the interview. In addition to the forward logical linkages shown by arrows from one statement to the next in the stream of utterances (linear

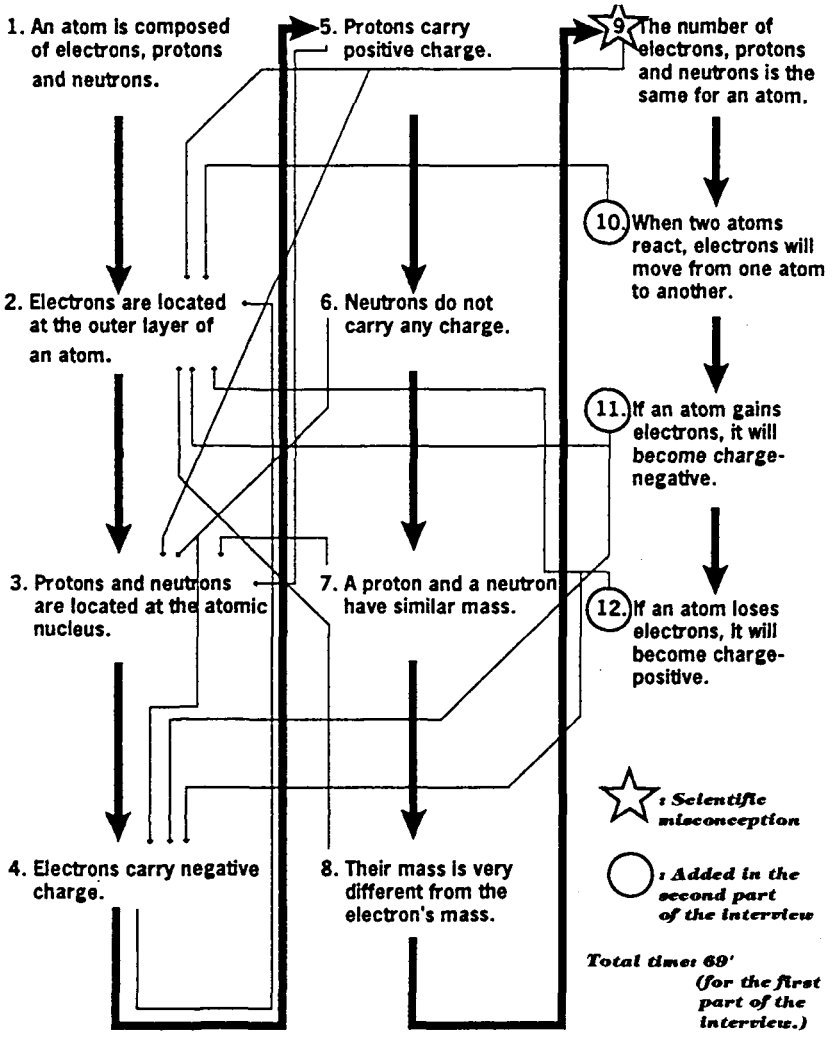

Figure 1. A sample of the flow map constructed based on a (male) student's recalled information about the atomic model. The map shows the flow of the student's verbalization of thought as it unfolds. The final three statements (statements 10–12) were added by the student after he re-listened to his earlier ideas presented in the first part of the interview (i.e. statements 1–9). Statement 9 is a scientifically incorrect concept.

linkages), relational statements, which link new ideas to earlier ones, are recorded in the flow map by inserting recurrent arrows that point back to the earliest step where the related idea (i.e. revisited idea) occurred (except statement 1, which was a general introductory statement). For example, statement 6, 'neutrons do not carry any charge', basically includes two relational unit ideas: neutrons and charge; therefore, two recurrent arrows should be drawn from it; one is drawn back to statement 3 (about neutrons) and one back to statement 4 (about charge). Finally,

the total time for the respondent's recall, after subtracting the interval of time where the interviewer was speaking, is entered at the end of the flow map. That is, only the time elapsed during the respondent's narrative is included and this provides evidence for the total time required to mobilize and utter ideas in response to the interview questions. The total time for recall is entered *only* for the initial recall before listening to the replay of the tape. It was not practical to measure recall time during the meta-listening period since there were frequent interruptions as the student listened and responded to the segments of the tape-recording.

Moreover, students' misconceptions (e.g. statement 9, figure 1) were listed in the flow map for this part of the analysis, even though they were marked on the map as scientifically incorrect, because they still represented part of the respondent's cognitive structure. A separate score was kept for the proportion of inaccurate statements or scientific misconceptions.

In order to examine the reliability of the flow maps used in this study, a second Chinese-speaking researcher who was trained in the flow-map technique was asked to analyse eight randomly selected students' interview data and convert them to flow maps. The inter-coder agreement for sequential statements was 0.95 and for cross-linkages was 0.92. This is in good agreement with the reliabilities reported in the original method by Anderson and Demetrius (1993). By employing the flow-map method, this study yielded the following cognitive structure (flow map) variables:

ILL: Initial linear linkages or initial linearly connected ideas enumerated in the flow map, a total count of linearly connected ideas in the first part of the interview (e.g. 9 in figure 1).

FLL: Final linear linkages displayed in the flow map, a total count of linearly connected ideas in both parts of the interview; i.e. including what the respondent modified in the meta-listening period (e.g. 12 in figure 1).

ICL: Initial complex linkages shown in the flow map, a total count of recurrent linkages in the first part of the interview (e.g. 8 in figure 1).

FCL: Final complex linkages enumerated in the flow map, a total count of recurrent linkages in both parts of the interview; i.e. including what the respondent modified in the meta-listening period (e.g. 13 in figure 1).

IPC: Initial proportion complex, showing the association density of the cognitive structure in the first part of the interview, equal to ICL/(ILL + ICL) (e.g. 8/(9 + 8), 0.47, in figure 1).

FPC: Final proportion complex, showing the association density of the cognitive structure (including the second part of the interview), equal to FCL/(FLL + FCL) (e.g. 13/(12 + 13), 0.52 in figure 1).

CLL: Change of linear linkages, the change of the amount of linear linkages as a result of the meta-listening period; equal to FLL minus ILL (e.g. 3 in figure 1).

CCL: Change of complex linkages, the change of the amount of complex (recurrent) linkages as a result of the meta-listening period; equal to FCL minus ICL (e.g. 5 in figure 1).

CPC: Change of proportion complex, the change of the proportion complex coefficient as a result of the meta-listening period; equal to FPC minus IPC (e.g. 0.05 in figure 1).

TT: the total time of the narrative for the first part of the interview (e.g. 69′ in figure 1).

SPS (Statement per second): the average number of statements the respondent recalled per second when conducting the first part of interview, equal to ILL/TT (e.g. 9/69, 0.13 in figure 1); an indicator for the respondent's information retrieval rate.

IPERR: Proportion of erroneous statements in the first part of the interview, equal to the total count of scientifically incorrect statements in the first part divided by ILL (e.g. 1/9, 0.11, in figure 1).

FPERR: Proportion of erroneous statements in both parts of the interview, equal to the total count of scientifically incorrect statements in both parts of the interview divided by FLL (e.g. 1/12, 0.08, in figure 1).

Therefore, by employing the flow-map method, this study at least could measure the following dimensions of learners' cognitive structure outcomes: size (linear linkages or number of ideas), richness (recurrent linkages), integratedness (proportion of recurrent linkages or association density), flexibility (change of linkages resulting from the meta-listening period), information retrieval rate (statements per second) and correctness (misconception rate).

Results and discussion

Relationship between students' science achievement and their SEB

For the sample of subjects, their epistemological beliefs about science were not significantly related to their science achievement ($r = 0.04$, n.s.). That is, at a certain achievement level, students could have various views about the epistemologies of science.

Relationships between students' science achievement and their coefficients in the cognitive structure (flow map) dimensions

In this study, students' science achievement (labelled as ACHV) was an important variable to predict students' cognitive structure outcomes; therefore, correlations between students' science achievement and their coefficients in the cognitive structure (flow map) dimensions were examined, and are presented in table 1.

According to the data presented in table 1, the amount of linear linkages students uttered (both initial and final; i.e. ILL and FLL), the amount of complex linkages they generated in their verbalization (both initial and final; i.e. ICL and FCL), and the proportion complexity of their cognitive structures (both initial and final; i.e. IPC and FPC) were all significantly positively correlated with their science achievement at the 0.05 level. That is, higher achievers tended to recall more ideas, show more richness and have more integrated information networks in the first part or in total parts of the interview. This finding concurs with the results of Anderson and Demetrius (1993) that students who achieve higher academically show more elevated scores on cognitive structure outcomes through the flow-map analysis. This is consistent with current schema theory which predicts that students with more complex or ideationally richer schemata should be more facile in assimilating new academic knowledge and reconstructing it during recall.

For the rest of the variables, students' science achievement did not play a statistically significant role. For example, higher achievers did not add significantly more information (CLL) or yield more recurrent linkages (CCL) in their cognitive structures as a result of the meta-listening period, following listening to their tape-recorded recall. It was also surprising to find that higher achievers did not have a significantly lower misconception rate in this immediate recall test than lower achievers (IPERR and FPERR).

Correlations between students' SEB and their cognitive structure (flow map) outcomes

In order to acquire the information about how students' SEB were related to their cognitive structure outcomes, the relationships between students' epistemological orientations toward science (labelled as EPSTMO) and their cognitive structural framework coefficients derived from the flow maps were explored. In other words, the correlations between students' responses in Pomeroy's (1993) questionnaire and the cognitive structure (flow map) outcome variables arising from their recalled scientific information were investigated. The correlation results are summarized in table 2.

According to table 2, in the first part of the interview, students who had SEB more oriented to constructivist views of science (viewed as 'knowledge constructivists', in Hashweh's (1996) terminology) did not tend to recall more information (ILL; $r = 0.17$, n.s.), nor to show more complex linkages (ICL, showing the extent of richness of the information; $r = 0.22$, n.s.) and did not display more integratedness (IPC; $r = 0.19$, n.s.) in their cognitive structures than those holding more empiricist-aligned SEB (labelled as 'knowledge empiricists'). However, after replaying the tape of their responses in the first part of the interview and soliciting additional recall, knowledge constructivist students, who expressed SEB more oriented to constructivism, as a total of both parts of the interview, tended to generate significantly more ideas (FLL, $r = 0.42$, $p < 0.01$) and produce more complex linkages (FCL, $r = 0.42$, $p < 0.01$) in their cognitive networks than knowledge empiricist-oriented students (but they did not show significantly higher association density in their cognitive structures (FPC). This indicates that students holding constructivist-oriented SEB tended to add significantly more statements and complex linkages than those having empiricist-aligned SEB during (or after) the meta-listening period, which resulted in the high correlations between EPSTMO and CLL ($r = 0.46$, $p < 0.001$), and between EPSTMO and CCL ($r = 0.44$, $p < 0.01$). However, knowledge constructivist-oriented students did *not* show a significant increase in the proportion complexity (CPC) of their cognitive structural frameworks as a result of the meta-listening period, when compared with their counterpartners, those who held more empiricist-oriented SEB ($r = 0.13$, n.s.).

Although students who adhered to more constructivist-oriented SEB did not show a statistically significant tendency to spend more time in recalling the scientific information than those who believed in more empiricist-oriented views of science (TT), knowledge constructivist students, on average, tended to have a slower rate of information retrieval than knowledge empiricist subjects (SPS, $r = -0.39$, $p < 0.01$). This implied that knowledge constructivists generally needed more time to retrieve and reconstruct information stored in their long-term memory, even though knowledge constructivist students did not necessarily have more proportionally complex cognitive structures than knowledge empiricist-aligned students.

In addition, knowledge constructivist students tended to have a lower proportion of misconceptions than knowledge empiricist students in the immediate recall interview (IPERR, $r = -0.46$, $p < 0.001$ and FPERR, $r = -0.45$, $p < 0.001$). It implies that there was a significant tendency that students who stated some scientifically incorrect information were likely to be those who were knowledge

Table 1. Correlations between students' science achievement and their results on cognitive structure (flow map) variables ($n=48$).

	ILL	*FLL*	*ICL*	*FCL*	*IPC*	*FPC*	*CLL*	*CCL*	*CPC*	*TT*	*SPS*	*IPERR*	*FPERR*
ACHV	0.49***	0.44**	0.49***	0.44**	0.33*	0.36*	0.01	0.03	0.00	0.28	0.26	−0.06	0.02

Note: * $p < 0.05$, **$p<0.01$,*** $p < 0.001$.

Table 2. Correlations between students' scientific epistemological views and their cognitive structure (flow map) outcomes ($n=48$).

	ILL	*FLL*	*ICL*	*FCL*	*IPC*	*FPC*	*CLL*	*CCL*	*CPC*	*TT*	*SPS*	*IPERR*	*FPERR*
EPSTMO	0.17	0.42**	0.22	0.42**	0.19	0.27	0.46***	0.44**	0.13	0.28	−0.39**	−0.46***	−0.45***

Note: * $p < 0.05$, **$p<0.01$,*** $p < 0.001$.

empiricist-oriented subjects. It was also informative to explore whether students, during (or after) the meta-listening period, corrected their misconceptions which were stated in the first part of the interview. Further analyses revealed that only two students, during the meta-listening period, corrected their erroneous conceptions presented in the first part of the interview, and these students were constructivist-oriented students.

Partial correlations between students' SEB and their cognitive structure outcomes, when controlling for students' science achievement

It is concluded from table 1 that students' performance on linear linkages, complex linkages and proportional complexity of cognitive structure outcomes (i.e. ILL, FLL, ICL, FCL, IPC, FPC) was significantly correlated with their science achievement. Thus, when discussing the relationships between students' epistemological beliefs and their cognitive structure outcomes on these variables, their science achievement has to be controlled to acquire an authentic description for these issues. Table 3 presents the partial correlation coefficients between students' SEB and these cognitive structure variables, after controlling for students' science achievement.

These correlation coefficients remain almost unchanged from those shown in table 2. In other words, after controlling students' science achievement, their SEB still did not show any significant correlation with their cognitive structure outcomes deriving from the first part of the interview (i.e. ILL, ICL and IPC). However, under the same control, knowledge constructivist students tended to recall more information and generate more complex linkages in their cognitive structural frameworks in total parts of the interview than knowledge empiricist learners (i.e. FLL, FCL). This implied that students, no matter whether high achievers or relatively low achievers, tended to add more information and yield more complex linkages (showing the richness of their thoughts) in the meta-listening period if they had SEB more oriented to constructivist views. This was further confirmed by integrating the results shown in table 1 and table 2 that students' epistemological beliefs about science, but *not* students' science achievement, was a significant variable related to changes of linear linkages and complex linkages in students' cognitive structures, as a result of listening to their own ideas (i.e. CLL and CCL). If the content of the added information was examined, it was found that most of these ideas were novel ones (94.8%). That is, these students were not simply repeating similar information presented in the first part of the interview or merely integrating two original ideas into a new one. Students holding constructivist-aligned SEB really tended to add more *new* information during (or after) the meta-listening period, which implied that they had a better metacogni-

Table 3. Partial correlations between students' SEB and their cognitive structure outcomes, controlling for science achievement ($n=48$)

	ILL	*FLL*	*ICL*	*FCL*	*IPC*	*FPC*
EPSTMO	*0.17*	*0.45***	*0.23*	*0.45***	*0.18*	*0.27*

Note: * $p < 0.05$, ** $p < 0.001$, *** $p < 0.001$

tive ability to monitor their ideas and they had more flexibility to control their learning and organize what they had acquired. This finding concurs with the hypothesis proposed by Gunstone (1991) that students' beliefs about the nature of science could be one major determinant influencing their metacognitive activities. It can also be concluded that if the students involved in this study had not been given an opportunity to explore their ideas deeply (that is, by replaying their responses in the first part of the interview), no significant relationship between students' epistemological beliefs and the amount of linear and complex linkages shown in their cognitive structures would have been found. Science achievement may still have been the sole significant variable related to students' coefficients on these cognitive structure dimensions. This implies that some students, perhaps knowledge constructivist learners, need more time to reflect upon what they already know and they can then show more potential for learning. This is also in agreement with an earlier finding of this study that knowledge constructivist learners tended to have a slower information retrieval rate. These students may feel frustrated by traditional achievement testing, which demands that students finish certain tasks in a short period of time.

Conclusions

Students' prior science achievement was correlated with many of the students' cognitive structure outcomes derived from the instruction of basic atomic theory. Higher achievers tended to recall more information, show more richness and high connectedness of their thoughts. However, their SEB were also significantly related to the structure of knowledge recall, following their listening to a replay of prior elicited recall. If students were allowed to monitor their own ideas and then possibly revise them, students who held more constructivist-oriented SEB tended to perform better in terms of the ideas recalled, the number of complex linkages generated, and the correct rate of recalled information, when compared with those who were more oriented to empiricist SEB. These findings support that students holding more constructivist-oriented SEB tended to recall more information, as well as show more richness, more flexibility and a higher precision of knowledge recall, indicating that they have a better metacognitive ability when reconstructing their ideas than respondents having more empiricist-aligned SEB. Moreover, when compared with knowledge empiricist students, knowledge constructivist learners tended to have slower information retrieval rate, perhaps indicating a deeper processing of information.

There are the following plausible interpretations for these findings. First, possibly because knowledge empiricist-oriented students believed that science was a collection of infallible facts, they may have hesitated to recall some information, if they were not certain about its correctness. Thus, they tended to recall fewer ideas than constructivist-oriented students. This interpretation can be further supported by the fact that two empiricist-oriented students stated something like 'Is it all right if I tell you some wrong ideas?' when they were asked to recall their ideas. However, in this study they did not display more scientifically precise knowledge structures than did other students. Second, knowledge constructivist students held the belief that science was constructed and was influenced by a complex interaction between existing theories and human decision making. Hence they tended to construct their knowledge by meaningfully interacting with

other existing ideas in their conceptual ecology, and consequently they tended to have a slower rate of information retrieval and show more richness in their information networks than knowledge empiricist-aligned students, those who tended to view science as isolated bits of correct information. Third, students who had SEB closer to constructivism tended to appreciate more the dynamic nature of scientific knowledge; consequently, they tended to show more flexibility in constructing their scientific ideas and it was plausible to find that they added significantly more information than empiricist-oriented subjects, who perceive science as a static enterprise. The major conclusion derived from this study indicates that both students' science achievement and their scientific epistemological beliefs are important predictors to explain students' cognitive structure outcomes. An introduction of the constructivist epistemology about science may help students construct a better knowledge structure of scientific concepts. However, science teachers should allow more time for students to reconstruct what they already know, especially for students who have epistemological orientations closer to constructivist views about science.

Note

1. Since there were missing data for students' questionnaire responses (i.e. those lacking students' confidence), this study could not properly conduct a reliability test to assess the questionnaire's internal consistency. The study finally used the correlation coefficients between the student's response on every individual item and his or her average score on all confident items to assess the consistency of this questionnaire. Except for one question, which was excluded from the final analyses, the correlation coefficients (ranging from 0.43 to 0.67) were significant at the 0.05 level (Tsai 1996).

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