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Secondary Induction Science Teachers' Conceptions of Teaching Science during their Professional Development

Hyun-Ju Park
(Chosun University)

ABSTRACT

Many studies on the professional development of science teachers demonstrated that induction teachers' conceptions of teaching science are important factors in developing their professionalism. The present study was conducted to describe in detail the progress of two science induction teachers, June and Mike, towards conceptual change teaching, and to investigate secondary induction science teachers' conceptions of teaching science by analysing their conceptual ecologies. The study was interpretive, using multiple data sources to achieve a triangulation of data. Both June and Mike held strongly positive learning in their views of knowledge and science. Holding positivist views of knowledge and of science is likely to be a major obstacle for anyone coming to understand constructivism and its implications in teaching for conceptual change. This argument resonates in several key ways with the teachers' cases, even though I recognize differences between scenario and teachers, and between teachers themselves.

Key words: secondary induction science teacher, conception of teaching science, professional development

I. Introduction

The theory of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) became the leading paradigm that guided research and instructional practices in the science education community for many years. However, it also became subject to a number of criticisms. One specific criticism of the theory of conceptual change is that it focuses only on the supposed underlying logical structures and a rational process, and lacks attention to affective aspects

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as well as motivational constructs in students' learning science (Demasters *et al.*, 1995; Pintrich, Max, & Boyle, 1993; Strike & Posner, 1992; Vosniadou & Ioannides, 1998).

I believe, however, that the criticism should not be directed at the theory of conceptual change. The theory of conceptual change begin with an analogy of one's learning to a way in which many contemporary interpretations in the history and philosophy of science knowledge has changed in the scientific community. When the theory of conceptual change is proposed, there are two important factors that can help a person experience conceptual change: status of conception and conceptual ecology.

The concept of the status of one's conception is represented in the view of conceptual change theory that one's learning is a rational process; conceptual ecology provides the context of conceptual change learning to influence the status of conceptions as intelligibility, plausibility, fruitfulness, and dissatisfaction. As Toulmin (1972) stated, the degree of the status of conception within conceptual ecology affects the influence of intellectual selection. And the development of one's intellectual disciplines creates a diversity of approaches limited only by the selective influence of active conceptual problems. Conceptual ecology contains the history of one's conceptions and views as well as the development of metaconceptual awareness and the construction of theoretical framework with greater systematic, coherent, and explanatory power.

Many studies on the professional development of science teachers demonstrated that induction teachers' conceptions of teaching science are important factors in developing their professionalism (Feiman-Nemser, 2001; Gess-Newsome, 1999; Khale, 1999; Shanker, 1996). Investigating these conceptions and how these conceptions change or interact during their first year of teaching science, I will have a clue with regard to decisions about how to facilitate induction teachers' professional development. I use the term conceptions of teaching science as an inclusive one that encompasses science, learning, and teaching, and the relationships between these three conceptions (Hewson *et al*, 1999)

The purpose of this study is to trace the progress of two teachers, June and Mike, towards the goals of the program, conceptual change teaching, and to investigate secondary induction science teachers' conceptions of teaching science by analysing their conceptual ecologies.

Ⅱ. Research methods

1. Participants and data collection

The data upon which this paper bases its conclusions was collected during the participants' preservice year and during their first year of teaching. For the former period, the data stems from four occasions during which we observed the participants' teaching

(twice during practicum, and twice during student teaching).

Data representing this period was also collected during opening and closing CTS (conceptions of teaching science) and CST (conceptions of scientific themes) interviews in which participants took part (described in Lemberger, Hewson, & Park, 1999), as well as from entries the participants made in their action research journals during the student teaching experience. The data and the analysis procedure of their preservice year have been described elsewhere (Hewson *et al.*, 1999). Data drawn from their first year of teaching was based on observation and interviews collected during 1994-1995. Both interviews and observations taken at this stage in the teachers' careers were designed to draw out the participants' conceptions with regard to teaching, learning, and the nature of science.

This paper follows secondary preservice teachers through their preservice science methods course in their first year of teaching. During the preservice year, the teachers who formed the focus of this series were enrolled in a science methods course that dedicated itself to conceptual change instruction and a constructivist approach to teaching. An action research seminar stressed reflective practice during student teaching. The two teachers were enrolled in the secondary teaching program at the University of Wisconsin-Madison, and were in their second year of teaching when the data were collected.

2. Data analysis

I made use of an interpretative research design based on principles of naturalistic inquiry (Erickson, 1986; Lincoln & Guba, 1985). I sought to understand and share the meaning of constructions in the context of science teachers teaching science (Erlandson, Harris, Skipper, & Allen, 1993). A key feature of our analytical procedures was constant comparative analysis (Strauss, 1987) which I applied to the texts generated from various data sources. My intention was to develop exemplary cases for induction science teachers' conceptions of teaching science. Two types of triangulation were implemented (Denzin, 1978; Mathison, 1988): Data triangulation and investigator triangulation.

Both data collection and analyzing were derived from various sources of interviews, teaching observations, journals, and information and profiles by the participants' supervisor. I also deployed different methods, such as interviews, census data, and reviewing documents to validate findings. In investigator triangulations, three colleagues who had been working on the same project with me were asked to analyze and to interpret the data. Each one was to read and to analyze transcripts of the participants. They were also asked to read interpretation of the data, and later to discuss with me whether they agreed with my analysis. All three concurred with my interpretation of the participants. Moreover, once the data analysis was done, I checked with the participants whether they agreed with my interpretations of them.

This paper contains two sections. The first of these provides a portrait of each teacher, focusing on his or her beliefs about teaching science during the preservice stage, the changing status of various conceptions of teaching, and an analysis on the first year of teaching. It also includes discussion of the ways in which the latter experience may have changed or influenced their teaching and the beliefs associated with it. The second section extends what I have learned about the two participants to a broader set of conclusions regarding the professional development of secondary science teachers towards conceptual change methods.

Ⅲ. Results: Case studies

1. June

(1) Summary of preservice experience

June's early views about the nature of knowledge, science, and teaching are available from analyses of interviews and observations done during her preservice year. Knowledge, in June's view, is external truth that students must discover through observation, discussion, sense making, and ultimately, reliance on the judgement of authorities, especially the teacher. As far as science is concerned, June defined it in terms of content and skills. The content of science has two aspects: a fixed body of facts and a changing knowledge base resulting from the process of discovery through experimentation. The skills are those needed to engage in the process of discovery, i.e., gathering facts and developing explanatory models of how things work. Finally, June's stated view of the nature of teaching was one of looking up information in a textbook, preparing an intelligible explanation of it for class, and then presenting the information to the students. June is a very introspective person who took time to observe and think about her classroom practice.

June's student teaching placement in south central Wisconsin was in a small rural town close to her home. The student population of predominantly white and middle class school was about 250. June's classes were small and contained students with a wide range of abilities. She taught a curriculum developed by her cooperating teacher under a district-wide scope and sequence umbrella. June was somewhat constrained in her teaching by her cooperating teacher's attitude about time. He thought that spending extra time on a difficult topic was babying the students, that they were just being lazy. In practice, however, she used considerable class time for students to present their conceptions about the topic of study. June saw it as her role then to step in with the authoritative 'correct' information, rather than using strategies to get students to make judgements about the status of their conceptions relative to other conceptions. The student liked June's student-centered discussions. In her action research seminar journal, June wrote about a survey she gave to

her classes about her teaching and how she ran her class:

> The question about discussion really surprised me. A lot of the kids thought discussion in class was pretty good.

Apparently, by keeping the discussions student centered, June captured the interest and approval of her students. She made them feel good enough about the value of their own ideas that they came to value discussion.

In June's view, her student teaching experience was an important step in her learning biology in a manner useful for teaching. She stated that she had a better understanding and more confidence in her biological knowledge from having taught it.

(2) First year of teaching

Context. June spent her first year teaching in a medium-size high school in Central Wisconsin. The school was well supported by the community and, according to an administrator, the faculty was content and stable. The science department offered Biology, Chemistry, Physics, Physical Science, and Environmental Science. There were nine teachers in the department, five of whom taught Biology for at least part of their day. While there was a district curriculum, it nevertheless allowed teachers to follow divergent paths within the constraints imposed by many labs they used in common and the need to spread equipment around. In June's view, the school administration was supportive of teachers.

June was the only permanent female faculty member. She taught two sections of sophomore biology, one section of physics, and two sections of LEAP, an alternative program for students at risk of not graduating. June had been free from the LEAP curriculum ("I was told I could do what I liked."). She had found the lack of guidance a stressful experience, but felt she was improving. June also explicitly stated that, were she to stop teaching LEAP, she would leave all her materials for her successor to provide the guidance she hadn't had.

Mr. David, a biology teacher with more than 20 years' experience, was assigned by the science department to mentor June in her biology teaching. She taught her biology class in his classroom, followed his curriculum closely, did the same labs he did, and used his handouts most of the time. As a first year teacher, she found the support provided by this arrangement invaluable; she commented, "I don't know what I'd do without him." It provided her with a broad curriculum structure and a wealth of resources she would have been unable to prepare in her first year. As the months passed, she found there were various points over which she disagreed with him, e. g., the level of detail in some of his handouts, his discussion of controversial topics such as abortion, and his low opinion of students' abilities. These disagreements, however, were never a problem to June because

she felt she had the freedom to do things differently, e. g., focus on big ideas rather than detail, leave out issues she believed did not belong in a biology curriculum, etc. As she commented:

> I don't really have any pressure from the school at all... so it's really up to the individual teacher as to what we would teach, so I guess it's my freedom in that sense.

It was clear that June was content with the school ("I think this is a wonderful school district"), she enjoyed teaching ("I do like what I do and I definitely want to teach more"), and felt she was making progress. The school was happy with her. An administrator said he was impressed with her handling of the LEAP class that he'd taught the previous year ("I went in 10 minutes before the end of the class and they were asking her questions about orbital levels!") and commented she was one of the best new teachers he'd seen.

Description. June was observed teaching three different biology lessons that were unrelated to each other. Twice it was possible to observe her repeat a lesson to another section later in the day. The tasks described took up a little more than half of the three lessons observed.

June's biology classes were studying the atomic structure of compounds. She handed out a set of questions as a review task for groups. The procedure for setting up groups and sorting out individual roles within the group was very familiar to the students; without any fuss, students formed groups, rearranged chairs, and started the task. They looked up their notes, consulted different textbooks, discussed their answers, and wrote them down. Later, each group reported back to the class items that were 'important to know' from their review sheets, writing them on the overhead for the rest of the class to copy down. June commented on their responses, asked questions about why some were important, occasionally amplified or changed a conclusion, and announced at the end that those were their notes for the topic.

As one part of the second lesson, June conducted a review activity, the purpose of which was to name parts of the human reproductive system. It had been some time since this had been done and there was to be a test the following week. She put up a diagram on the overhead, pointed at particular organs, and asked different students, some with their hands up and others without, to respond. The emphasis was largely on nomenclature, with little mention of function.

The third lesson I observed was the fourth day of a 'chick' lab, a department-wide activity designed to follow the influence of a hormone, testosterone, on the growth and development of young chicks. Once a week over the period of about a month, students had

taken measurements of secondary characteristics of chicks that had been, respectively, injected with the hormone, painted with the hormone, and left untouched as a control. This was the fourth and final occasion for gathering data. June gave a brief introduction to remind students of salient features of the experiment. Small groups of students then worked independently, identifying their three chicks in the common cage, weighing them, measuring their combined size, and observing the frequency of various aspects of their behavior. These were not all easy procedures to accomplish with agitated, mobile chicks, but for the most part students responded with enthusiasm to the tasks, to the chicks as creatures to be petted and played with, and to others in the classroom (including the observer.). June kept a watchful eye on the class, circulating, answering questions, and keeping an eye on the clock to remind students to clean up before the end of the class. She also encouraged them, if they had time, to start graphing their data so that they could study the results of the experiment the following day.

(3) Conceptions

Science and Scientific Knowledge. June appears to view science as having two aspects. She sees it as a discipline that has much factual material, embedded on the other hand in a social structure that produces the possibility of opinion and controversy, e. g., evolution, birth control. In teaching it, she chooses to steer clear of the controversial. For instance, in commenting on her review of factual material, she said:

> ... unfortunately that's what a lot of biology is, knowing what terms are and what things are... there's only so many questions that you can ask in biology that are opinion questions at least at this stage... most of the questions are going to be factual: Do you know what an ovary is? ... I usually try to put in some type of thought questions..but it's hard to think of these questions.

The contrast June drew here between factual and opinion questions reiterated earlier comments she had made about the role she saw for herself as a biology teacher. In talking about a decision she had made not to discuss birth control in class, she said:

> I think that biology should be factual material on... the human body, plants, and animals. Whether you decide if you want to get pregnant or not, you know, is not a fact... it's a judgment, it's a moral issue, it's something that someone is going to decide on their own. Whether I tell you how you can or cannot get pregnant, I don't think..it's not the place to do it as a teacher in a public school.

In order to probe June's two-part view of biology, she was asked the following day whether she saw a balance between providing information gathered by scientists and

talking about the process of finding out that information, she commented:

> We teach the kids at the beginning of the year about the scientific method...we do go over what a theory is, something that has evidence but hasn't been proven beyond a reasonable doubt that it's true... kids basically think what they get in class is fact and what their teacher says is true. I think they put a lot of emphasis on so and so said it so it must be true..you have to be careful about that because if you do say something that is kind of opinionated or a theory, they may think it's true.

In other words, it appears that June thinks of biology in terms of matters of fact and matters of opinion, including theories and moral issues. The methods by which scientists produce knowledge appear to play a minor role for her. Thus she sees that her responsibility is largely to teach the facts, in part because she doesn't want her students to come to accept her opinions as the truth.

Learning and Learners. There is a strong focus on students in June's teaching. This shows up in her classroom in the extent to which she gives students opportunities to talk with each other in groups and laboratories, to ask and answer questions, and to provide input in whole class settings. She is prepared to listen to students and to adjust her lesson plan in response to what she has heard, particularly if there is confusion and lack of understanding. This approach was reflected in both the group review and the "chick" lab described above where, within the constraints of tasks clearly defined by the lab instruction sheet, she wanted students to take responsibility. It seems clear that students had come to accept this expectation and behaved accordingly.

When asked about her expectations of her students, she replied:

> ... the one main expectation was 100% effort... I guess I judge it by how they use their time in class... it's a lot of me observing them and I guess getting to know them.

Teaching. In talking about her teaching, June supported these observations. In different contexts she reiterated the importance for her of making sure that her students were engaged in the lesson. In talking about her planning she said:

> The question comes to my head of something they might ask so I write it down and ask it to them and go from there... again just to get them vocal and not to make it a passive class.

She commented about her teaching:

> ... kids will say that they don't understand stuff and then we'll stop... it takes me out of my lesson plan but... we work around it... I'm pretty flexible...I tend to get off track... that's good that they're at least engaging in the conversation and they're thinking about it.

On another occasion:

> ... I just think if I just try to jam so much stuff down they're not going to remember anything.

The importance, for June, of engaging students recurred as she talked about her use of a question-and-answer review of detailed factual material points to her focusing on issues in teaching other than students. She commented about two aspects of the review, its format and its content. She wasn't happy with its format, saying:

> We always try to play some type of game..rather than me just standing up there... and basically go[ing] through everything... I'll think of some little activity that we can do that will get them thinking about what they know and what they don't know.

In other words, in order to improve student engagement, June would ideally have chosen to format the review differently. In summary, June focused strongly on the students she was teaching. Her relationships with them was excellent, she respected them, she listened to them, she varied her teaching in response to their words and actions, and she constantly sought to engage them in the tasks she set for them. The classroom environment was congenial and cooperative.

Curriculum. With respect to her biology curriculum, June tacitly accepts the district curriculum by basing her teaching largely on the resources provided by Mr. David(her mentor teacher), her other colleagues in the science department, and textbooks. As she said:

> I'd say 95% of the hand outs I get are from [Mr. David]... he lets me look through and see which ones I want to use... which is just great... I don't know what I'd do without him...he gives me about a month in advance everything like a sentence or two, on what he's going to do... I kind of follow his schedule ... because there are so many teachers here, too, we all do the same labs and so they're available.

June also relies on textbook:

> I have four or five textbooks at home... and I see what they see as important... I don't take it into my own hands... I guess through time I'm just going to know through experience whether I should have done this or didn't need to.

On a day-to-day level, she does her own planning:

> I'm pretty flexible... I usually write down a pretty detailed lesson... notes... questions.

Colleagues and school. June was to a very large extent content with the degree of support she received from her colleagues and the school. While she acknowledged some constraints from the school curriculum and the need to coordinate with Mr. David, she also felt that she had the freedom to make her own professional judgments as she saw fit. In her words:

> The only thing would be in...the actual order of the content that we teach, we do that the same, so we do the same labs because he has all the materials ordered... I probably don't cover as much [as other teachers] but I don't feel pressure that I have to... I guess it's my judgment to pick out what is important... I don't really have any pressure from the school at all... so it's really up to the individual teachers as to what we would teach, so I guess it's my freedom in that sense... I think this is a wonderful school district.

(4) Discussion of June

There seems to be a strong continuity between June's approaches to her students in her preservice year and first year of teaching. As a student teacher she believed it was important to give students time and space to express themselves, in spite of her cooperating teacher's attitude. Her strong focus on the importance of engaging students and having them involved in lessons continued in her first year of teaching.

There is also an important strand of June's view of science that remains unchanged. In both years, a key aspect for her regarding science in general, and biology in particular, is the body of factual knowledge representing the objective truth about the world. I can see this explicitly in many of her statements above. I can also see it tacitly in her need to step in with authoritative information, in both years, and from her substantial reliance on the district curriculum guide, her textbooks, and her colleagues' written materials and laboratory activities during her first year of teaching.

There are, however, two changes in the above account. First, in her preservice year June spoke about science incorporating a process of discovery through experimentation that

changes the base of available knowledge, a process in which students can participate to learn objective truths about the world. In her first year, June did not appear to emphasize discovery as a way of thinking about experimentation. Second, in her first year of teaching June spoke on several occasions about the role that matters of opinion played in biology and stated she did not think she should teach these in her high school biology classroom. June did not appear to emphasize this aspect in her preservice year. In noting these changes, I recognize that they are based on interactions with June that were necessarily the same between the years. It is possible that the structure of the interviews and conversations, and the context in which June was working at the time would influence her to emphasize the different aspects reported above.

2. Mike

(1) Summary of preservice experience

Mike began and ended his preservice year with a didactic view of teaching. Like his cohorts in the action research seminar, Mike developed a greater focus on his students (Tabachnick & Zeichner, 1993), but this did not result in a change in his teaching. His unchanging, non-constructivist conceptions of science (positivist) and knowledge (factual truths about reality to be transmitted from teacher to student) might have been important factors blocking his development towards conceptual change teaching (Tabachnick & Zeichner, 1993). Mike was aware that his students brought their own conceptions about the world to his classroom. These conceptions were important to Mike because they were often wrong or incomplete. This informed Mike about what to teach. Once Mike identified a misconception he presented the scientific conception with an explanation of why it was the correct conception. He called this dispelling the myths.

Mike's cooperating teacher was also an important influence on Mike's teaching. He often praised Mike's teaching, reinforcing Mike's views of science and knowledge. Mike's cooperating teacher was very positive about Mike, and stated that Mike was the best student teacher he had ever worked with.

(2) First year of teaching

Context. Mike's first year of teaching was in a medium-sized public school in northeastern Wisconsin. The school had many resources to offer Mike. He admitted, however, to being too busy to make use of many of them. His resources included eight Macintosh computers in the science department and a good variety of science software programs. There were another 58 computers available for use within the school. Even though he was too busy to think about how to use the computers during his first year of teaching, Mike hoped to incorporate more computer work into his classes during this second

year. There were also a number of nature areas and a planetarium near the school that the science department used for field trips.

Mike also had some human resources to call upon. The science department head, Mr. Johnson, was an informal mentor for Mike in Biology, and Mrs. Lawrence played the same role for Mike in Science 9. Both were experienced teachers who offered Mike advice, for example, on how well different labs worked, and what resources were available for those labs. In addition to Mrs. Lawrence and Mr. Johnson, the science department had four other teachers. Mr. Johnson and Mike taught sophomore biology. Mrs. Lawrence and Mike taught the Science 9 sections.

Although Mike used his text book and his informal mentors quite a bit during his first year of teaching, they were not his only resources. Because he was unable to find the time to familiarize himself with many of the resources of the school, Mike used the resources he had become familiar with during his college years. These included notes from classes that he had taken in college along with college textbooks and work books, personal experiences, and video presentations he'd seen.

Mike was happy to be teaching. He thought that he was having an impact on his students' lives. He felt teaching was an outlet for his creativity which offset the pressure of his feeing solely responsible for what his students were learning about in biology or earth science. He admitted that teaching was a lot of hard work, but felt that, if he could get through the first two years, things would get better.

Description. I observed Mike's teaching on two different occasions. The first occasion was a one day observation in late January. Mike's 5^{th} hour sophomore biology and 7^{th} hour freshman science classes were observed. The second occasion, done about three months later, was a two day observation of his 5^{th} and 6^{th} hour biology classes.

During our first observation of Mike, his sophomore biology class was studying photosynthesis and the absorption spectrum for chlorophyll. This was a lively, good-natured class. Mike seemed to have established a fairly good rapport with the students in this class. Mike began by leading a lecture/discussion about photosynthesis. As part of this lesson, he questioned the class about what they could recall of the light reaction and the by-products of the Calvin cycle. Their responses were recorded on the blackboard. Mike then quickly summarized the Calvin cycle, and asked if there were any questions before going on. The rest of the class time was spent introducing a chromatography lab. Mike had the students open their text and look at an absorption spectrum for chlorophyll a and b. Mike asked the class what they thought the color of light might be. The class had some very interesting reponses: white, nothing, black. Mike, however, chose not to digress from his lesson plan and continued on with the role of chlorophyll in light absorption. He explained later that he was going to do a chromatography experiment the next day and he needed to prepare the class ("I didn't want to get into it because I wanted to make sure we got through the stuff

for the lab on Monday"). Since most of the labs were prepared cooperatively with Mr. Johnson, Mike needed to stay on the same pace.

During our second observation of Mike, the 5th hour biology class was studying meiosis. Mike began by asking the class to get out their text and notebooks. He then asked if chromosomes came in odd or even numbers. The ensuing discussion centered on why they came in even numbers. Students wrote down what was put on the black board into their notebooks. Mike proceeded to take the class through prophase, metaphase, anaphase, and telophase for mitosis and then compared those phases with the first meiotic division. The students in this 5th hour class were very curious about the genetic implications of meiosis. They kept stopping the train of Mike's lecture/discussion with questions like, why babies are born with blue eyes that later change to brown, or, if a person is born blind, will their children be blind. These seemed like genuine questions and not just attempts by the class to delay the lesson.

The next day the class took out their notebooks and picked up right where they had left off the previous day. Mike began by reviewing yesterday's lesson. He asked the class for the stages of mitosis. These he wrote on the blackboard, along with the characteristics of each phase. Mike then asked the students to open their texts. Mike then went over the second meiotic division. At this point a solar eclipse was imminent. Mike dismissed the class so that they could go outside to observe the eclipse. The students were very excited about the eclipse, and were very concerned that they would be dismissed too late to see it.

After the eclipse, Mike had the class draw the stages of meiosis in their notebooks. Mike circulated among the students to make sure they were doing it right. Next Mike asked them to draw a cell and to draw one homologous pair of chromosomes going through meiosis. There was a lot of confusion about chromosomes and chromatids. Mike continued to circulate and check drawings. At the end of the period, Mike drew the correct answer on the blackboard so that everyone would have it right in their notebooks.

The 6th hour class began with a scuffle between two students which Mike handled very well. This class was also studying meiosis. Mike used the same comparison of mitosis and meiosis that he used in the 5th hour class. One student asked, what were homologous pairs (of chromosomes).

Mike responded that that was covered yesterday, but had another student read the definition from his notebook. Mike took a class poll to see how many daughter cells were produced in meiosis. Mike also had this class draw the stages of meiosis while he circulated to check their work.

(3) Conceptions

This discussion explores whether Mike's experience during his first year of teaching resulted in any dissatisfaction with his view of science teaching or with his views about

the nature of knowledge, science, learning and the learner. These latter issues are important because it was becoming increasingly clear from our earlier work (Lemberger, Hewson, & Park, 1994) that one's views about knowledge, science, learning, and the learner indicate a predisposition to certain kinds of teaching. Evidence for Mike's views on these topics came from observations of his actions in the classroom, and interviews with Mike about his teaching.

Knowledge. Mike seemed to hold onto his positivist view of knowledge as fact based truths about an external reality to be transmitted from teacher to student. At one point Mike told his Science 9 class that he had the knowledge to teach them. Mike obviously viewed his students as receivers of knowledge. One important role of the student was to write down teacher-approved facts from their lessons in to their notebooks, and recite them when called upon. Mike did a good job covering out the structure and content of the subject under study. Mike asked his students to supply answers to questions he wanted them to know about the topic. This knowledge was kept in the students' notebooks.

Science. We found no evidence that Mike's view of science has changed from his preservice view (Lemberger, Hewson, & Park, 1994). He still seemed to regard science from a positivist perspective. Science was a collection of facts generated from observations of reality, information the students recorded in their notebooks. The scientific method was covered as a separate topic early in the year and then not revisited.

Learning and the Learner. Mike's classes seemed subject centered and teacher directed. The role of the learner in Mike's classes was mainly receiver and recorder of scientific knowledge generated by scientists. Students were often called upon to recite information from their notebooks that had been presented in lecture or recorded from the text. Student misconceptions were viewed by Mike as opportunities for him to give correct explanations. In fact, Mike admitted that he often intentionally called on someone in class who he thought likely to give a wrong answer in order to create that opportunity.

Teaching. If Mike determined from the student's answer that there were some gaps in his knowledge, or some misconceptions, he gave the class the scientifically acceptable information or called on students until he found someone who knew the answer. He referred to this practice during his reservice year as 'dispelling the myths'. Mike expected his students to get the 'correct' answers to his questions either from the readings he assigned or from his lectures or other classroom activities. He commented about his teaching:

> I throw out a question and try to get them to answer the question. When they start to get in the right area, if I don't get the exact right answer, then I lead them to the answer and we do note taking from that.

When asked directly about how he used his students' conceptions in his teaching, Mike admitted that he didn't use them very much ("A little. Not much.") His interpretation of using his students' conceptions in his teaching is contained in the following statement:

> Back at the beginning of the year I asked them what things they wanted to study. Not really looking towards conceptual change, but it was more about what sorts of things they were interested in. During the year I've looked back on that list and made sure we've covered them.

Mike admitted in an interview that his teaching methods relied too much on lecture. He said he tried to balance it out as much as he could with group work and labs:

> I spend approximately 20-25% of class time doing labs.

The group work may have been in response to his vice-principal's desire to see more cooperative learning introduced into the science curriculum and also because he found that his students liked cooperative learning activities. Mike said:

> The vice-principal very much wants to see cooperative grouping and things like that.

Mike made the following comment about his teaching of a photosynthesis unit using a lecture/discussion format:

> So I just basically had to feed them the steps and say this is what I want you to know about the light reaction and take them through the steps. And ask for questions and go a few more steps and ask for questions. They seem to pick up on that pretty well.

Curriculum. According to Mike, the school practiced informal tracking. All the incoming freshmen were required to take Science 9. Starting their sophomore year the students were split. The academic top two thirds of the Science 9 classes were placed in biology, while the lower third of the sophomore class took life science.

The biology curriculum and Mike's teaching were constrained, in Mike's view, by Mr. Johnson's selection of a very difficult biology textbook for the sophomore biology course (book title, Biological Science - The Molecular Approach by the BSCS). This book was written for grade 14, and Mike found its molecular approach far too detailed for his 10^{th} graders. Mike felt locked into this curriculum, because of shared lab preps, and other shared

resources, but mostly because many of the students switched biology sections at the semester break, so all the sections of biology needed to stay pretty much together. In his Science 9 classes, however, Mike was given complete freedom by the science department and Mrs. Lawrence to teach whatever he wanted, and he chose astronomy to begin with and later did earth science.

Mike stated several times during our visits that he wanted to switch to a more 'macro' based biology curriculum. He lamented that there were no dissections scheduled for sophomore biology, and planned to add some during his second year of teaching.

Colleagues and school. Mike seemed to feel that he received a good deal of support from his colleagues in the science department, especially Mr. Johnson and Mrs. Lawrence. The administration, however, was not entirely happy with his teaching. After several positive evaluations, Mike received one poor evaluation from the vice-principal. This was due both to discipline problems Mike was having with his Science 9 class and, the vice-principal's desire to see Mike use more cooperative learning techniques in his classroom. Mike admitted that the poor evaluation had shaken his confidence. He used this evaluation, however, in a positive way by rethinking what he was doing in his classroom. Mike took some time with his classes to discuss what a good student and what a good teacher should be like. From these discussions, Mike set up some guidelines for his classroom that ultimately had a good effect on his practice. His classroom management improved and he felt there was an increase in the mutual respect between him and his students.

(4) Discussion of Mike

Mike's teaching practice during his first year did not change much from what I observed during his preservice year. Like most first year teachers, he had some rocky moments in his classroom, but nothing occurred to make him question his basic conception of science teaching. The only encouragement for changing his classroom practices came from his vice-principal who asked Mike to adopt more cooperative learning activities in his instruction. Without the development of dissatisfaction in a conception it is unlikely that new conception will be allowed to compete for status with the old one (Hewson, 1981). In Mike's case it appears that, even if he did eventually become dissatisfied with his teaching, conceptual change teaching was never made clear enough to him by his methods class instruction to be a plausible alternative.

Mike's dissatisfaction was directed mainly towards his textbook which did not emphasize the level of biology he wanted to teach. He was locked into this curriculum by a variety of factors, but especially by the guidance department which required him to use the same book and keep pace with the science department head, Mr. Johnson, who taught the other sections of sophomore biology. The guidance department wanted this so that students could be switched to other sections at the end of the first semester.

An additional factor which affected Mike stemmed from time constraints (felt by most teachers). This precludes the possibility that he might be reflective in his practice. Although he had been part of the action research seminar during his student teaching (designed to promote reflective practice) he did not use the technique during his first year of practice.

Most of the influences Mike was under during his first year of teaching provided an adequate context for the continuation of Mike's didactic teaching style. The force of change Mike encountered was from the vice-principal, whose negative evaluation in a formal review constituted the most significant factor promoting change in Mike's first year practice. Mike's reaction to this review was to try to use more group activities in his classroom, but deeper change may require dissatisfaction by Mike with his conception of science teaching.

Ⅳ. Conclusion and implication

I conclude this paper by extending what I have learned from these case studies to a broader set of conclusions regarding the professional development of secondary science teacher vis-a-vis conceptual change teaching. As they approached the end of their second year of teaching, both teachers expressed increased levels of confidence in their teaching competence, with respect to both their classroom performance and their place in their place in their departments and schools. According to their administrators, both were developing into 'good science teachers.' There is every reason to regard the two teachers as successful graduates of the secondary science certification program. The specific goal of the program, however, was conceptual change teaching, an approach that neither of them had fully implemented. This raises the questions of why this was so, and what the factors were that influenced their practices. After summarizing key aspects of their practice, I consider the extent of their dissatisfaction with typical teaching approaches and the opportunities that helped to increase and/or reduce for them the status of conceptual change teaching, particularly focusing on the influence on plausibility of their conceptions of knowledge and science (Table 1).

Despite June's reservations about aspects of choice and implementation in the curricula she has been expected to teach, neither she nor Mike have questioned broad curricular goals and sequences.

June has focused strongly on students in her teaching, carrying patterns that were evident in her student teaching into her own classroom. She engaged students and involved them in their lessons, being willing to change her plans in mid lesson if necessary. She often expressed this student centered orientation as concern about motivation, student engagement in the lesson, and student interests and activities. In contrast, Mike was satisfied from the outset with traditional forms of teaching. This was reinforced during his

Table 1. Conceptions of teaching science

	June	Mike
Science	· Science is a matter of fact and matters of opinion, including theories and moral issues. · Science is a discipline that has a lot of factual material, and · a social structure that produces the possibility of opinion and controversy, e. g., evolution, birth control. · Therefore, she doesn't want her students to come to accept her opinions as the truth	· Science is a collection of facts generated from observations of reality. · The scientific method was covered as a separate topic early in the year and then not revisited. · Therefore, scientific knowledge as fact based truths about an external reality must be transmitted from teacher to student.
Learner & Learning	· Her expectation of her students is 100% effort. · Learners must take responsibility in their learning. · Learners must show their confusion and lack of understanding, so that she is prepared to listen to them and to adjust her lesson plan by that.	· Learners are mainly receiver and recorder of scientific knowledge generated by scientists. · Learners' misconceptions are needed for him to give the correct answer.
Teaching	· She focuses strongly on students in her teaching. · She respects them, listens to them. · She varied her teaching in response to their words and actions. · She constantly sought to engage them in the tasks she set for them.	· He gives the class the scientifically acceptable information. · He calls students until he found someone who know the answer. · His teaching methods relies too much on lecture.
Curriculum	· She accepts the district curriculum by basing her teaching largely on the resources and textbook. · On a day-to-day level, she does her own planing.	· The school practices informal tracking.
Colleagues & School	· She is to a very extent content with the degree of support she received from her colleagues and the school. · She acknowledges some constraints from the school curriculum and the need to coordinate with colleagues. · She, however, feels that she had the freedom to make her own professional judgments.	· He feels that he receives a good deal of support from his colleagues. · The administrator was not entirely happy with Mike's teaching. · He received one poor evaluation from the vice-principal.

semester of student teaching by his cooperating teacher who praised the way in which he taught.

While June and Mike were interested in eliciting students' ideas, there was a sense, particularly during their student teaching, that they were not sure what to do with these ideas beyond noting that they were often wrong and in need of correction. It seems reasonable that, for them, elicitation revealed the deficits in students' knowledge, the teacher's task was to remedy these shortcomings, and telling students the right answer was their major strategy for accomplishing the task. Not helping their students to address the status of their own ideas against scientific ideas was a key indicator that June and Mike had not fully implemented conceptual change teaching.

There appeared to be several reasons why June and Mike had not fully implemented conceptual change teaching methods. From my perspective, this required that each of them personally go through a conceptual change with respect to their conceptions of teaching science, from traditional teaching to conceptual change teaching. I shall use the conceptual change model to frame our discussion of the reasons mitigating against full implementation.

An important prerequisite for conceptual change is dissatisfaction with the image of 'traditional teaching.' As indicated above, Mike was content with his teaching (except over matters of control) throughout the period of this study. Under the circumstances, why should he have changed? Similarly, June expressed very little dissatisfaction with her teaching during the study; it seems she came into the program with a strong student focus, influenced in part by her own experiences in high school. The next thing to consider is the relative status of competing conceptions of teaching science in terms of their intelligibility, plausibility, and fruitfulness.

Making a new conception (such as conceptual change teaching) intelligible is a crucial starting point if the conception is to gain high status within the conceptual ecology of a learner. In the teacher training program, the only opportunity for discerning the intelligibility of conceptual change teaching came in their science methods class (For a detailed analysis of this course, see Marion, *et al*, 1994). Conceptual change was modeled by their science methods class instructor throughout the semester, and discussed at the beginning of the methods class. However, based on the teachers' statements about conceptual change, and their actions in the classroom, this did not appear to have been an adequate opportunity to gain a firm understanding of conceptual change teaching. In addition, teaching differently from their mentors and peers without a doubt represented a risk for student or first year teachers. It might have been unrealistic to expect them to take such risks with only an emerging understanding of conceptual change teaching.

Second, the teachers, June and Mike, needed the opportunity to test the plausibility of conceptual change teaching. This meant exploring how conceptual change teaching fit in with their beliefs about knowledge, science and even learning. Conceptual change is an

attempt to explain learning using constructivist epistemology. Conceptual change teaching requires these same assumptions on the part of the teacher. The teachers seemed to be hold conceptions of science and knowledge that weren't commensurate with constructivist epistemology. A key factor in understanding their dilemma about what to do with students' ideas seems, to me, to be their views of knowledge and of science. They tended to regard knowledge as a manifestation of an external reality, and science as a body of factual knowledge that is tested, true, and obtained by a scientific method that uncovers this reality. From this perspective, the task of a teacher was to present (or otherwise make available), explain, and help students understand this body of proven knowledge. When students strayed from the path, the teacher needed to point out their errors and help them return. Exploring the terrain off the path would be an unnecessary and time wasting diversion.

To summarize, holding positivist views of knowledge and of science is likely to be a major obstacle for anyone coming to understand constructivism and its implications in teaching for conceptual change. This argument resonates in several key ways with these teachers' cases, even though I recognize differences between scenario and teachers, and between teachers themselves. Both June and Mike held strongly positive learning in their views of knowledge and science.

In contrast to this, a constructivist view of learning stresses the critical role that prior knowledge plays in learning and understanding new ideas. There was little evidence that both of the teachers thought of learning from a constructivist perspective. While on occasion they elicited students' ideas, they didn't go further; i. e., they didn't encourage students to explore metacognitively the status of their ideas or the basis on which they justified them. There were no indications that the teachers saw the importance of further exploration of students' ideas to identify what might be useful for future learning. This strongly suggests that, for these teachers, a constructivist view of learning had low priority; thus they had little incentive in exploring its implications for instruction. In other words, these teachers did not teach for conceptual change because in part their views of knowledge constituted a barrier to their grasping the significance of constructivist views of learning. A forum, such as action research, for understanding how conceptions of knowledge, science, and learning fit together with conceptions about teaching might be necessary before conceptual change teaching appears plausible to a new teacher.

June and Mike also needed to be able to test the fruitfulness of conceptual change teaching. There are few classroom where secondary student teachers can work with cooperating teachers versed in conceptual change teaching theory or even a constructivist theory. Because of this, student teachers are socialized into more traditional kinds of teaching practice. Without more scaffolding, it appears difficult for fragile conceptions of conceptual change teaching to find the reenforcement needed to gain in status in the

conceptual ecology of the developing teacher.

Finally, the intellectual and practical aspects of the teacher's environment appeared to be important. None of these study participants had the time, nor were they encouraged to try conceptual change teaching by their colleagues during the first year of teaching. In stead, they found that they were often expected to teach in a traditional manner in order to keep up with the other teachers who were teaching the same course. Covering the same materials as their colleagues teaching the same course was a consistent theme among our teachers. This was partly a self imposed constraint, and partly at a very real, external constraint imposed upon the three teachers by structures in place in the schools.

The points discussed above represent a challenge to the science education community. If we are to create an environment in which beginning teachers are able to develop appropriate conceptions of science teaching, we must find creative solutions to the problems described in this study. Such solutions need to be developed for the different phases through which a teacher passes. Initially, prospective teachers' high school and college experiences are significant influences on their development of key conceptions about teaching, knowledge, science, and learning that are largely unexamined and unquestioned. As this study shows, these conceptions can have a significant impact on a teacher's practice. A second phase is the professional education of a developing teacher; this has been the focus of this study. The failure to achieve fully our desired goals of producing conceptual change teachers who are reflective of their practice points to the need to reconsider our programs. Finally, the school environments in which teachers work have a strong socializing influence on new teachers. Thus the need to find ways of encouraging change amongst practicing teachers and the schools within which they work is also great.

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