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USING SOCIOCULTURAL THEORY TO UNDERSTAND THE
RELATIONSHIP BETWEEN TEACHER CHANGE AND A
SCIENCE-BASED PROFESSIONAL EDUCATION PROGRAM

ABSTRACT. This paper focuses on a model of teacher change based on a study of a science discipline-based professional education program and on an understanding of teacher change in terms of an agency|structure dialectic. Professional education programs should expand teachers' capacity to act in a range of fields. Conducted over one year, this study used socio-cultural theory to examine the role of cultural schema and resources in the enactment of new pedagogical structures by two teachers who demonstrated widely variable responses to their experience of a professional chemistry education program. Hermeneutic and phenomenological methods of study supported the examination of teacher actions and narratives as sources of data. The analyses of these data sources resulted in greater understanding of the relationship between schema, resources and structure and the relationship between structure and teacher agency. Structures are dynamic and if a teacher uses a resource such as an inquiry-based instruction protocol without the attendant cultural schema such as the value of questioning then the structure that is implemented will be different from that the teacher experienced in the professional education program. This understanding supported an explanation of teacher change in terms of teacher agency that constituted our learning from the study and resulted in changes to aspects of the professional education program.

KEY WORDS: agency, structure, cultural capital, social capital, teacher change

INTRODUCTION

(Hugh is standing in the general chemistry lab with the rest of the chemistry education teachers working on a lab to make synthetic dyes. He has just placed some water in a beaker on the hot plate to heat and turns to face the videographer.)

Hugh: Ken, if I told you that none of my chemistry classes get a lab what would you say?

Ken: What would you say?

Hugh: I would say it stinks. And I would go on the record with saying that too. Is this on tape?

Ken: Yes.

Hugh: I told my administrator, this is not good. Not only is it boring it's wrong.

Cath: What's this? (Cath, the instructor, has been moving around the laboratory space, observing teachers setting up their laboratory activity and being available if they have any questions. She stops at Hugh's laboratory station)

Hugh: No lab. With the chemistry classes I have, no lab.

Cath: Why don't they have a lab? (Raised inflection as she asks the question)

Hugh: They're general kids, so they don't need a lab. They're algebra challenged so they are in general chemistry.

Cath: Ah.

Hugh: That's all I teach all day, general chemistry and general life science kids without a lab.

Cath: So you say they don't have a lab. Do they have someone who can help you set up in your classroom or can you do something in your classroom?

Hugh: I have electricity, but that's about it. I could do more [lab] than I do but having three different preps. I'm not used to that. But it is wrong that I don't have lab. (Hugh is stirring the mixture in the beaker on top of the hotplate)

Cath: I find that amazing that somehow if you are not considered the cream of the crop [making reference to the way students are identified in Hugh's school].

Hugh: Right! They take away, [pause] the things that would interest kids.

The people in this interaction are teachers, instructors, or researchers participating in a professional education program for high school science teachers. With eight courses in chemistry and two in chemistry education, the program emphasizes learning chemistry content and there is an assumption that the program will enable teachers to change their practice. However, this vignette highlights how issues that are part of a teacher's lived experience, such as the access to a laboratory, influence how teachers enact their *agency* as science teachers and the implications this has for *teacher change*. One senses Hugh's frustration at the lack of availability of laboratory space for "low achieving" chemistry students. Although Catherine, the instructor, is concerned for Hugh's situation, she does not provide Hugh with resources to consider ways that he could overcome this limitation and his frustration with the students. It is a cultural schema or norm of this chemistry education program that laboratory activities are important to the overall learning of chemistry and of science. The field of the vignette in which the teachers were working on a laboratory activity developed for high school chemistry, encouraged Hugh's reflection on his teaching situation and the lack of available laboratory experiences for his students. Hugh's school administration had a policy of limiting expensive resources

such as laboratory space to “higher achieving students” thereby denying laboratory access to students labeled as low achieving. The vignette highlights the intersection between the goals of a discipline-based professional education, how the participants construct themselves as science teachers, and the contexts in which they work. This intersection became a major focus for this study as we examined how teachers responded to their teaching contexts when enacting the knowledge gained from graduate studies in chemistry and education.

SOCIOCULTURAL STRUCTURE FOR TEACHER CHANGE

One purpose of science teacher education is to assist science teachers to improve their teaching through their lived practice. When the teachers involved are relatively experienced, this is associated with *teacher change*. Professional science teacher education provides a *field* in which professional science educators and science teachers come together to construct professional education. A field is a site at which resources and cultural schema exist dialectically with cultural and social structures: a site at which culture is enacted (Bourdieu, 1993; Sewell, 1999). Professional educators bring resources and cultural schema that they apply to the development of course outlines and their attendant practices. In the case of the professional education program in this study, one of the cultural schemas was that effective chemistry teachers needed to know and understand chemistry content. Teachers bring another set of resources and cultural schema to the learning environment of professional education that may differ from those of the professional educators. If different groups bring to the field different resources and cultural schema, and there exists a power differential between these groups, then the field can become a site of negotiation and contestation as teachers and professional educators negotiate what counts as symbolic and cultural capital in science education.

Cultural capital is knowledge, internalized codes (schema), or cognitive components (resources) equipping social agents to decipher cultural artifacts and relations accumulated through a long process of learning at home, at school, and in society (Bourdieu, 1977). This definition assists our understanding of how professional education might influence teacher action when we consider the iterative relationship between schemas and resources. Symbolic capital refers to the degree of honor that one might accumulate based on the dialectic between knowledge and recognition. To garner symbolic capital teachers need to convince their peers and instructors that they have the knowledge to support their practice. It is through the process of negotiation that teachers, both consciously and unconsciously,

decide on the cultural schema and resources they will appropriate from their professional education experiences to use in other fields, such as science classrooms and schools. Bourdieu reminds us that this negotiation is influenced by the possibilities for generating cultural, symbolic, and social capital. Such an analysis confirms the complexity of this field also illustrated in arguments about the nature of “a highly effective teacher” and how professional education might contribute to the development of these types of teachers (Darling-Hammond, 2002). In discipline-based professional education programs such as the one that is the focus of this study, this negotiation can be more problematic because so much cultural and symbolic capital is associated with knowing chemistry. One might assume that having access to a resource such as more chemistry knowledge would be an advantage for teachers as they enact their practice in schools but since a knowledge of schemas implies an ability to act creatively how teachers react to different schemas might also provide us with insight into the effect of professional education on their agency.

Agency and *structure* exist in a dialectical relationship that can constrain and promote possibilities for a teacher’s action to interact with available schema and resources (Sewell, 1992). Agency is an umbrella term for an individual’s capacity to act. Professional education should provide opportunities for teachers to develop complex social relationships, to utilize their capital by converting cultural capital to social and symbolic capital, and to explore new resources via authentic tasks/practices (Wenger, 1998). As teachers are involved in these activities individually and socially and come to understand their relationship to these activities they will be involved in tinkering with how they construct themselves as science teachers. As professors in a professional education program, we have questioned how the program expanded or limited each teacher’s agency and what evidence was required to answer this question. If the program affords teachers the opportunity to explore new resources and schema that are not part of teachers’ dispositions or habitus, then these experiences can expand teachers’ options for action, thus transforming teachers’ agency and encouraging teacher change.

CULTURAL SCHEMAS AND RESOURCES IN CHEMISTRY EDUCATION

Cultural schemas emerge from social actions involving transposable procedures or dispositions. Teachers’ dispositions (or habitus) develop with experience in a social field, and therefore require consistent use over time in order to become deeply ingrained habits of behavior, feelings and thoughts (Bourdieu, 1977). Although dispositions are embodied in practice, they

are often unconscious and therefore not amenable to self-description or self-fashioning. However, constant subjection to experience can modify or reinforce dispositions (Bourdieu & Wacquant, 1992). Therefore, a teacher's teaching habitus can change over time. This generative nature of habitus provided a rationale for instructors to emphasize the constant use of specific schema and access to specific resources within the professional science education program so that through continuous exposure teachers might begin, consciously and unconsciously, to use those schemas and resources in their teaching.

Our definition of schemas as internalized codes also suggests the ability of teachers to creatively apply a "rule" to different contexts. For professional educators, one indication of the program's effectiveness would be the capacity of teachers to apply resources and schemas acquired through their participation in the program to the context of their schools and classrooms. As instructors in the program, we wanted to encourage teachers to develop specific dispositions to being adventurous with their use of specific pedagogical resources in their teaching, and to critically evaluate emerging classroom structures in terms of student learning. We recognized that our use of specific resources in the classes we taught, carried with it specific schema or rules about the use of these resources, which together created a specific structure for teacher education, but that this interaction was not static. We wondered how these experiences might structure the teaching practice of the teachers involved. We also recognized that the relationship between the structures we created as we interacted with teachers in a college learning environment and the resources and schemas that were available to teachers in schools was a complex one leading to emergent outcomes in teacher actions and narratives that might not be those for which we had initially anticipated or hoped. Both schema and resource use can be identified through observation of teacher actions and narratives but schemas can be less amenable than resources to conscious cognition.

An actor's capacity to extend schemas has implications for resource accumulation or loss (Sewell, 1992). If a teacher decides to use a practice with her/his students the consequences for her/his social and cultural capital with students and colleagues cannot be predicted. The implications of this for teachers' ongoing use of specific schema can be very variable. For example if a teacher "tries out" a strategy such as small group work with her students and it does not seem to engender the learning environment for which the teacher was hoping, she might decide, consciously or unconsciously, to remove small group work as a strategy of action from her cultural toolkit (Swidler, 1986). Part of a teacher's identity is associated with "strategies of action", that is, habitual ways of ordering action through time. Culture is a diverse collection of "tools" that "are understood

as a means for the performance of action” (Swidler, 2001, p. 46). Tools are discrete, local and intended for specific purposes. They can be used as explanatory variables in a way that more global notion of culture cannot but consistent with our knowledge of the relationship between understanding and explanation they exist as resources for understanding and consist of both resources and schemas.

All the teachers enrolled in the professional education program were science teachers. Consequently, their professional characteristics were based on structures with which they interacted in their schools in specific educational contexts. Such structures would have included the construction of a science discipline they taught in terms of resources and schema including text resources such as textbooks, material resources such as chemicals and glassware, human resources such as teachers, students, administrators, and laboratory technicians and spatial resources such as classrooms, laboratories and offices. A teacher is constituted by an amalgam of her agency and structures that constrain and promote possibilities for her action. Teachers’ choices about classroom organization, pedagogical styles, and learning activities provide evidence of schemas that constitute an important aspect of their ways of being. Professional education should offer teachers opportunities to change by expanding their options for action thereby changing their ability to participate in the world of being a science teacher or a chemistry teacher. What counts as being a chemistry teacher? If professional educators begin with teachers who possess competence what new dimensions can we add for the negotiation of self so that teachers experience education that is transformative and supports them as they change structures through their use of resources and attendant schema? To understand science teachers there is a need to examine how they engage in the teaching of science and how this is related to who they are and who they want to be. A goal of professional education is to expand each teacher’s options for action by assisting her/him to acquire resources she/he can use to construct or join a new community. In order to be able to do this, professional educators need to address questions such as what aspirations do teachers have and how do they reveal themselves in their narratives and practices? All of us give form to lived experience by producing resources such as stories of experience that “congeal” experience into “thingness” (Wenger, 1998). Thus, teacher narratives are a rich source of information about teacher agency.

TEACHING AND RESEARCH AS PRAXIS

If teaching is theorized as praxis then teacher education should focus on the specific contexts in which teaching occurs and on the conscious and

unconscious aspects of action. Praxis is willed action by which a theory or a philosophy becomes a social actuality and by which critical evaluation of primary experience leads to the development of local theory. If teaching is an example of praxis, then to categorize teaching in terms of content knowledge, pedagogical content knowledge, pedagogical knowledge and teaching practice is artificial and reductionistic. Teaching as praxis means that teacher action is purposeful and directed, and leads us to recognize the tensions that teachers feel when they critically reflect on their actions.

Praxis was a useful resource for us to understand teacher change because it led us to examine the relationship between structural change and teachers' variable use of resources and schema. Analysis of teacher narratives and actions provided us resources to understand teacher action and to explain our observations. We recognized the role of deep critical reflection for assisting teachers to identify structures and the resources and schema they use (Ricœur, 1991) while acknowledging that aspects of teacher action remain unconscious. Thus, we used both observation of teacher action and teacher narrative as primary data sources to identify how individual teachers used resources and schema to enact their agency. However, although hermeneutic phenomenology encouraged us to value these components teachers' lived experience, we recognize the importance of reflecting critically using sociocultural theory and our experience of the field (Ricœur, 1981; Roth & Tobin, 2002). Teachers' narratives provided us referents of teachers' lives that we examined with an expectation of finding evidence for the effect of the professional education program on their lived experience as teachers. In our analysis we sought to observe and understand teacher actions in various fields and then explain what we observed. Sociocultural theory and our experience provided resources and schemas that we used to make sense of teacher action. We also acknowledge the partial nature of our explanations but their power lies in assisting the development of understanding of the relationship between teacher agency and cultural structures in order to make claims about teacher change. These claims also served as a basis for us to enact our agency and change the structure of the chemistry education courses within this discipline-based professional education program.

THE CONTEXT FOR THE STUDY

Program description

Teachers enrolled in a Master of Science in Chemistry Education (MSCE) degree program developed by chemistry faculty at an urban research

university participated in this study. The MSCE program was established to:

1. Increase the possibility of U.S. high school students majoring in chemistry by improving the chemistry knowledge of their teachers.
2. Improve the praxis of chemistry teachers, especially those teachers located in urban schools, who did not have a degree in chemistry.

The program's entry requirements included successful completion of two semesters of undergraduate chemistry, a portfolio, which included a video of teacher's teaching, and an essay on why they wanted to enroll in the program. To assist in the final selection of each cohort of twenty, program faculty and administrative staff interviewed qualified applicants.¹ In this study, we use socio-cultural theory to interpret the practices of two chemistry teachers who demonstrated variable responses to their experience as a teacher and a learner within the MSCE program.

MSCE's ten courses, eight in chemistry and two in chemistry education, were taught over three consecutive summer sessions and the two intervening academic years. Teachers completed two chemistry courses during an intensive eight-week summer program. Throughout the academic year, while maintaining their full-time teaching responsibilities, teachers attended classes twice a month on Saturday mornings to complete two courses – one in chemistry (in the first year the chemistry course is organic chemistry and in the second year, molecular spectroscopy) and one in chemistry education. Tenured faculty members taught the chemistry courses, while science educators taught the chemistry education courses. Faculty developed courses specifically for the program and using internal evaluation revised courses in response to the teachers' emerging needs. The resources available for the development of the program included the expertise of the professors involved and the physical resources of the institution at which the program was offered. Combined with schemas such as specific ideas about how chemistry should be learned, professors developed course outlines that provided a structure for each course. Teacher actions in the fields in which these courses were taught and of their schools and classrooms provided a context for our investigation professional education and teacher change.

THE STRUCTURE OF RESEARCH

In this study, we constructed a model of teacher change based on the relationship between professional science education and teacher agency. All of us were university researchers. Catherine was the course developer for the program and Tracey was a graduate of the program. We understood

that observations of teacher actions would provide us with information on the intersection between teacher change and professional education. We began by establishing ourselves as observers in all courses experienced by the teachers over a period of two years. Our initial observations of teacher action in the fields of the university classroom and the school science classroom led to a specific change in the curriculum of the introductory chemistry education course in the second year of the program's operation that had implications for the second cohort of teachers. It required teachers to provide evidence from their teaching practice of their use of specific resources from the MSCE program. This requirement brought into sharp relief the differential responses of teachers that led us to focus on two specific teachers from the second cohort. We examined more critically the actions, artifacts and narratives that these teachers presented over their first year in the program. Throughout the academic year we met once a month after class to discuss our observations and analyze data. The study enabled us to understand the teachers' differential responses to professional education and to evaluate our role in the development of professional education that would support teachers as they interacted with the resources and cultural schema.

Research participants

After conducting site visits to teachers from the first cohort working in their school context, Catherine reported little evidence that the MSCE program had impacted teachers' classroom practice. When asked about this observation, teachers cited a lack of time to enact the pedagogical strategies while enrolled in the program. In the following year, after much discussion we changed the assessment tasks requiring teachers to implement and to evaluate a specific tool or resource that they had used in the program. These resources included using an inquiry-based method of instruction, using historical approaches to teach chemistry concepts, applying macroscopic, microscopic and symbolic levels of representation to teach an aspect of science, and introducing collaborative learning strategies.

Consistent with Guba and Lincoln's (1989) serial and contingent criteria and using our personal knowledge of the participants, we selected two teachers, Beth and Hugh, whose responses across the different fields in which they enacted their identities as teachers were very different. Beth left industry to work as a science teacher and had taught for three years at a dropout prevention program based at an alternative urban high school (grades 10–12) with a student population of about 300 students. Her science background was biology, but she also taught chemistry. Beth entered the MSCE program because she wanted to become a better chemistry

teacher. Hugh, a chemistry major, had recently commenced teaching several different science courses involving multiple “preps” at a private suburban middle/high school of about 900 students. Previously, he had taught for more than ten years at a large, ethnically diverse, successful, urban neighborhood high school, which he left because according to him the school’s focus was moving away from high academic standards. His students at the new school were predominantly White, from middle class backgrounds. The school practiced “tracking” and Hugh knew he would be teaching chemistry and biology to “low level” students. Hugh joined the MSCE program to “freshen” his chemistry knowledge and to be a better teacher.

Data sources

We used teacher narrative and teacher action as resources to understand teacher agency and change. Because of our role as participants, our understanding and explanations provide a narrative that connects us with Beth and Hugh. We recognize the usefulness of teacher narratives for our study, while acknowledging their partial nature. Our analysis was grounded in hermeneutic phenomenology (Ricoeur, 1981). Consequently, we collected vignettes of teacher interactions and narrative that constituted a record of teachers’ lived experience as professional learners and as science teachers in their first year of the program. Data consisted of videotape of teacher action in their high school science classrooms and in the university classrooms, artifacts produced by teachers, field notes of classes at university, and research meetings. Teacher narratives of their use of specific tools and innovations were also videotaped and provided another source of data.

We analyzed video vignettes constructed from these data sources based on our understanding what constitutes “good” science teaching examining the iterative relationship between specific resources and schemas and structures demonstrated in teacher practice and narrative. Explanations were constructed from critical reflection on these experiences as captured on videotape and as articulated by us. This critical reflection helped to make the unconscious conscious and informed our development of local theory such as the relationship between the resources and cultural schema of professional education, agency, and teacher change. As a major research tool, this process of understanding, critical reflection, explanation, and further understanding provided a basis for possible action for the researchers to change the structure of courses within the MSCE program.

In the following sections we present our analysis of the narratives and actions of Beth and Hugh as we sought to understand their variable responses

to the MSCE program and explain this variability in terms of agency, structure, resources and schema.

UNDERSTANDING TEACHERS' ABILITIES TO ACT

In order to develop an understanding of Beth and Hugh's teaching agency and of the fields in which they are recognized as teachers, we began an examination of their ability to act in specific fields beginning with their science classrooms and the schools at which they teach. Their narratives provide insight into the intersection between their agency and available resources and schemas and how they constructed themselves as science teachers. Initially, we were impressed by Beth's willingness to experiment with the "tools" she had used in the MSCE courses with the classes she taught at her school and somewhat dismayed by Hugh's apparent inability to do the same. This was important to us because we thought of culture as a diverse collection of tools available for performance of action (Sewell, 1999) and Beth's practice indicated her transposition of cultural tools from one field to another, which concurrently expanded her options for action. We did not observe this with Hugh indicating either a lower level of transposition and change or none at all. However, as we conducted a more nuanced analysis of Hugh's actions we realized that we needed to examine more closely Hugh's social actions in order to distinguish the schemas associated with the resources. We understood that these schemas could be identified from the interaction between his actions and cultural structures as he used specific resources in the high school classroom. In order to conduct this analysis we wanted to begin by understanding how Beth and Hugh represented the fields in which they worked. Beth describes the school at which she teaches:

It's a small school. We have about 300 students there. We cater to students who have dropped out. It's a dropout prevention program. Students are in Grades 10, 11 and 12. They have terrible attendance and socio-economic problems. The reason for these problems is not that they're just lazy. They have real issues going on. They have to be home to baby sit or something because Mum has to go somewhere. I just wanted to show you this as part of whom I teach.

(Beth, Innovation Presentation, Spring 2002)

This narrative vignette illustrates Beth's awareness of, and empathy towards, her students and the challenges they face and her awareness of what might be her peers' perceptions of her students' ability and commitment. In her racially diverse classes in which the majority of the students were African-American, she saw her responsibility as providing learning

experiences that enabled her students to be successful learners when they had not been well served by traditional public education.

Hugh describes the students and the school at which he currently teaches:

I went from a very large city school to a very small middle/high school, 7 through 12. It has about 900 kids so it is a totally different environment to the massive creation that North City high school has become. I had three different preparations, which wasn't to my liking because I had a lot of different things to do. The homework, quizzes, everything had to be new. I had nothing to draw upon so I was extremely busy. Then this course [MSCE chemistry education]. Life was full. All five of my classes were general students. No college prep. No honors. Many of them aren't going to school after high school, except to a tech school. Many that are going have low math proficiency. It's [math] not my forte either so it's a challenging group as far as teaching chemistry. So what they do is they reward these students by not giving them a lab. I think it's horrible but no lab [echoes of consternation from the room]. So it's dry classroom work.

(Hugh, Innovation Presentation, Spring 2002)

In contrast to Beth's perceptions of her students as being capable science learners despite their challenging life situations and history of school failure, Hugh saw his students through a deficit lens. He chose to focus on their "low math proficiency" and the expectation that they would not be going to college after high school in order to justify his teaching methods. His comment that his students were 'general' reflects the common practice in suburban schools of "tracking", that is placing students in different classes of the same science discipline: honors, college preparation, general, based on each student's perceived ability or lack thereof. The cultural schema of the school is that students should be hierarchically organized into classes on the basis of their ability and those of "highest" ability should be rewarded by having access to limited resources such as laboratory space. Hugh's perceptions of his students seem to be influenced by his school's designation of this group of students as unworthy of access to a resource such as a laboratory facility. This was an area of frustration for Hugh. A claim reinforced by Hugh's comments during a laboratory activity in the first chemistry education course:

Hugh: They're general kids, so they don't need a lab. They're algebra challenged so they are in general chemistry.

Cath: Ah.

Hugh: That's all I teach all day, general chemistry and general life science kids without a lab. . . . I could do more [lab] than I do but having three different preps. I'm not used to that. But it is wrong that I don't have lab.

Cath: I find that amazing that somehow if you are not considered the cream

of the crop [making reference to the tracking of students at Hugh's school]

Hugh: Right! They take away, [pause] the things that would interest kids.

Hugh's first comment "They're general kids, so they don't need a lab," is his representation of the schools' schema with respect to "low ability" students. The issue of laboratory access is a major one for Hugh. However, as we analyzed the interaction between Catherine and Hugh we noted that access to laboratory space was a resource which each of them associated with a very different cultural schema. Catherine comments on the unethical nature of providing a resource to one specific group of students and not to another. Hugh's response reflects his schema that learners, especially low ability ones, should have access to a laboratory to improve their interest in science. The implication being that better ability students would make sense of the content regardless of how it was taught. Thus, although the instructor and the teacher value access to laboratories for students their interaction implies different schema suggesting that the instructor and the teacher would structure laboratory activities with students very differently. His response to the lack of this spatial resource is to throw up his hands and say, "So it's dry classroom work," signifying his belief that there existed no pedagogical alternatives between laboratory activities and seatwork that was framed by a didactic pedagogy. We wanted to understand the relationship between each teacher's agency and the resources and schema associated with professional education and the use of these resources and schemas in a different field, that of their schools and classrooms.

Agency, resources and schema

While Hugh often voiced his frustration at not having access to a laboratory and presented it as a barrier to laboratory activities with his chemistry students, Beth and her students worked together to conduct modified laboratory activities in the classroom.

Beth: [Beth is talking about a heat of combustion laboratory activity from ChemSource (Orna, Schreck, & Heikkinen, 1998) that the chemistry education course had carried out in the general chemistry laboratory at the college] I did the lab with my students to see [She points to photographs of her students working on the same laboratory activity.] –because we did it here and it worked fine when we did it [laughter from the teachers listening to Beth's narrative] but I wanted to see if it would work with my students. One of my colleagues at work suggested I try using these little votive candles instead of the regular lab candles [When the teachers carried out this laboratory activity they used kitchen or plumbers' candles]. It was very good. Much safer. They (the candles) didn't fall over. And then instead of using the soda cans [The bottom and top of a soda can were removed to make a

tube and placed around the candle to try to reduce the air movement around it.] we used little like little Chinese take-out food containers that are metal, aluminum, with a plastic lid on it. You can see [Pointing to the photographs of her students working on the laboratory activity in their classroom] that we don't have a proper lab where I work so they're doing this (the laboratory activity) right on desks. So it could be a bit of a worry that they're doing it right on desks but with these little containers it made it a lot safer.

In this narrative Beth provides evidence of her agency and her desire to use resources introduced in the MSCE program. Her narrative also indicates cultural schema of her school experience including collaboration with colleagues and the importance of tinkering with resources to use appropriately in a different local field. The resulting structure is similar and different to the pedagogical structure established when Catherine conducted this laboratory activity in the professional education program. Beth accepted the value of laboratory activities for her students and used the resources available to her, such as collaborators, classroom space, and the students she taught, to modify the activity so she could enact a slightly revised but contextually appropriate activity. Hugh's actions indicate that he did not feel the same level of agency as did Beth. Instead he seemed overwhelmed by the effort that would be required to enact laboratory activities in a classroom space.

The variable experiences of Beth and Hugh with respect to laboratory activities also communicated to us the cultural schema of each school regarding students identified as low performing. Neither Beth nor Hugh had access to a laboratory. Hugh's students were denied access because their academic standing, while Beth's students had no laboratories because the school existed in a space that had previously been an office building. Beth and her students constructed a laboratory space in the classroom. What emerges is a *multiplicity of structures* that serve to support a variety of practices and versatility among teachers (Sewell, 1992). Outside structures associated with their role as teachers overlapped with the structures of professional education. This implies that teachers bring to their experience of professional education specific resources and schemas that affect their agency or ability to apply schema from the professional education program to a new field such as their school science classrooms. This examination of Beth and Hugh indicates that some of the structures in which they practiced had implications for their variable responses to a professional education program such as the MSCE.

Beth's agency was evident as she described her goals for the professional education program:

The goals of my project that I came up with last year were: to incorporate technology; to teach more chemistry content; personally, to get a better handle on

the chemistry that I am teaching; to use the inquiry approach; to raise academic standards; and to initiate a peer mentoring program.

Beth's ability to identify personal goals helped her to frame her ability to act and provided a focus for her agency as she used specific resources from the MSCE in the fields of school and classroom. In contrast, Hugh used the resource of the inquiry-based model of instruction, but without personal goals his actions lacked purpose. He acknowledged a lack of personal goals:

Hugh: Not knowing what to expect when I got to (the new school at which he started teaching in the 2001/2002 academic year). I really wasn't able to, you know, predict how much I would be able to do. So this [Hugh points to a diagram of the inquiry-based instructional model used in the MSCE program] became the mantra of the year.

At least two courses in the MSCE program, one in chemistry and the other chemistry education, required all teachers to implement and evaluate one of the resources they were using in the program with their own high school science classes. Hugh chose to use the inquiry-based pedagogy with his chemistry class. Beth describes the interaction between one of her goals and her agency as a teacher:

Ok, the other thing was for me to become a better chemistry teacher [Puts her arms out wide]. So I found I learnt a lot from the course I took with Cath on teaching and learning chemistry. How do you make decisions about what to teach and the readings really helped me with that and also coming up with assessments. Also part of my proposal from last year was to use this book, Amsco - Chemistry a contemporary approach. It's a little paperback. I used that this year instead of ChemCom. I do have a set of ChemCom so I go back them to them every now and then for some activities. I found using this book (Amsco) helped me to learn more chemistry. It helped me to come up with a better sequence of how to teach chemistry. This is the book I'm going to use next year. It has a lot of labs in it and looks like a lot of fun.

Beth's narrative and our observations of her classroom practice indicate an expanded capacity when compared with Hugh to use her agency to establish new structures. Her narrative indicates the changes she implemented as she acted purposefully on the goals that she had set for herself as she participated in the program. Beth also provided data of her students' learning as a result of these changes in the chemistry course.

As you can see in 2000 about 30 percent of my students passed here and 40 percent passed here (different marking periods). I'm pretty mean aren't I? But I improved or they improved. Here we have better grades for this year [Beth presents a slide of the grades of the students she is teaching chemistry in 2002 showing over 70 percent of the students successfully completed the course]. Now I didn't plan this. Seriously! I looked at these graphs in June and I noticed it so I must have been

doing something better. I think it could be a better-paced course. I had a better handle on what I was teaching.

Beth chose the textbook, developed material resources, made use of human resources such as the librarian, technology teacher, and students, to develop curriculum and lessons. Since the school building was originally an office building in an urban area, she used the classroom as a laboratory space. Beth believed that the readings and discussions in the chemistry education course helped her decide the sequence and scope of her curriculum. She introduced research projects based on students' questions and encouraged her students to use more technology in composing and writing text. Her comments indicated that she found the MSCE program expanded her agency as a teacher by involving her in authentic pedagogical tasks and by expanding collaborations with her school colleagues that led to the development of a nascent community of practice. Hugh, as the new science teacher, was assigned all "low achieving" classes based on departmental policy (schema). As his earlier comments indicated, he also had three different course preparations for which he was unprepared since his prior experience had been teaching only chemistry. While the MSCE program seemed to provide Beth with further justification to enact the practices she valued in her high school teaching, it made greater demands on Hugh's agency and his narratives and actions indicate the conflict he experienced.

Teacher change and transposing schema

Through our examination of Hugh's practices and narratives, we began to understand the importance of schemas to the sociocultural learning structures teachers and schools enact. This was particularly evident when Hugh decided to apply the inquiry-based instructional approach that he had experienced in the chemistry and chemistry education courses to his chemistry class.

So this [Hugh points to a diagram of the inquiry-based instructional model used in the MSCE program] became the mantra of the year. They start with a question, work in a group, and what they have to do is to come up with a little agreement here so I've got a little applause [as the sound of clapping comes from his Power Point presentation]. It does work. I think we've heard from several people that that one of the major thrusts this year (in the MSCE program) was the . . . (inquiry-based) Instructional Model and it works.

This vignette included Hugh's description of the inquiry-based pedagogical model that was an important resource for the MSCE program. Compare his description with the following description of the structure of the model

developed for, and enacted in, the MSCE courses. Originally developed by chemistry faculty, the inquiry-based model reflected the structure of scientific research. It began with a question to which teachers applied deductive reasoning to develop a possible answer to the question. Working in small groups the teachers were directed to reflect on the relationship between the group's collective information, from individual knowledge or textbooks, and the posed questions. By organizing the information, each group decided if it needed more information and how to obtain it through research, experts and/or experiments. The relationship between existing information, reflecting and organizing the information relative to the question, and deciding on the need for more information, was iterative. Once a group had developed an appropriate response, they presented it publicly for peer review. The responses became part of the class's community knowledge. Hugh constructed the model in terms of students working in small groups to solve a problem but in the MSCE program the schema of the model included the value of prior knowledge and research for answering solvable questions and the importance of peer review for the development of agreed knowledge within a class or learning group. These values were not evident in Hugh's application of this inquiry-based pedagogy with the students he taught.

Hugh reported that he used this inquiry-based pedagogical model and it worked:

Kids actually cooperating. Doing some constructive work. These are the heartening moments [photograph of students working on a question or problem]. Of course there's going to be some disheartening moments. It's rather hard to see but this is a young man [Hugh refers to a photograph he has of a student]. This is a head in that hand. That kinda summed up that day. Some of the kids really needed to be pushed. They'd come in with an attitude of maybe I've already failed chemistry. If I haven't failed chemistry I snuck by biology with a D. I'm here for the third credit. What are you going to do? What can I expect and where is the least resistance? That was unfortunately what I saw all too often. So I thought of myself as a coach often times. They may be given questions individually they've got an answer. They're done! The first thing that pops into their head. They've got an answer. What more could you want Mr.? Well I wanted more. Why did I want more? Because if you keep working you come up with a little bit more involved. Something that's closer to the [?] of what we just saw and what we expect to happen. So that was my job to take that idea and drive them a little bit and maybe they'd have a better idea. From using the (. . .) Model in a co-operative type classroom I did come up with a few things I hadn't done much of before I have to admit. Fourteen years in [a large urban center] it just became a very traditional class. Boom. Boom. Boom. Here's the problems [Hugh gestures as though he is handing out papers]. Hand them in. We're going to do it that way. Traditional classroom that we all have in the back of our heads somewhere. I just kinda fell into that rut. This course has kinda kicked me in the butt. Now it's my turn to do it to them.

Hugh's account of his use of the inquiry-based pedagogy that was so important to the teaching of courses in the MSCE indicates some of the challenges he faced teaching students identified as "low ability." He describes unmotivated students, who viewed chemistry as difficult and as a hoop to jump through for graduation. However, when he used the model and probed student responses to the questions, he encouraged them to recognize that they possessed the resources to develop more thoughtful and complex answers to questions. His account of using the inquiry-based model of instruction led us to envisage classroom practices that were consistent with the schemas such as the importance of questions, the role of collaboration throughout the activity, and the importance of access to resources for the groups working on the questions, all schemas integral to the use of this model in the MSCE courses. Even though Hugh did not seem to value such schemas, a video vignette of him introducing a question to his students led us to a richer appreciation of the relationship between resources, schema, and structures in professional education and teaching.

Hugh using the inquiry-based model:

Hugh: [To the class] Remember yesterday we did some Boyle's Law – pressure and volume. Today we're going to do something a little different – temperature and volume [Hugh is using a portable butane burner to heat an aluminum can into which he has placed a little water. Beside the burner is a large tray of water and ice cubes]

At this point in our review of the video, we questioned why Hugh did not provide students the opportunity to see him put a small amount of water into the empty drink can. He wanted part of the demonstration to be a mystery and we speculate that his use of the schema that chemistry is mysterious obscures understanding of the demonstration and serves to reinforce for these students the impenetrability of chemistry thereby making Hugh's task that much harder.

Mike: Hey you're not allowed to have lighters at school.

Sam: Hey the books are burning.

Hugh: I put a little water in the can. What happens when I heat the water up?

Fred: It boils.

Mac: It boils.

Hugh: What's it turn to?

Mac: A gas.

Sam: Can we bring in a can and just keep on doing this?

Hugh: No.

Paul: Can I bring in marshmallows and make smores?

[Hugh plunges the hot can into cold water and there is a loud crack. He lifts the can out of the water and allows the water in the can to drain out. Immediately Hugh prepares to repeat the demonstration]

Stan: Wow [In a cynical sort of way.]

Mac: Why did it smash?

Hugh: Why did it smash?

Sam: It got too hot.

Hugh: Well you know what.

Sam: And the gas was [?] and the air wasn't.

Hugh: Shh. I didn't ask for you to answer yet. I filled the can with what when I heat it?

Fred: Water.

Pete: Alcohol.

Hugh: Water vapor. Water gas. Pushed everything out. All the other gases.

Sam: How hot's that burner?

Hugh: I don't know pretty hot five or six hundred degrees probably.

Pete: Put your finger on it. I'll give you a dollar.

Hugh: I think I would need more than a dollar.

[Other students chime in and suggest to Hugh that they have a "couple of twenties." He ignores the students and continues to heat the can.]

Hugh: So I am filling the can with water vapor.

Sam: Look at the flame coming off the steam.

Mac: What flame?

[Six seconds later, Hugh plunges the can into water]

Hugh: Obviously I can't crush the can like that, just with the tongs, I didn't do it, something else happened. What you are going to do now is to break up into groups. Tell me what happened, you are going to work on it for a couple of minutes. The groups are going to report back, your groups are as follows.

The students sit in rows, with their desks at various distances from the front of the room where the demonstration was conducted. During the conduct of the demonstration, Hugh asked the class one question. Although Hugh claims he wants the students to work to address the question of what happened when the can was heated and then immersed upside down in freezing water, he cannot help himself providing some of "the answer" as evidenced by his comment to the class:

Hugh: Shh. I didn't ask for you to answer yet. I filled the can with what when I heat it?

Fred: Water.

Pete: Alcohol.

Hugh: Water vapor. Water gas. Pushed everything out. All the other gases.

He was focused on heating the can and when he gave his explanation regarding the water vapor pushing out the other gases in the can, he waved his “free” hand to indicate how the gases would “escape” from the can. A review of the video vignette showed a majority of students engaged with the demonstration: that is they are watching as Hugh heats the can. But there was little positive emotional energy from Hugh or the students. Although when the students engaged in their byplay with Hugh about paying him to place his finger in the flame the tone and tenor of the exchange was upbeat and playful. Silences stretched for over five seconds as the students watched the demonstration. At the end of the demonstration, Hugh took the can out of the water and placed it behind the butane burner and stand. He then gathered up an overhead projection sheet, stepped around from behind the desk towards the projector and told the students what they were to do. One resource generated as the lesson unfolded, was the crushed can. Hugh did not attempt to use the can as a resource, to share with the students and to provide them the chance to see in more detail the outcome of the demonstration.

Hugh’s goals did not extend to developing an inquiry lesson. Although he was an experienced teacher, he did not engage students in a discussion on their observations, and thus, use those discussions as a resource for students to use to provide explanations of the scientific phenomena. He could claim, as he does in his narrative, that he used the inquiry-based pedagogical resource from the MSCE. However, Hugh’s schema that informed his use of the model was very different from those used by his MSCE educators. Hugh adopted a didactic approach that resulted in a different pedagogical structure. While his use of inquiry-based pedagogy, even in this reduced form, allowed him to recognize the value of probing students for more thoughtful responses and rather than accepting the first answer the students provided, his use of inquiry as a mode of instruction was limited. Hugh’s practice suggested that using the format of the inquiry protocol, the resource, without the attendant inquiry schemas of openness, questioning, and problem solving, did not greatly expand the pedagogical resources available to him or his students.

Over time Hugh realized that if he used an inquiry-based method of instruction and increased his expectations, his students would develop richer responses to his questions. Hugh acknowledged that as a teacher he had “gotten into a rut” and into the habit of presenting learning as the distribution of problems on worksheets for students to answer. Changing this practiced action requires a teacher to become aware of a practice that has become unconscious and then engage in a prolonged effort to change such practice. As

Hugh indicated in his presentation, in stressful situations his habitus was to revert to his practice of constructing learning in terms of worksheet completion by students. Such actions provide further evidence that although Hugh claimed to have implemented the inquiry model and changed his practice, this change was minimal at best as the schemas that informed his use of resources remained unexamined and unchanged. However, Beth provided evidence of creatively using both resources and schemas from the MSCE program.

The MSCE program provided teachers with access to a wide array of resources including a richer knowledge of chemistry, inquiry-based approaches to pedagogy, strategies for organizing thinking including graphic organizers and “levels of representation” and variable assessment strategies. Levels of representation is based on the understanding that explanations of observable chemical phenomena such as chemical reactions require the use of sub-microscopic particles such as molecules and atoms and that communication of observations and explanations use words and symbols. Beth found this tool useful:

They [the students] enjoyed doing the lab and making observations at the macroscopic level. Trying to get them to understand what was happening at a micro level or a molecular level was a little harder. But there were some good suggestions in the ChemSource book about what you could do to get the students to understand that what was actually happening was that the paraffin wax was turning into a vapor and igniting. I had them build a giant paraffin model that's $C_{25}H_{52}$ and long [Beth spreads her arms wide to show long]. They took that and broke it apart and they got the CO_2 (carbon dioxide) and H_2O (water) out of that and they could actually see with the little models what happens in the reaction [Beth has photographs of the students building and breaking apart the model].

Beth encouraged her students to use representations in the form of (structural) models, and to develop an understanding of combustion at the gross molecular level. This teaching event actively engaged students in developing and then dismantling the simulated model at the molecular level. The narrative provides further evidence of Beth's agency as she used a resource from the MSCE program. However, by emphasizing the relationship between the macroscopic and submicroscopic aspects of this laboratory activity, she changed the schema associated with the resource because the initial laboratory activity emphasized the calculation of the energy released in the form of heat and the associated levels of percentage error. While exercising her agency as a chemistry teacher, Beth made a pedagogical decision to focus the activity on levels of representation, which became a shared resource for the students. Beth demonstrated a capacity to enact the resources and schema from the MSCE program in creative ways that aligned with her goals and expanded her students' resources. In contrast to

Beth, when Hugh took the tool of an inquiry-based pedagogy, he applied different cultural schema that resulted in a restricted learning experience for the students. The result was a different structure to that intended by the faculty of MSCE program.

The actions of Beth and Hugh also indicate the risk teachers take when they decide to change their classroom practice. Their experiences serve to illustrate the unpredictability of this process. Beth decided that her students needed to increase their use of written genres, appropriate technology, and be involved in developing a research paper based on a question that they had about their environment:

I am going to work more with the computer teacher and the English teacher to incorporate technology more. We have Mac computers at our school. I have a computer just like that in my classroom [Has a photograph of a student working at a computer in the library] and another older one. In the library we have several and we went down there and did work and they also used the computers in my classroom. This is an example of a lab report that someone typed up [Beth has a photograph of a laboratory report from one of the students in her class]. I wanted them to become more familiar with using word processing and we tried Excel.

She involved the students in conducting experiments and in developing graphic organizers that provided more resources for organizing their knowledge and being researchers. Videotape of classroom interactions indicate that Beth's students responded positively to these initiatives and she built social capital with her students. However, Hugh's initiatives remained consistent with the didactic model of teaching that had served him well in previous teaching fields. It is in the classroom that a teacher's prior teaching experiences and her/his professional education experiences intersect. By requiring teachers to use resources they experienced in the professional education program with the classes they taught in high school, Catherine forced the teachers to enact strategies they otherwise may have avoided. However as Hugh's actions indicate, requiring teachers to enact various pedagogical practices rather than allowing teachers to make their own decisions about whether they will modify their practice in light of their professional experiences can result in structures that have little positive effect on student learning and might reduce the options for teacher and student action. This ineffectual enactment of teaching strategies is likely to occur if instructors pay more attention to the tools or resources rather than the attendant and equally important schema. In professional education, schemas need to be examined as thoroughly as resources so that teachers can enact their agency in creative and thoughtful ways.

EXPLANATION OF TEACHER CHANGE

Our analyses suggested that to promote teacher change, professional education should provide a field that expands teachers' cultural schema so that through their actions with these new schema teachers change the structures that they construct and experience in their lived world as science teachers. Our study indicated that it was possible for teachers to use resources experienced in the MSCE program with their high school students. But if they did so without the underlying cultural schema, and applied another schema, they created a different structure that was reinforced by their ongoing actions. These structures had the potential to constrict the learning of their students. Consistent with the arguments of Wenger (1998), the program provided teachers opportunities for the negotiation of new dimensions of self as a science teacher. However, Hugh's actions indicated his belief that he lacked agency in the new field to adopt cultural schema that constituted an integral aspect of the professional education program. Alternatively, Beth demonstrated her ability to apply schemas from the professional education program. She adopted schemas such as the value of inquiry and questioning that led her to modify resources such as laboratory activities. This is an example of Beth's expanding agency as she transposed and extended schemas to new fields.

Introducing new tools into a classroom required the teachers to exert more effort than if they used their habitual practices. For Hugh, using new tools required time to change his teaching dispositions. Those dispositions included teacher lecture and student responses, laboratories conducted once a week over two lessons in a designated laboratory space, an emphasis on mathematical computation to solve well defined chemistry problems, and the use of algorithms to assist students to understand chemistry. Hugh's experiences reinforced the facility of these approaches to his teaching of chemistry. Moving to a new school, a change of field, and the experience in the MSCE program, where he began to use new tools, encouraged Hugh to cast a critical eye over his previous experiences and led him to realize that he could not continue to teach chemistry in the manner with which he had become comfortable. However, changing his disposition required a level of commitment that Hugh could not make and raises the issue of how the variable fields experienced by teachers before their involvement in professional education affects the level to which each teacher is invested in a professional education program, even one for which they had volunteered.

It is possible to dismiss Hugh as a lazy teacher who taught with a set of rigid practices. However, his involvement in MSCE indicated that he also recognized the limitations of his current teaching practices but struggled

to enact his agency in a new school. The structures enacted at the school at which Beth taught empowered her differently to the way the structures enacted at Hugh's school seemed to dis-empower him. Because his position was collectively created, Hugh was positioned as the "new" teacher which collectively produced differences in power that had implications for how Hugh experienced his agency. There is a tendency in professional science education to focus on the new tools that teachers are learning and teachers may argue they need new tools that have immediate application to their teaching. However without an examination of attendant schema, teachers may use resources in purposeless ways or associate them with schema the teacher already values resulting in a teaching/learning structure very different from that envisaged by the professional educators. This has implications for the "toolkit" model of teacher action because it reminds us that a teacher's cultural toolkit needs to include not only resources that teachers find so attractive but also cultural schema that are intimately associated with these "tools in use" in order to develop strategies of action that are consistent with the goals of the professional education program. It behooves professional educators to recognize the schemas associated with the resources they use in professional education programs and make them explicit in their interactions with teachers. Apart from being conscious of the schema and resources that structure specific professional education programs, professional educators also need to give thought to how teachers might use schema or resources to expand or constrain their options for action.

As this study illustrates, for professional educators and teachers the high school classroom sits on the intersection between possibly different espoused modes of teaching and learning. The multiplicity of structures at a specific site such as the chemistry classroom can explain the capacity of teachers to apply variable schema to arrays of resources. The classroom figures as a crucial resource for these structures and the meaning and consequences of structure multiplicity for both professors and teachers remain open and contested. As sets of mutually sustaining schemas and resources, structures empower and constrain social action and are reproduced by that social action. However, this reproduction is not automatic. Thus, social actions can engender both social change and social stasis as our teachers demonstrated. Our study indicated that capacity for agency involves forming intentions, acting creatively and setting goals. Beth used these actions as resources that informed her adaptation of resources and schemas associated with the MSCE. Lacking these resources and acting in an environment that he found oppressive, Hugh did not. Thus how one is constituted, as a science or chemistry teacher, will vary enormously because it is culturally and historically determined through education, experience,

and background. Our study indicated that new cultural schemas from professional education allowed teachers to mobilize resources in ways they had not done before and access to new resources allowed them to enact specific schemas associated with the program. This suggests that professional education has the potential to provide resources and schemas that teachers can enact in ways that transform structures in new fields such as high school science classrooms and schools. However, such change is always variable and dependent on the social actions of the teachers involved.

Our understanding of, and explanation for, agency and teacher change through professional education leads us to argue that professional education requires a number of facets to positively affect the practice of experienced science teachers. Teachers need to articulate their goals for professional education because this action can frame their ability to act and provide a focus for their agency to use resources and schemas in different fields. Professional education should provide authentic pedagogical tasks that involve teachers in “tweaking” resources so that they can creatively use the resources in different fields. Assigned readings on education research provide teachers with access to other resources and schema to use in the discourse of professional collaborations and in developing curricular structures. Professional educators should foreground the important schema and resources within the professional education program to clarify the relationship between resources, schemas and structures thereby expanding teachers’ options for action while acknowledging the complexity of the interaction between agency and structure within specific fields.

EXPANDING THE UNDERSTANDING OF THE PROFESSIONAL EDUCATORS

Our examination of Hugh and Beth’s responses to MSCE’s chemistry education courses highlighted that as professional educators we could have offered more support to Hugh. For example, rather than sympathizing with him over the lack of a laboratory, we should have discussed strategies for action that could have become resources for Hugh. Reflecting back on the program, led us to recognize the need for chemistry education courses to emphasize the sociocultural aspects of being in the world for the teachers and to explicitly examine issues of agency, practice, resources and cultural schemas and their iterative relationship with the structures that exist in various fields. These interrelationships became a major focus of the introductory chemistry education course when the course emphasis moved towards involving teachers in examining questions or issues that were important

to their practice rather than imposing requirements that they implement specific resources from the program. As a result, teachers were engaged in catalytic activities and action research. Catalytic activities were designed to foster collegial interactions by involving teachers in actions that had a broader impact on the school than just the chemistry classroom. Instructors explicitly structured the catalytic activities to enact change on structures and practices of the field of the school or science department. Action research involved each teacher using resources and schema from the MSCE program to examine a question about the practice of science education that was of interest to her.

The second chemistry education course builds on the resources and schema of the initial course to reinforce the importance of specific resources and schema to the overall program. Our recommendation to ourselves and to other professional educators is the importance of acknowledging the schemas associated with resources. Care needs to be taken when thinking of resources as tools because it can lead us to forget the attendant schemas that facilitate the construction of structures, since these are the structures that promote learning. We understand that based on their habitus, teachers will appropriate and incorporate specific resources into their practice using different schema that results in new structures. However, as experts in the field of professional education it is important that we are explicit about the schema that we associate with specific resources. This practice promotes greater teacher agency because both resources and schemas provide teachers with more options for action. Our understanding is that these enacted changes in the chemistry education courses have the potential to lead teachers to a richer appreciation of their agency in schools and in the classroom. These changes also promise to foster a more sophisticated understanding among all participants of the relationship between resources, cultural schemas and structures in fields.

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NOTE

1. The interview process began after the program's first year.

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