RESIDENT SCIENTISTS' CONCEPTIONS OF SCIENCE TEACHING

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Abstract

*This study explored the conceptions of science teaching held by Resident Scientists who were providing content and pedagogical support to teachers in schools through the National Science Foundation (NSF) GK-12 project in USA. Their conceptions of teaching were compared with those held by teachers and the appropriate conceptions of science teaching reported in previous studies. A sample comprised nine Resident scientists from three science disciplines: biology, chemistry and physics. All the Resident Scientists were training to be scientists and not to be certified as teachers. Data was collected through a questionnaire and semi-structured interview. Data were analyzed by first coding the responses to identify recurring themes and categories. F*ive *conceptions of science teaching emerged: Facilitative process, Conceptual and skill development, Ability and attitude development, Dynamic interactive process, and Content knowledge delivery process. Most conceptions of science teaching held by the Resident Scientists were similar to those held by teachers reported in previous studies. They also had elements for appropriate conceptions of science teaching. However, some Resident Scientists' views on teaching supported the knowledge transmission instructional mode. The findings have implications for teacher education, science teaching and learning, and the National Science Foundation (NSF) GK-12 program.*

Key words*: teaching, conception, GK-12, and resident scientist.*

Introduction

Science teachers' conceptions of teaching have increasingly been recognized as important elements for effective science teaching at different levels of education (Martin & Balla, 1990; Mellado, 1998). As such, several studies have examined science teachers' conceptions of teaching (Hewson & Hewson, 1987; Aguirre, Haggerty & Linder, 1990; Gallagher, 1993; Gustafson & Rowell, 1995; Hewson, Kerby & Cook, 1995; Lederman, Gess-Newsome, & Latz, 1994; Sanchéz & Valcarcél, 1999; Skamp, 2001; Porlán, & Martín del Pozo, 2004). For example,

Gallagher (1993) identified six conceptions of teaching among science teachers: teaching as a transmission of content to students; teaching as organization of the science content; teaching as a set of manipulative activities; teaching as a learning cycle; teaching as a conceptual change; and teaching as a guide through a constructivist process. Gallagher avowed that the last three conceptions of teaching constitute different degrees of the constructivist model of science teaching. However, the differences among these six conceptions of teaching are in the responsibilities a teacher gives students during instruction. In a similar study, Porlán and Martín del Pozo (2004) found three conceptions of teaching among primary school teachers: knowledge transmission; technical mode; and alternative mode. The knowledge transmission mode relies upon the teacher's belief in the accuracy of his or her own content knowledge, where the teacher must precisely transmit accurate knowledge intact to the students. The technical mode conceptualizes teaching as being the teacher's task to organize content into forms that students can digest. If the teachers apply the prescribed techniques in their classrooms, learning is guaranteed. On the other hand, the alternative mode identifies the importance of students' participation and the teacher's role as a facilitator. These three conceptions of teaching appear to be similar to those reported by Gallagher (1993). The technical and alternative mode conceptions of teaching in Porlán and Martín del Pozo's (2004) study are similar to Gallagher's teaching as organization of the science content and constructivist process categories, respectively. Both studies attribute the diversity of views about teaching among the teachers to their different backgrounds and science teaching orientations.

Teachers' conceptions of teaching reported by Gallagher (1993) and Porlán and Martín del Pozo's (2004) are somewhat different from university lecturers' views on teaching reported by Kemper (1997). Kemper reported that university lecturers viewed teaching in terms of the following: the essence of learning and teaching, the roles of student and teacher, the aims and expected outcomes of teaching, the content of teaching, and the preferred styles and approaches to teaching. Based on these studies, there are small differences in the views of teaching held by teachers and university lecturers due to differences in the contexts in which these two groups function. Therefore, it is realistic to assume that teachers' conceptions of teaching are context-dependent (Mellado, 1998; Gao, 2002), because teaching is a cultural activity which varies from one place to another. To confirm this assumption, Gao (2002) explored conceptions of teaching among Chinese science teachers and compared them with those held by science teachers in western countries. Gao found five conceptions of teaching among Chinese science teachers: examination preparation, knowledge delivery, ability development, attitude promotion, and conduct guidance. Chinese teachers viewed students' performance on external examinations as the most important indicator of effective teaching and successful schooling, while its parallel conception in the western context focused more on internal standards of learning set by institutions. Chinese teachers also viewed good conduct as an important aspect of teaching. However, both Chinese teachers and their western counterparts valued promotion of good learning attitudes and facilitation of students' interest in learning.

Other studies have focused on identifying elements of appropriate conceptions of teaching science that are associated with effective science teaching practices. Hewson and Hewson (1988) and Hewson, Kerby, & Cook (1995) suggested that appropriate conceptions of science teaching should consist of tasks and activities that are: aimed at helping students learn the content knowledge and skills and are indicative of particular content to be learned and expressed so that it is possible for particular students to learn. Additional elements of appropriate conceptions of teaching are: teachers' good understanding about how students learn, and knowing students' conceptions on the topics to be taught and the extent to which these conceptions are scientifically correct or incorrect. Teachers should also be aware of some topics which students might find difficult and why that is the case. In addition, teachers should know and be able to model the instructional strategies that take into account students' prior ideas and those that bring about effective learning.

It is lucid from these studies that in spite of the differences in the labels and descriptions of teachers' conceptions of teaching, there is a high degree of commonality in the findings. However, as shown in Gao's (2002) study, there are small differences in the views of teaching

held by teachers due to the difference in the contexts (in this case- countries) in which they function. As such, the existing knowledge base on teachers' conceptions of teaching elicited from teachers in different places (contexts) has been essential in providing sound frameworks for designing instruction that facilitates pre-service teachers' development of appropriate conceptions of science teaching and effective instructional practices for different settings (Hewson, Kerby & Cook, 1995).

Although studies have examined science teachers' conceptions of teaching the focus has only been on pre-service and in-service science teachers, except for the two studies (Kember, 1997; Kember & Kwan, 2000) that examined university lecturers' views of teaching. No study has explored the conceptions of teaching held by university students in traditional science degree programs who are providing content knowledge and pedagogical support to teachers in K-12 schools through funded science outreach programs. The term *traditional science degree program* refers to a university study program (in a science discipline such as chemistry, physics, and biology) that prepares scientists. Students in such programs have a training background and career goals that differs greatly from those of K-12 pre-service and in-service science teachers. As such, the context in which these students intend to function is different from that of teachers.

Therefore, this study explored the conceptions of science teaching held by graduate students (Resident scientists) who were providing content knowledge and pedagogical support in schools through the National Science Foundation (NSF) GK-12 project in USA. The NSF GK-12 program is a nationwide mathematics and science education outreach program that is utilizing the content knowledge and skills of Resident Scientists to help improve the teaching and learning of mathematics and science in schools (NSF, 2000). Since its inception in 2000 the NSF GK-12 program has funded several GK-12 projects across the nation. As such, hundreds of Resident Scientists, across the US, have provided content, resources and pedagogical support to teachers in schools through this program. The acronym GK-12 is used to mean that the Resident scientists can provide content knowledge and instructional support at any grade level from kindergarten to twelfth grade depending upon the objectives, goals and design of the individual GK-12 project. The Resident scientists are offered fellowships as compensation for their work in schools. The fellowships pay for tuition, living and travel (to schools) expenses. These Resident Scientists, however, are not training to become full-time teachers, nor do they become certified to teach as a result of their involvement in the NSF GK-12 program. Instead, they are training to become scientists.

The Resident Scientists plan and teach science lessons in schools. As such, we believe it is worth finding out what they think and believe about teaching. Additional reasons for exploring their conceptions of teaching include the following: teachers' decisions and pedagogical acts are influenced by their conceptions about teaching (Tobin, Tippins, & Gallard, 1995) and nested epistemologies (Tsai, 2002); science teachers who have good understanding of effective teaching can thoughtfully evaluate their instructional practices and use practices that facilitate student learning (Russell, 1993; Staver, 1998; Tobin, Briscoe, & Holman, 1990); science teachers' beliefs (Pajares, 1992; Prawat, 1992; Calderhead, 1996), as well as their science discipline background and orientations (Mumba, Chabalengula, Moore & Hunter, 2007) influence their views and actions about how they plan their lessons, the processes and content of their instruction, and the means of communicating content and values to students (Sanchez & Valcarcel,1999). As such, it was logical to explore the conceptions of teaching held by the Resident Scientists in our NSF GK-12 project and find out whether their views of teaching were similar or different from those held by trained teachers (Hewson & Hewson, 1987; Aguirre, Haggerty & Linder, 1990; Gallagher, 1993; Gustafson & Rowell, 1995; Hewson, Kerby & Cook, 1995; Lederman, Gess-Newsome, & Latz, 1994; Sanchéz & Valcarcél, 1999; Skamp, 2001; Porlán, & Martín del Pozo, 2004) and elements of appropriate conceptions of science teaching reported in previous studies (Hewson & Hewson, 1988; Hewson, Kerby & Cook,1995). In particular, this study attempted to answer two questions: What conceptions of science teaching are held by the Resident Scientists? How do their conceptions of science teaching compare with those held by science teachers and the elements of appropriate conceptions of science teaching reported in previous studies?

The knowledge base on scientists' conceptions of teaching is essential for designing sup-

portive programs that would be successful in helping scientists working in science education outreach programs. These supportive programs would assist scientists to develop conceptions of science teaching that are associated with effective science teaching in K-12 settings. The assumption is that these scientists would translate desirable conceptions of science teaching into effective instructional practices in K-12 classrooms and this, in turn, would improve the quality and outcomes of science learning among K-12 students in participating schools. It was anticipated that the findings in this study would be useful to teacher educators, the NSF GK-12 program, and those who are involved in similar mathematics and science outreach programs elsewhere.

Context of the Study

This study was conducted in a mathematics and science education outreach project at a medium-sized university (20,000 students) in the Midwest of the USA. The outreach project is one of the NSF GK-12 funded projects. This is an eight-year long project involving the departments of Biological Sciences, Chemistry, Physics and Mathematics and more than twenty school districts within 60 miles (100km) of the university. The project has four goals: to use science content knowledge and skills of university graduate students and professors to increase scientific literacy among high school students; to enhance teachers' science content and pedagogical knowledge; to enhance teachers' knowledge and skills for conducting Action Research; and to enhance existing and create new partnerships among the university and local school. The project is following the NSF GK-12 program model of placing graduate students (Resident Scientists) in K-12 classrooms to assist teachers with subject matter knowledge, instruction, and other resources. The model is based on the premise that these Resident Scientists can be valuable content resources to teachers and K-12 students. The project started in 2001 and is in its final year. Since its inception, the project has recruited and supported more than 100 Resident Scientists in biological sciences, chemistry and physics to work with teachers and students in participating schools. The Resident Scientists plan and teach science lessons in schools. Resident Scientists are allowed to participate for a maximum duration of two years.

At the beginning of each school year, the Resident Scientists are matched to schools and teachers by the project coordinator. Later in the year, as the Resident Scientists establish stronger working relationships with teachers in participating schools, matching with additional teachers occurs. In some settings, they work with a single teacher. In other cases, a pair of Resident Scientists work with a single teacher or with a pair of teachers. The Resident Scientists are instructed to work with teachers and among themselves in order to deliver inquiry-based science lessons. A week-long orientation workshop for Resident Scientists and teachers is conducted at the beginning of each school year in August. Several aspects on teaching and learning are discussed and taught in the workshop such as: learning theories, inquiry-based teaching, collaborative skills, national and state learning standards, curriculum development, assessment, and classroom management. In addition, the Resident scientists and project leaders meet bi-weekly during the school year to discuss pedagogical and logistical issues the Resident scientists experience in schools.

Methodology of Research

Nine Resident Scientists comprised the sample: four in chemistry, four in biology and one in physics. Their profiles have been provided in Table 1 below.

Table 1. Profiles of the Resident Scientists.

Subject Area	Name	Gender	Degree Program	Prior school teaching experience (years)	Intended Career
Biology	John	M	MSc	0	Scientist.
	Ken	M	MSc	0	Scientist.
	Rachael	F	PhD	0	Scientist.
	Karen	F	MSc	0	Scientist
Chemistry	Andrew	M	MSc	0	Scientist.
	Jessica	F	MSc	0	Scientist.
	Beth	F	MSc	3	Former high school Teacher, now a Scientist.
	Tiffany	F	MSc	0	Scientist.
Physics	Amanda	F	MSc	0	Scientists

As shown in Table 1, one Resident Scientist was in a doctoral program and the rest were in masters' degree programs. There were six females and three males. The average age of this group was 26 years. Only Beth had formal teacher training and high school teaching experience prior to joining the project. The rest of the Resident Scientists had no formal teacher training and teaching experience in K-12 classrooms before joining the project. However, some had teaching experiences as teaching assistants in undergraduate classes that ranged from one semester (five months) to two years before joining the project.

Data sources were a questionnaire and semi-structured interviews. The questionnaire had seven open-ended items on science teaching and teaching in general in K-12 classrooms. Some of the questionnaire items are: What is teaching? What are your views on science teaching? What are the elements of effective science teaching? The questionnaire was administered to nine participants because these were the only Resident Scientists in the project at the time of data collection. Three weeks after the participants completed questionnaires follow-up semi-structured interviews were conducted to validate participants' responses in the questionnaires. These interviews included the questions on science teaching and teaching in general similar to those in the questionnaire. During the interviews, the participants were provided with their questionnaires and allowed to read their responses and asked to explain them further. Most interviews lasted 30 minutes each, though some interviews took longer. All the interviews were audio-taped and transcribed for subsequent analysis.

Data were analyzed using a constant comparative method (Strauss & Corbin, 1998). The procedure involved reading (and re-reading) responses in the questionnaires and interview transcripts in search of the answer to these two questions: "what is this about" and what is being referenced here?" Then the participants' responses were open-coded to identify recurring themes. Thereafter, categories were generated through comparing the themes for similarities and differences. These provided the representative profiles of the group being studied.

Data analysis showed that some participants' responses contained ideas that supported more than one theme or category of conceptions of teaching. A similar observation was reported by Hewson and Hewson (1987) and Gustafson and Rowell (1995). In the present study, such cross-categorization was prevalent in both data sources. For example, Tiffany, a biology Resident Scientist, provided the following response in the questionnaire:

> In my view teaching is passing knowledge to students. It is also a way to facilitate students' acquisition of knowledge and skills they need in order for them to pass a science course.

In this case, the response contains two ideas about teaching and would therefore be inter-

preted as providing support for two categories: Knowledge delivery ("…passing knowledge to students."), and Facilitative process ("…facilitate students' acquisition of…"). Despite the high number of responses containing more ideas about teaching, data analysis clearly showed the themes that appeared with high frequency.

Results of Research

Resident Scientists held five conceptions of science teaching: Facilitative Process, Conceptual and Skill Development, Ability and Attitude Development, Dynamic Interactive Process, and Content Knowledge Delivery Process.

Facilitative Process: This conception of teaching is based on Resident Scientists' view that a teacher's role is to help students gain knowledge and skills. For example, Jessica, a chemistry Resident Scientist, wrote that:

> Science teaching is not about pouring knowledge into students' minds but helping them learn. Their minds are not empty…they have some ideas... which may not be correct. So…..I view science teaching as a way to facilitate students' understanding of correct science ideas… and gain skills for doing science.

This conception emphasizes that students have prior science ideas and learn correct ideas through guidance and support from their teachers. This is also seen to be teaching that begins with knowing students' prior ideas and continues with teachers providing help to students in understanding science ideas which are different from or better than their own.

Conceptual and Skill Development: Although this conception of teaching appears to be a learning outcome rather than a teaching process, the Resident Scientists imply that teaching is a process through which students gain conceptual understanding and science process skills for doing science. For example, Andrew, chemistry Resident Scientist, said:

> Science teaching is an act that is aimed at helping students learn about science ideas, concepts, and skills to do science. Science is an investigative discipline… so I expect my students to gain knowledge through explorations.

From this excerpt, teaching helps students to construct and develop scientific knowledge and skills. All Resident Scientists subscribed to this view.

Ability and Attitude Development: Similarly, this category appears to be a learning outcome. However, this conception of teaching is based on the view that learning can only occur if the teaching process stimulates students' positive attitude towards science. For example, Amanda, physics Resident Scientist, said that before she starts teaching a class she tries to know students' attitudes towards science.

> I view science teaching as a process for helping students to learn how to do science and apply the skills in life. Teaching is also about fostering positive attitudes towards science among students, if you want them to appreciate it.

This conception of teaching emphasizes the interactions among learning, performance, and attitude. Students with positive attitudes towards science are more likely to appreciate science, become good consumers of scientific ideas, be dutiful citizens, and consider careers in science (Cavallo & Laubach, 2001).

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Dynamic Interactive Process: Through this conception the Resident Scientists view teaching as an interactive process that occurs between a teacher and students. For example, Karen, a biology Resident Scientist said:

> Teaching involves…active interactions between a teacher and students… and this changes many times. There is no way you would teach without interacting with them. There are also interactions among themselves in class.

From this conception of teaching, both teachers and students are at the center of the teaching-learning process. This conception of teaching also implies that the interaction has influence on student learning.

Content Knowledge Delivery: This conception of teaching is based on the view that teaching is a process where teachers pass knowledge and skills on to students. For example, John, biology Resident Scientist said:

> In my view teaching is passing cutting edge scientific information to students. As a Resident scientist working in schools I view this to be important process if I have to help students learn science. Most students don't know scientific facts …so we just have to tell them...

From this excerpt a student is viewed as a passive receiver of content knowledge. A science teacher is the knower and the deliverer of scientific knowledge to students. The content of teaching is pre-determined by the external factors and the teacher.

Discussion

Except for the *Dynamic Interactive* P*rocess,* the other four conceptions of teaching held by the Resident Scientists are similar to those held by pre-service and in-service teachers reported in previous studies. For example, the *Content Knowledge Delivery* conception of teaching identified in this study was also widely identified in previous studies even if it was reported in different phrases such as knowledge transmission (Gao, 2002; Gow & Kember, 1993), transmission of content to students (Gallagher, 1993), presenting structured knowledge (Larson, 1983), or delivering content (Pratt, 1992). *Facilitative,* and *Ability and Attitude Development* categories of conceptions of teaching identified in this study parallels learning by facilitation (Gow & Kember, 1993), facilitator of thinking and learning (Christensen, Massey, Isaacs, & Synott, 1995), alternative mode (Porlán & Martín del Pozo, 2004), cultivating the intellect (Pratt, 1992), helping students develop conceptions and helping students change conceptions (Prosser, Trigwell, & Taylor, 1994), teaching as motivating learners (Gao, 2002), and teaching as encouraging active learning (Martin & Balla, 1990). The term *ability* in the *Ability and Attitude Development conception* of teaching held by the Resident Scientists is used to mean underlying knowledge and skills that relate closely to human intellect but which can't simply be acquired from teachers; rather, it has to be developed by students themselves during the process of learning. The term *attitude* is used to mean an implicit manner of helping students to set up good learning predispositions through active interaction and by creating a good learning environment.

While some previous studies reported distinct categories of conceptions of teaching, the present study found some overlaps among the categories of conceptions of science teaching held by the Resident Scientists. For example, both *Facilitative Process* and *Dynamic Interactive Process* conceptions of teaching involve some interactions between a teacher and students, though during instruction such interactions are encouraged in a variety of ways. Comparisons among *Facilitative Process*, *Ability and Attitude Development*, and *Conceptual and Skill Development* categories show that students are in an active mode position under these three conceptions of

teaching. The content of teaching may include daily life issues and methods of learning beyond knowledge and skills as well as attitude and conduct reflected in students' performance. Another common element among these three categories is that during instruction teachers and students interact in multiple ways and form a learning community. The three conceptions of teaching also focus on cognitive abilities. However, the attitude development in a student relates to some non-cognitive aspects, and the expected outcomes of each category are different accordingly.

Since many alternative teacher certification programs in the US draw from the pool of candidates targeted by the NSF GK-12 fellows program, teacher educators and teacher professional development providers should be aware of the tendencies among future scientists to hold mixed ideas about teaching that support both knowledge and non-knowledge delivery methods. The NSF GK-12 projects coordinators also need to take into account their Resident Scientists' pre-existing conceptions of teaching if they are to effectively move them towards more appropriate and preferred structure of conceptions about teaching. Similarly, other science education outreach projects elsewhere should provide explicit instruction on teaching strategies that are linked with active learning to help the participants develop more appropriate conceptions of teaching. Strengths and weaknesses of different conceptions of teaching should also be explicitly addressed to the participants. Such intervention, coupled with a continuous and supportive environment, would help the NSF GK-12 program in USA achieve its goal, which is to improve mathematics and science teaching and learning in schools.

Future research should (1) investigate the nature of the relationship between the Resident Scientists' conceptions of science teaching and their actual teaching practices in K-12 classrooms and (2) identify some factors that facilitate or hinder the translation of their conceptions of teaching into practice in schools.

Conclusions

To large extent Resident Scientists' conceptions of teaching are similar to those held by teachers. Except for the *Content Knowledge Delivery* the other four conceptions of teaching have the elements of effective science teaching. The conceptions of teaching identified in this study are also consistent with the appropriate conceptions of science teaching suggested by Hewson and Hewson (1988).Since the Resident Scientists' ideas about teaching supported more than one conception of teaching, it can be concluded that they had many different levels of conceptions of what constitutes effective science teaching. Therefore, substantive changes to the quality of teaching in schools by some Resident Scientists are unlikely to happen without complete changes in their conceptions about teaching.

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