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The Pedagogical Content Knowledge and beliefs of newly hired secondary science teachers: the first three years

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ABSTRACT

The first years of teaching are often discussed with reference to all teachers. More studies focusing on early career content specialists are needed in order to ensure that teachers are supported adequately as they learn to teach in their content area. In this study, we followed 76 newly hired secondary science teachers to determine how their teaching beliefs and knowledge changed over a three-year period. This study used qualitative and quantitative data collection and analysis techniques. Interviews and classroom observations were collected and analyzed quantitatively using teachers as a group and the teachers' induction programs as a subgroup. The findings from this study suggest that over time new teachers are more influenced by their school cultures than by their induction programs. However, from the data it is evident that beliefs and practices are malleable, but that they are impacted differently and by different factors. As a result of this study, we suggest new directions for science teacher educators in their work and potential research regarding newly hired science teachers.

KEYWORDS: pedagogical content knowledge, beginning teachers, induction teachers, beliefs, newly hired teachers

Resumen (Conocimiento Pedagógico del Contenido y creencias de profesores de ciencias de secundaria recién contratados: los primeros tres años)

Los primeros años de enseñanza son a menudo discutidos con referencia a todos los profesores, no con relación a aquellos que imparten un nuevo contenido. Se requieren más estudios diseñados para los especialistas en contenidos de carrera temprana, para asegurar que están apoyados adecuadamente conforme aprenden a enseñar en su nueva área de contenido. En este estudio seguimos a 76 maestros de ciencia de la secundaria para determinar cómo sus creencias y conocimientos se transformaban durante un periodo de tres años. En él se utilizaron técnicas de análisis y colecta de datos tanto cualitativas como cuantitativas. También se emplearon entrevistas y observaciones de clase, y estos datos se analizaron cuantitativamente con el uso del grupo de los profesores y los programas de inducción de los profesores como subgrupo. Los hallazgos de este estudio sugieren que los nuevos profesores están muy influidos por la cultura de su escuela. No obstante, a partir de los datos resulta evidente que sus creencias y prácticas son maleables, pero que se ven impactadas de forma variada por diferentes factores. A partir de este estudio se sugieren nuevas recomendaciones para los educadores de profesores de ciencia, tanto para su trabajo como para su investigación potencial, con relación a profesores de ciencia recién contratados.

Palabras clave: conocimiento pedagógico del contenido, profesores principiantes, profesores de inducción, creencias, profesores contratados recientemente

The first years of a science teacher's career are marked by rapidly changing beliefs, knowledge and instructional practices (Davis, Petish, Smithey, 2006; Luft et al. 2011). For some teachers, the changes result in significant departures from constructivist, conceptual change, or learning-oriented traditions (e.g., Bransford, Brown, & Cocking, 2000; Mintzes, Wandersee, & Novak, 2005; Posner, Strike, Hewson, & Gertzog, 1982). These teachers adopt ways of teaching that emphasize the student as a recipient of science knowledge, a teacher-centered orientation. For other teachers, the changes result in the adoption or solidification of orientations that embrace the student as a learner. The latter approach to science instruction provides the student with opportunities to engage in knowledge production, which could include engaging with natural phenomena, developing arguments, or constructing explanations. This is often referred to as student-centered instruction.

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Our understanding of the development of a newly hired teacher can help guide the teacher towards a more student-centered orientation (Luft et al., in review). The beliefs and knowledge that a teacher holds may play a significant role in the development of this orientation (e.g., Abell, 2007; Jones & Carter, 2007). These beliefs and knowledge are a result of the newly hired teachers' experiences during elementary and secondary school, an initial certification program, or the first years of teaching (e.g., Fletcher & Luft, 2011; Loughran, Mulhall, & Berry, 2008).

Even though newly hired teachers have malleable beliefs and practices, they are at least familiar with and experienced in student-centered forms of instruction. After all, they have just emerged from initial certification or teacher preparation programs that provided them with opportunities to embrace student-centered instruction. Most new teachers are influenced by the context in which they teach (e.g., Bianchini & Cavazos, 2007; McGinnis, Parker, & Graeber, 2004). This context can constrain, sustain, or strengthen their beliefs and knowledge. Among newly hired teachers, beliefs and knowledge are often constrained by the context of their workplace (Luft et al., 2011).

One way to circumvent a slide toward teacher-centered instruction is to provide support to the teacher in his or her first years (Luft, 2007). In this study, newly hired secondary science teachers were followed for their first three years as they participated in one of four different induction programs, which lasted two years. The different induction experiences of the teachers in this study included science-specific university programs that worked with local schools and districts to support secondary science teachers; electronic mentoring programs offered by universities and national associations to a large number of science teachers; general induction programs offered by school districts that were developed for all of their teachers; and alternative certification programs that provided coursework towards certification while teachers began their education career. The first two programs specifically focused on the teaching of science, while the other programs addressed the general instructional needs of the teachers. By following the newly hired science teachers as they participated in these different programs, we had an opportunity to explore the development of teachers' knowledge and beliefs, as captured in this research question:

> How do the beliefs and pedagogical content knowledge of newly hired teachers change in their first three years, as they participate in different induction programs?

The hypothesis associated with this study suggests that induction programs focused on science will have a greater impact on the beliefs and pedagogical content knowledge of newly hired teachers than will induction programs focused on general teaching strategies.

Framing of Study

This study is framed within science teacher development and assumes that there are distinct phases in a teacher's career. Feiman-Nemser (2001) has provided an important overview of these phases within early career teacher development. Within this overview, we focus on two phases of teacher development. The first phase involves the initial certification program that supports future teachers as they build their knowledge and skills. The second phase takes place during their first years in the classroom, as the newly hired science teachers expand and refine their instructional competencies.

Feiman-Nemser's (2001) framework for early career teacher learning articulates central tasks for each phase of development. During initial certification programs teachers develop preliminary skills, knowledge bases, and beliefs. During the first years of teaching and beyond, the tasks take on complexity and result in enhanced skills, knowledge, and beliefs that can guide equitable and sound instructional practice. In order to support this development, it is important that early career teachers purposefully interact with their colleagues and other education professionals.

In order to enhance the work of Feiman-Nemser (2001), Luft (2012) infused a discussion about subject matter knowledge into the learning continuum. By explicitly addressing the teaching of science, Luft (2012) suggested a preliminary progression about learning how to teach science. The focus on subject matter knowledge allows early career science teachers to purposefully extend and deepen their subject matter knowledge, which in turn impacts their pedagogical content knowledge and classroom practices. As their beliefs develop, the use of student-centered science instruction is strengthened. An expanded discussion of the learning continuum for early career science teachers can be found in Luft (2012).

Related Literature

Beliefs

Research by several educational researchers guides the view of beliefs used in this study. Drawing upon the work of Jones and Carter (2007), Nespor (1987), Pajares (1992), and Richardson (1996), we define beliefs as personal constructs that are important to a teacher's practice; beliefs guide instructional decisions, influence classroom management and shape the way teachers represent their subject matter. The beliefs of teachers consist of both core beliefs and peripheral beliefs. Core beliefs are formed during prior educational experiences. From these core beliefs emerge peripheral beliefs, which are shaped in response to new experiences (Rokeach, 1986). In science education, a teacher has core beliefs about teaching, but then develops peripheral beliefs about teaching science, which ultimately guide the acquisition of knowledge and practice.

Research on the beliefs of newly hired science teachers has explored the relationship between beliefs and instructional practice. In the area of initial certification programs, there is some evidence that these programs provide strong support for the initial formation of student-centered approaches produce teachers with student-centered beliefs and practices (Marbach-Ad & McGinnis, 2008). However, when a teacher enters the professional formally, beliefs and practices are constantly challenged by experiences with students and colleagues. As a result, beliefs and practices are being modified in response to the school context during the first years of teaching (Luft et al., 2011).

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) plays a critical role in transforming content knowledge into appropriate learning experiences for children (Shulman, 1986, 1987). According to Abell (2007) and Kind (2009), research in the area of PCK has increased dramatically and has resulted in a significant number of descriptive studies. These descriptive studies point to various components of PCK and different ways in which it is cultivated within a teacher's practice.

Among studies with new science teachers it is evident that PCK develops as teachers work with students in the classroom (e.g., Friedrichsen et al., 2009; Mulholland & Wallace, 2005). In a study by Luft et al. (2011), beginning teachers were engaged in various induction programs that supported their knowledge of science instruction. These teachers developed their PCK while working with students, while the induction program enhanced their PCK. Communication between mentors and new teachers was also found to contribute to PCK development by Simonsen, Luebeck, and Bice (2009). In addition to interactions with colleagues, educative curricular materials (Schneider & Krajcik, 2002) and prior and current science course work have been noted as supporting PCK development among science teachers (Adams & Krockover, 1997).

Methods

Participants

The 76 secondary science teachers in this project were predominately from two states in the United States. Each teacher participated in one of the four induction programs. The general induction programs (GEN), electronic mentoring programs (eMP), and science-specific university programs (SSUP) had approximately an equal number of teachers, and approximately 30% of these teachers worked with students in poverty (free and reduced lunch recipients). The alternative certification (AC) group had less than half of the participants of the other groups, and they worked predominately with students in poverty (free and reduced lunch recipients). More than half of all of the teachers taught in their area of expertise. Table 1 provides demographic data about the newly hired science teachers in this study.

Table 1. Demographics of Newly Hired Science Teachers at Year 3 (N = 76).

	Induction Program			
	GEN	*eMP*	*SSUP*	*AC*
N	22	23	22	9
Middle School	5	6	7	2
High School	17	17	15	6
FRL[1]	5	9	7	6
Infield teachers[2]	12	12	13	6

[1] Schools with more than 30% of the students participating in free and reduced lunches (FRL).
[2] 50% or more assigned teaching time in area of expertise.

Methods of Data Collection and Analysis

Prior to the study, demographic information was collected from each teacher, as were the new teachers' expectations for the upcoming years. In addition to this interview, there were two different forms of data collected in this study. The first data source involved the Teacher Belief Interview (TBI) (Luft & Roehrig, 2007), which is a semi-structured seven-question interview with coding maps that captures the epistemological beliefs of teachers. Teachers were interviewed using the TBI prior to the start of the study, and after each year for three years. All of the interviewers were trained prior to interviewing teachers, and each digitally recorded interview lasted between 30 and 90 minutes. The development of the TBI, the interview questions and example responses can be found in Luft and Roehrig (2007). Previously, a Cronbach alpha coefficient was calculated at 0.77 for this interview protocol.

The responses from the teachers on the TBI were reviewed, analyzed and scored by two independent researchers using the corresponding coding maps, and then scored collectively. This process contributed to the reliability of the data collection (Silverman, 1993). These responses were then quantified following Miles, Huberman, and Saldaña (2013). *Traditional* and *instructive* responses represented more traditional or teacher centered beliefs, and were scored one or two respectively. *Responsive* and *reform-based* responses represented beliefs aligned with the goal of the current science education reforms and student centered learning, and were scored with four or five respectively. *Transitional* responses, scored with a three, demonstrate an affective response toward students, but do not clearly affirm the students' role in the classroom as co-constructors of knowledge. The responses for each participant were summed and used in the analysis. A total score of 35 indicates student centered beliefs, while a score of 7 indicates teacher centered beliefs.

The second form of data collected was the PCK interview, which was used to elicit how teachers transformed content into lessons for students (see Lee, Brown, Luft, & Roehrig, 2007). The semi-structured interview asked teachers to discuss the planning and enactment of a best lesson in science and was drawn from the work of Loughran, Milroy, Berry, Gunstone, and Mulhall (2001). The interview focused

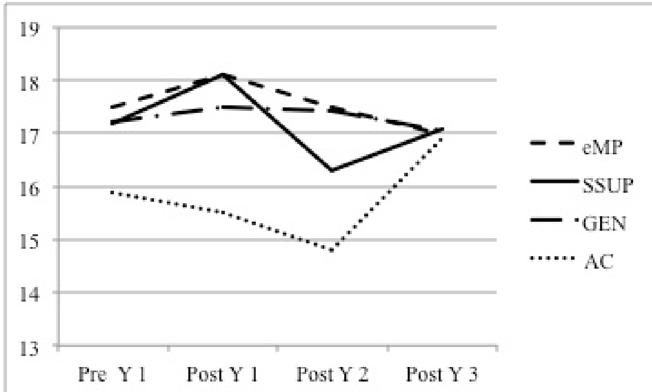

Figure 1. Belief Scores over Time (N = 76).

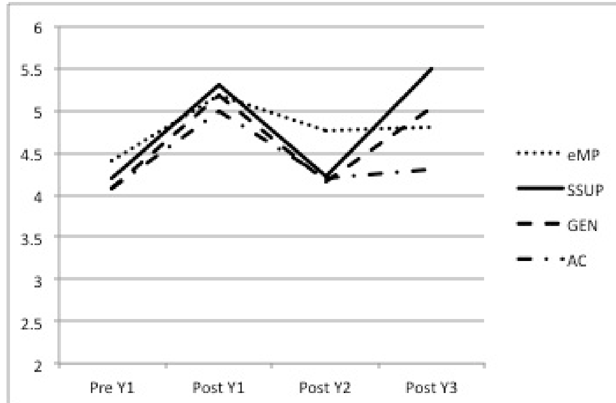

Figure 2. PCK –Category 1 –Student Knowledge - Scores over Time (N = 76).

on five aspects of PCK, which fall into Category 1: Knowledge of Student Learning, or Category 2: Knowledge of Instructional Strategies and Representations. The PCK interview followed the TBI, and used the same data collection and analysis processes as in the TBI protocol. The only difference was that answers were scored as limited, basic, or proficient, and scored one, two, or three respectively. These numbers indicate a progression, with a score of three indicating PCK that is more proficient. The Cronbach alpha coefficient for the overall PCK interview was calculated at 0.73. In the analysis, the scores for each teacher were summed by category and overall, with a total score of 15 representing proficient PCK, and a score of three indicating limited PCK. An expanded discussion of this interview protocol can be found in Lee et al. (2007).

The TBI and PCK scores were analyzed using the inferential statistics associated with Statistical Package for the Social Sciences (SPSS). All of the collected beliefs and PCK data were analyzed comparatively with an analysis of variance over time and by group, and follow-up tests were conducted as needed.

Findings

Quantitative Analysis of the TBI

Figure 1 shows the change in beliefs of teachers by induction program over three years. Overall, the science-specific groups (eMP & SSUP) and the GEN group maintained transitional beliefs over three years, with the AC group of teachers moving towards traditional, then back to transitional beliefs. However, the results of the analysis show that there was no significant difference in teacher beliefs between time points. Over the three-year period there was no significant difference in the beliefs of all teachers over time ($F(2.96, 213.31) = 1.57$, $p = 0.21$, $n = 76$), and the main effect by induction program was also not significant ($F(8.89, 213.31) = 1.16$, $p = 0.32$). In this analysis, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(5) = 12.64$, $p = 0.027$, therefore degrees of freedom were corrected using estimates of sphericity ($\varepsilon = 0.91$).

Quantitative Analysis of the PCK

In the first quantitative analysis, there was a significant difference in the PCK of all teachers over time ($F(2.86, 206.08) = 24.39$, $p = 0.00$, $n = 75$) , but not by induction program ($F(8.59, 206.08) = 0.75$, $p = 0.66$). Posthoc comparisons, using the Bonferroni correction (controls for alpha inflation), revealed a significant difference between preyear 1 and postyear 1 ($MD = 2.06$, $SE = 0.29$, $p = 0.00$), postyear 1 and postyear 2 ($MD = 1.52$, $SE = 0.29$, $p = 0.00$), postyear 2 and postyear 3 ($MD = -0.92$, $SE = 0.20$, $p = 0.00$), and preyear 1 and postyear 3 ($MD = -1.46$, $SE = 0.23$, $p = 0.00$). Teachers' PCK increased after postyear 1 and postyear 3, but was low at preyear 1 and decreased after postyear 2.

The second analysis examined the change in teachers' PCK in the area of Student Knowledge by induction program over three years (see Figure 2). A repeated measures ANOVA with a Huynh-Feldt correction determined that there was a significant difference in this category among all teachers over time ($F(2.84, 204.40) = 12.89$, $p = 0.00$). However, the main effect by induction program was not significant ($F(8.52, 204.40) = 1.04$, $p = 0.41$).

Posthoc comparisons, using the Bonferroni correction

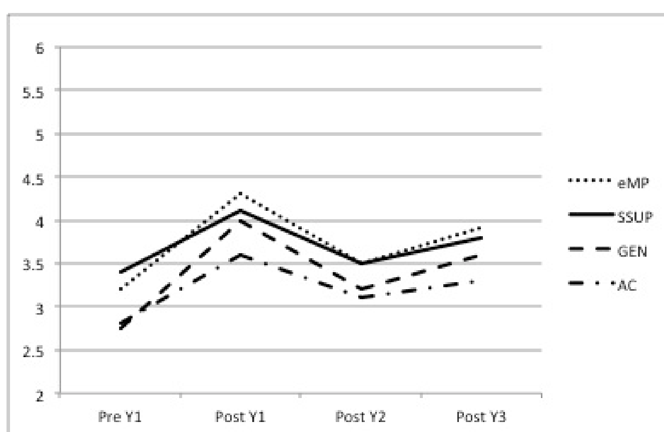

Figure 3. PCK- Category 2 – Instructional Strategies - Scores over Time (N = 76).

(controls for alpha inflation), revealed a significant difference between preyear 1 and postyear 1 (MD = –1.01, SE = 0.19, p = 0.00), postyear 1 and postyear 2 (MD = 0.83, SE = 0.21, p = 0.00), postyear 2 and postyear 3 (MD = –0.60, SE = 0.15, p = 0.00), and preyear 1 and postyear 3 and (MD = –0.78, SE = 0.16, p = 0.00). Teachers' knowledge of students was high after postyear 1 and postyear 3, but low at preyear 1 and postyear 2.

A third analysis examined the change in teachers' PCK in the area of Instructional Strategies and Representations by induction program over three years (see Figure 3). Over the three-year period there was a significant difference in this area among all teachers over time (F(3, 69) = 17.87, p = 0.000, n = 75). However, the main effect by induction program was also not significant (F(8.52, 204.40) = 1.04, p = 0.956).

Posthoc comparisons, using the Bonferroni correction (controls for alpha inflation), revealed a significant difference between preyear 1 and postyear 1 (MD = –1.03, SE = 0.16, p = 0.000), postyear 1 and postyear 2 (MD = 0.72, SE = 0.14, p = 0.000), postyear 2 and postyear 3 (MD = –0.34, SE = 0.12, p = 0.047), postyear 1 and postyear 3 (MD = 0.38, SE = 0.14, p = 0.042), preyear 1 and postyear 3 (MD = –0.65, SE = 0.13, p = 0.000). In this analysis, teachers' Knowledge of Instructional Strategies and Representations were highest at postyear 1 and postyear 3, and lowest at preyear 1 and postyear 2. Overall, there was a curve increasing sharply, then moving downward and then increasing again.

Discussion, Conclusions, and Additional Research Questions

This study was conducted to determine if a two-year science-focused induction program could change the beliefs and PCK of newly hired teachers over time. The analysis of data revealed that there was no significant difference between the teachers who participated in the different induction programs over time. However, there were significant differences between the teachers at certain time points, and general differences between the teachers in the different induction programs. The following paragraphs will elaborate on these differences.

In terms of the beliefs of the newly hired science teachers, there were no differences between the induction program groups. However, it is evident that the beliefs of the teachers were changing over this period of time, with the AC group of teachers moving towards more student-centered positions, and the other groups sustaining their transitional beliefs. This subtle change suggests the importance of initial certification programs for cultivating beliefs that are student-centered (Marbach-Ad & McGinnis, 2008), as the SSUP, eMP, and GEN teachers had participated in initial certification programs. These teachers potentially held more developed core and peripheral beliefs (Rokeach, 1896), which contributed to the limited fluctuation of their beliefs over time.

The subtle change in beliefs among all groups illustrates how school context can influence the beliefs of newly hired science teachers (Luft et al., 2011). In the case of the SSUP, eMP, and GEN teachers, their initial beliefs aligned and were potentially strengthened with the school context. This alignment could be important in future years, as these teachers may have a disposition toward student-centered instruction (Crawley & Salyer, 1995). The AC teachers were influenced by the school context, but the strength of their beliefs is unclear. Over time, these teachers may be influenced by school contexts which emphasize traditional approaches.

It is generally agreed that new experiences can contribute to the modification of teacher beliefs (e.g., Jones & Carter, 2007; Nespor, 1987; Pajares, 1992; Richardson, 1996), and there is little disagreement that new teachers are rapidly modifying their beliefs as they engage in new classroom and school experiences. However, little is known about how newly hired teachers modify their beliefs. Moreover, the nature of this modification may be significant to the teacher, but appear insignificant to the observer. More explorations are needed in this area from the teacher's perspective.

In terms of the PCK of the newly hired science teachers, there were also no significant differences between induction groups. However, it does appear that there were some differences between the SSUP and eMP teachers, and the AC and GEN teachers. Throughout the three years, SSUP and eMP teachers had higher scores pertaining to their instructional strategies than did their peers in the other programs, and the SSUP teachers held more knowledge about students than did their peers at the end of three years. This subtle change may be attributed to the induction programs that were focused on science (Luft et al., 2011), but more studies are needed.

More importantly, this data reinforces that PCK is developing and changing as teachers work with students in their classrooms (e.g., Friendrichsen et al., 2009; Mullholland & Wallace, 2005). PCK may fluctuate as newly hired teachers interact with their mentors and colleagues (Simonsen, Luebeck, & Bice, 2009), curricular materials (Schneider & Krajcik, 2002), and prior and current science course work (Adams & Krockover, 1997). While it is not clear what factors are moderating or mediating the significant changes of a newly hired teacher's PCK, there seems to be some small interaction between an initial certification program and an induction program. Teachers who participated in initial certification programs and science-focused induction programs seemed to hold PCK with student-centered features. Roehrig and Luft (2006) noted the importance of this alignment between these programs in the development of the newly hired teachers' beliefs and practices. They did not explore the development of newly hired teachers' PCK.

This study ultimately contributes to our understanding of early career teachers' learning (see Feiman-Nemser, 2001; Luft, 2012). The degree of fluctuation within the area of beliefs and PCK suggests that newly hired science teachers need programs that are conducive to sustaining and strengthening beliefs and PCK. Such programs should focus on fortifying student-oriented beliefs and knowledge, so that science instruction can be enacted that supports student learning. Addressing science explicitly throughout the early career of a teacher is essential, but often overlooked. Most induction programs are developed to support all teachers and not subject matter specialists. Clearly, future researchers will need to focus on articulating and assessing the tasks that support early career science teacher development. Luft (2012) and Feiman-Nemser (2001) have just proposed a model to be examined and studied.

This study adds to a growing body of work around newly hired science teachers. It suggests that newly hired science teachers are in a period of change, but that there is more to know about their experiences and development. In addition to the areas of exploration that are noted in this discussion, there are specific questions that will be important in the area of newly hired science teachers. These questions are:

- How do newly hired science teachers change their beliefs and knowledge within the different induction programs over longer periods of time? This question calls for longitudinal qualitative and quantitative explorations of newly hired teachers. The findings could provide specific information that could guide the development and enactment of initial certification and induction programs.
- How do the practices of newly hired science teachers correspond to their beliefs and knowledge? This question links cognitive attributes to classroom instruction, and attempts to clarify this relationship. The findings from this question could provide insight into the design of initial certification and induction programs.

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