“Now I’ve seen what they can do”: How implementing a cognitive apprenticeship can impact middle school science teachers’ beliefs and practices

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Abstract

In this paper, we take a longitudinal case study approach to explore changes in two middle school teachers’ beliefs and their self-reported changes in practice, as they implemented a cognitive apprenticeship intervention focused on teaching written scientific explanations. We collected interview data as the primary data source and triangulated it with the teachers’ choices of tasks to explore how their beliefs about their students, their beliefs about writing, and their choices of instructional tasks changed over time. Findings suggest shifts in teachers’ beliefs and changes in their instructional practices (i.e., choice of tasks) following implementation of the cognitive apprenticeship. Our study found that the utilization of cognitive apprenticeship influenced their beliefs and, consequently, their choice of writing tasks.

Introduction

Recent science education reform presents a vision for scientific proficiency based on a view of science as both a body of knowledge and as a way of knowing, and promotes teachers involving students in the *practices* of science, which includes *constructing explanations* (Next Generation Science Standards [NGSS]; NRC, 2013). Participating in scientific practice routinely involves writing to develop models, construct and critique explanations and arguments, and engage in mechanistic reasoning (Lee et al., 2013).

In recent years, there have been efforts to interweave science content with language skills in curriculum and instruction with heightened expectations for science literacy. Students are expected to read and write as they engage in scientific practices (Lee et al., 2013). High-stakes standardized science tests also reflect this emphasis on scientific literacy through heightened expectations for written explanations and arguments (NRC, 2013). Yet, two-thirds of students in the U.S. lack even the most basic academic writing skills, and consequently, experience steeper struggles in developing scientific literacy (NCES, 2012).

Students need science teachers to engage and instruct them in unpacking the scientific practices in writing. This depends on science teachers’ learning and motivation to “take-up” practices that are unfamiliar and may not align with their existing beliefs about students, about pedagogy in general, or about writing in science specifically. Substantial literature demonstrates that teachers’ beliefs play an important role in how they take up new practices and select tasks (see Fives & Gill, 2015). As beliefs can influence practices, so too can the implementation of new practices, and the awareness of their effectiveness, influence teachers’ beliefs (Guskey’s 1986, 1989). Little research has addressed how implementing a Cognitive Apprenticeship influences teachers’ beliefs and practices of engaging students in scientific practices through writing. The motivation for this paper came from interviews with two middle school science teachers (“Maggie” and “Kim”) as they participated in a larger project implementing a Cognitive Apprenticeship intervention designed to support students in writing scientific explanations.

Cognitive Apprenticeship is an instructional approach that focuses on modeling, scaffolding, and fading support to “apprentice” students in complex reasoning and practices (Brown et al., 1989). As a form of curriculum intervention, CA may potentially be educative for both teachers and students. This model was effective in teaching domain-general literacy skills (Harris et al., 2006) and other domain-specific practices in math (e.g., Schoenfeld, 1985) and history (e.g., De La Paz et al., 2017). Through CA, teachers can model, scaffold, and fade the use of specific strategies or reasoning to complete complex tasks to help students learn to use them independently (e.g., Harris et al., 2006).

In this study, we address the gap in understanding how implementing a CA influences teachers’ beliefs and practices of engaging students in scientific practices through writing. We explore how implementing a CA influenced teacher

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beliefs along dimensions identified in the literature (Fives & Buehl, 2012) and their teaching practices, specifically, their choice of writing tasks (Fives & Gill, 2015). Due to the small size and specific context of this case study, we present our findings in the form of a hypothesis about how implementation of a CA may influence teachers' beliefs and practices. We anticipate that this hypothesis can be further addressed through larger-N studies.

Literature Review

Traditional Writing Instruction and Tasks in Science Classrooms

Although writing can potentially deepen students' conceptual understanding in science (Brown et al., 2010; McNeill & Krajcik, 2007), teachers struggle to incorporate suitable writing tasks that go beyond transcribing texts or short responses (Applebee, 2011). Drew and colleagues (2017) surveyed middle and high school content area teachers (e.g., science, history math) and only a third reported assigning written tasks in class. Similarly, Kiuhara and colleagues (2009) found that teachers spent minimal time teaching students how to write in science classrooms through a self-reported survey. When they did focus on writing, chosen tasks were not cognitively demanding. Step-by-step lab procedures, note-taking, fill-in-the-blank worksheets, lists, and short- answer expository questions were common (Kiuhara et al., 2009). Some of these tasks may support students' conceptual understanding, but rarely are they designed to promote analytical thinking and reasoning. Kiuhara and colleagues also found that 60% of the science teachers voiced a need for more training on writing instruction (Kiuhara et al., 2009).

Challenges Science Teachers Experience with Writing Instruction

Many evidence-based writing interventions exist for students with diverse learning needs and are used by English teachers and special educators (e.g., Graham & Perin, 2007). While there are some research studies on evidence-based writing approaches in science (e.g., Sampson et al., 2013), they have not routinely made their way into classroom practices (Kiuhara et al., 2009). Teachers' reluctance to integrate literacy instruction in science classrooms partially comes from a lack of understanding of evidence-based writing instruction in content-area classrooms (Graham & Perin, 2007).

Traditional teacher education programs do not provide adequate training on writing instruction for teacher candidates (Drew et al., 2017). Consequently, science teachers feel underprepared to integrate writing instruction (Gillespie & Graham, 2014). Teacher education, professional development (PD), and high-quality curricula are pivotal in providing both novice and experienced teachers with much-needed support in delivering effective writing instruction.

Cognitive Apprenticeships in Professional Development

There is a body of evidence supporting the notion that curricular materials and interventions can be "educative": that is, they can promote teacher learning (e.g., Davis & Krajcik, 2005), and potentially, impact beliefs and other cognitive and affective constructs. It is instructive to consider the way in which implementation of CA may be educative in this way.

CA has been used in professional development (PD) to improve science teachers' instruction (e.g., Kardash, 2000; McNeill & Knight, 2013; Peters-Burton et al., 2015). This body of literature points to the potential impact of these CA-based PD on teachers' beliefs (e.g., McNeill & Knight, 2013; Peters-Burton et al., 2015), pedagogical content knowledge (e.g., McNeill & Knight, 2013), and marginally, their teaching practices (Lewis et al., 2015).

Peters-Burton and colleagues (2015) provided teachers with PD on CA to enhance their ability to design effective inquiry-based instruction. The PD deepened teachers' scientific reasoning, however, a shift in this knowledge did not translate into practice because of perceived time constraints or deficit views of their students' abilities. McNeill and Knight (2013) and McNeill and colleagues (2006) also designed a CA-based PD to support teachers' understanding of scientific argumentation using students' oral and written argumentation in the science classroom.

Both teams of researchers provided opportunities for teachers to analyze the quality of students' arguments. They found that teachers developed some understanding of the structure of arguments (i.e., claim, evidence, and reasoning; see McNeill & Knight, 2013). 70% of the teachers were able to apply their knowledge of the argumentative structure when analyzing students' writing; however, they found that teachers struggled to apply this understanding when guiding classroom discussions, resulting in difficulties with fully integrating acquired instructional strategies in class (McNeill & Knight, 2013). Consistent with Peters-Burton et al.'s (2015) study, McNeill and Knight (2013) found that teachers' increased understanding of certain skills did not necessarily translate into their teaching practices. In fact, teachers often misapplied what they learned from the PD. While a CA-based PD helped teachers develop more sophisticated knowledge, it rarely sustainably impacted teachers' practices (e.g., Luft, 2001; McNeill & Knight, 2013; Peters-Burton et al., 2015).

Drawing on prior literature (Fives & Gill, 2015; Guskey, 1986, 1989), we make the assumption that changes in teachers' beliefs are integral to changes in their practices, and any professional development or curricular intervention that influences teachers' beliefs should be explored more fully for its potential effect on teachers' beliefs and practices. In the sections below, we describe our theoretical approach to understanding teachers' beliefs and practices, before turning to a description of our methodological approach and findings.

Theoretical Framework: Teachers' Beliefs and Practices

There are a variety of theoretical frameworks that relate teachers' practices and beliefs (e.g., Fang, 1996). For understanding the role of CA on teachers' beliefs and practices, we chose Guskey's model (1986, 1989; see Figure 1) because it conceptualizes how the implementation of teaching practices can lead to changes in teachers' beliefs, mediated by changes in students' learning outcomes (in our case, the work students produced as a result of the CA).

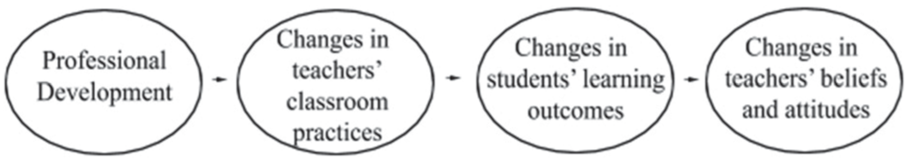


Figure 1. Guskey's (1986; 1989)'s model for teacher change.

A large literature base now supports a view of teachers as active decision-makers who hold "complex systems of beliefs that influence how they view students, themselves, and science" (Bryan, 2012, p. 427). A wide variety of teachers' beliefs have been described in the literature. Researchers have defined teachers' beliefs broadly in six topics: "(a) self, (b) context or environment, (c) content or knowledge, (d) specific teaching practices, (e) teaching approach, and (f) students" (Fives & Buehl, 2012, p. 472). Specific descriptions of beliefs also include teacher self-efficacy or the belief in one's ability to plan and manage a given situation or a task (Bandura, 1997; Pajares, 1996), and teachers' epistemological beliefs about learning and teaching science (Levin et al., 2018). In the context of this model, students' learning outcomes acts as a catalyst for teacher change. To guide our inquiry, we began with deductive codes grounded in the prior research on teacher beliefs, but we allowed the most salient categories to emerge inductively from the data, as we describe in our methods section below.

Methods

We took a longitudinal qualitative case-study approach (Yin, 2003) to understand teachers' beliefs and changes in the design of writing tasks. This approach is appropriate for beginning to chart the terrain of changes in teachers' beliefs and choice of tasks in order to generate new hypotheses for systematic testing in future studies. It allows us to draw on a variety of data sources to find patterns that "allow for multiple facets of the phenomenon to be revealed and understood" (Baxter & Jack, 2008, p. 544). While we only focused on two teachers, the longitudinal nature of our study allowed us to develop a fuller picture of changes in teachers' beliefs and choice of tasks over time. Gouvea (2017) highlights the value of small-N longitudinal case studies and notes: "As in medical research, small-N case studies allow for deep examinations of phenomena in real-life contexts, shedding light on the underlying mechanisms…" (p. 1). Ultimately, we propose a hypothetical mechanism for the educative nature of CA that could be tested in larger-N studies.

PD and Curricular Context of the Study

In this section we add some detail to describe the broader context of our work in light of its position within a larger study (see Levin et al., in press).

Maggie and Kim participated in PD focused on creating writing tasks to promote students' construction and critique of scientific explanations. The CA-based PD took place over two years. In the first year, we began by exploring the types of writing teachers assigned and learned that they primarily used writing mostly for assessment. Consequently, we made efforts to help them learn to incorporate writing during instruction in the service of scientific practices. We helped teachers develop lesson ideas for constructing and critiquing written explanations that are aligned to the topic areas in the science curriculum. Eventually, we asked the teachers to construct their own lessons. This occurred before the implementation of the CA.

In the summer between years 1 and 2, the teachers participated in two days of PD and then met for 60-90 minute sessions every other week during the school year. The team discussed how to implement a CA model of instruction and collaboratively planned an initial set of writing prompts over the summer.

In the second year, teachers implemented CA. The CA was designed to guide students through a process of constructing and critiquing explanations of natural phenomena that fit within the teachers' science curriculum. It was composed of six mini-lessons focused on scaffolding students' explanation writing and critique of it. It also included a set of "critical questions" that teachers used to scaffold students' writing. Students took a pre-test and a post-test designed to measure their abilities to construct and critique explanations and the Fourth-Edition of the Test of Written Language (TOWL-4) (Levin et al., in press).

Co-designing with the teachers, we developed a set of prompts that asked students to construct explanations for scientific phenomena (e.g., *"Why are some lakes made of freshwater and others are made of saltwater?"*). The six lessons were delivered using a CA approach, beginning with teacher modeling of how to think through constructing an explanation and critiquing using questions. Following the modeling, students constructed and critiqued explanations using a scaffold (e.g., graphic organizer), and finally fading out the use of the scaffold (see Levin et al., in press for further description of the intervention). Throughout the year, we collaboratively assessed students' ability to generate additional writing probes and solve issues with implementation, providing continuous support for the teachers.

Participants

Maggie and Kim both had been undergraduate science majors who subsequently graduated from a master's program in science education at a public four-year university in the mid-Atlantic region of the United States. At the time of this study, both teachers were in their third year of teaching. They each taught five sections of seventh-grade science at a suburban middle school, and they implemented the CA in all of their classes. As part of their graduate program, Maggie and Kim took a series of science methods courses taught by the second author. Although these courses aligned with expectations of NGSS, like most science methods courses, they did not go into great depth on scientific literacy and writing.

Data Sources

We conducted semi-structured interviews to capture the teachers' articulation of their beliefs (Glesne & Peshkin, 1991). In the first-year interview, we primarily collected data to evaluate the project and did not intend to explore teachers' beliefs in-depth, so we did not ask specific questions about their beliefs. What emerged from this first interview presented an opportunity to learn more about the teachers' beliefs about writing and their self-reports on their practices of supporting student writing. This drew our attention to understanding how participating in the PD and CA influenced the teachers' beliefs and, ultimately, the nature of the tasks they created.

We used a similar approach in the third-year interviews to determine if and how teachers' beliefs and choice of tasks changed over time. We ultimately interviewed the teachers three times: at the end of the first year (before the CA), after the CA in the second year, and a year after the implementation of the CA, to see if changes we detected between years one and two had persisted (see Appendix A for interview protocol). We audio-recorded and transcribed each interview verbatim (Creswell, 2005). We also collected lessons the teachers had independently written in the first year and again in the third year, after the CA. Since we constructed the writing tasks the teachers used during year two (when the CA was implemented) there are no teacher-constructed tasks from that year included in our analysis.

Data Analysis

To analyze the teachers' choice of tasks, we reviewed the tasks they produced in the first and third years, focusing on how the tasks could facilitate students' construction and critique of explanations. To explore their tacit and expressed beliefs, we analyzed the three years of interviews and considered their choice of tasks.

We organized the interview transcripts using HyperResearch software and the first author began the analysis by coding the data using a combined deductive and inductive approach (Maxwell, 2013), using deductive codes derived from the literature on beliefs (e.g., Fives & Gill, 2015) and adding other codes as they emerged from the data using an open-coding approach (Glaser and Strauss, 1967). She used these codes to develop broader themes regarding the teachers' beliefs by aggregating similar codes together and writing analytical memos (Saldaña, 2016). See Appendix B for the list of codes and Appendix C for the categorization of themes. From these themes and memos, we constructed a case study narrative using representative examples. The trustworthiness of the findings was established by using rich and thick descriptions of the cases, member-checking following the third-year interviews, and by reviewing and resolving disconfirming evidence (Creswell & Creswell, 2017).

Findings

Our analysis revealed two major categories in which we hypothesize the teachers' beliefs changed through implementation of the CA: (a) beliefs about students and (b) beliefs about the functions of writing in science class. Analysis of the task choices also revealed differences before and after implementation of the CA.

Changes in Beliefs About Students

Our analysis of the first-year interviews, before teachers implemented CA, suggested both teachers expressed some deficit beliefs about students. For example, Maggie said her students were "not really good at evaluating each other on anything" and noted that it was "like a struggle to get them to really elaborate." Both teachers' descriptions of their choice of tasks and instructional practices reflected beliefs that their students had such deficits that the teachers could only take "baby steps" in using evidence to make a written explanation for a phenomenon. Kim suggested that constructing explanations was too challenging for their students and offered them definitive "rules" for making a claim. As she reported: "[T]hey do a lot better when they have something very concrete like, like, if it has A, B, and C, it's a good claim." The teachers had particularly strong deficit beliefs about their students who were English learners. Kim categorized them as "lower-level" performers: "[T]here are a lot of my ESOL students or my lower-level students that just don't use those words or have never heard them before." Analysis of their writing tasks showed that the teachers created scaffolds to support writing, but never faded the use of those tools, which implies a tacit belief that their students could not make progress without scaffolds remaining in place.

In the second year interviews, after implementation of the CA, the teachers expressed more positive beliefs about what their students could do. Maggie, for example, continued to acknowledge her students' struggles, but she also noted improvements, such as their ability to reason using data: "They're good at being like, 'Oh the temperature changes by eight degrees, so it must be a chemical change.'" Maggie also described growth in her students' abilities to construct written explanations. "I feel like once they get it (how to write an explanation), they're really good at doing it." Kim even referred to her earlier deficit beliefs when she described what she saw during the CA implementation and discussed what she saw in her students' abilities:

> *I think that last year, I overcompensated a bit for some of my students when I thought that they needed help, but now I've kind of stepped back and seen what they can do, and they were really good this year.*

Kim also reported that her ESOL students, who she previously described as struggling learners, made huge improvements in science writing after implementing CA. In Kim's words, "A lot of English learners this year grew a lot. Their writing improved a significant amount."

The shift to asset-based beliefs persisted a year after the completion of the CA implementation. While continuing to acknowledge areas of improvement, Kim noted improvements more generally in her students' writing: "[B]y now the average student is pretty good with what I want with their seventh grade [writing] standards." These and other examples of asset beliefs that persisted beyond the CA implementation suggest a contrast from the first year, where the teachers rarely highlighted students' strengths.

Changes in Beliefs About the Functions of Science Writing

This quote marks the development of new beliefs about writing: as valuable for instruction.

> *...[T]o write about [chemical change phenomena], and the reasoning to be like, "A chemical change has one of these five signs. Because my solution went from clear to purple, it's representing one of those signs. Therefore, this must be a chemical change," -- that's a really higher-level thinking skill, where they have to connect multiple pieces together.*

Before implementing the CA, Kim and Maggie believed writing in classrooms was primarily for communication and assessment. In particular, Kim saw writing as a tool for getting students to display the correct answer so they could be assessed by her and on high-stakes tests. In describing the kinds of writing tasks she assigned, Kim expressed a preference for close-ended "correct answer" questions that addressed factual content covered on her assessments and high-stakes tests. She also reported she included more "structured" forms of writing like laboratory reports. We inferred from the description of tasks she chose that she did not believe writing served as a tool for instruction, but rather a tool for communication (i.e., structured laboratory reports) and for simple assessment that was easy to grade (i.e., close-ended questions).

Like Kim, Maggie expressed beliefs that suggested writing in science class was primarily for communication and assessment. She tied it to a school-wide approach to writing that was intended to prepare students for high-stakes tests: "[W]e taught biology where they make them write a lot. So, they're expected to write longer lab reports to prepare them for AP and IB classes." Thus, even though Maggie did report using writing in instruction, its use in instruction was primarily for practice communicating clearly in higher-level classes.

After implementing the CA, both teachers' beliefs about the role of writing expanded from a tool for communication and assessment to a vehicle for instruction. Kim believed critiquing each other's writing helped students develop metacognitive and critical thinking skills:

> *"But when they look at someone else's to evaluate, they're like- 'oh well, obviously, that's wrong. Obviously, you should have done this'...I think that has just helped them grow in that reflective, metacognitive way of looking at their writing…"*

Maggie's beliefs about writing also expanded over time, as revealed in the tasks she chose. She described the value in having students write explanations, noting in particular that critiquing explanations goes "hand in hand" with writing: "[I]t would make sense to me if you learn how to write [explanations] then you learn how to critique."

Importantly, both teachers did not abandon their beliefs about the importance of writing for assessment and communication, but the nature of what they began to notice and assess changed. A quote from Kim describes what the teachers came to believe was worth assessing: "A lot of them when they were going through their writing, you got to see more of that cause and effect in their thinking, which was great to see."

A year after delivering the CA, teachers retained these beliefs about writing instruction and believed writing plays a key role in helping students engage in explanation and argumentative reasoning. In many cases, we inferred teachers' tacit or unexpressed beliefs through their instructional practices. Shortly after, the school district began introducing a claims-evidence-reasoning approach (CER; McNeil & Krajcik, 2007). Although it was not required, both teachers reported investing time in teaching students to write explanations and arguments in class using a CER approach.

More generally, teachers came to believe writing was a valuable tool for reasoning, as Maggie described in the quote that opened this paper.

> *...[T]o write about [chemical change phenomena], and the reasoning to be like, "A chemical change has one of these five signs. Because my solution went from clear to purple, it's representing one of those signs. Therefore, this must be a chemical change," that's a really higher-level thinking skill, where they have to connect multiple pieces together.*

Thus, after implementing CA, both teachers demonstrated an expansion in beliefs about the functions of writing from communication and assessment to learning and reasoning. This change was also evident in their choice of tasks and reported instructional practices preceding and after the CA implementation.

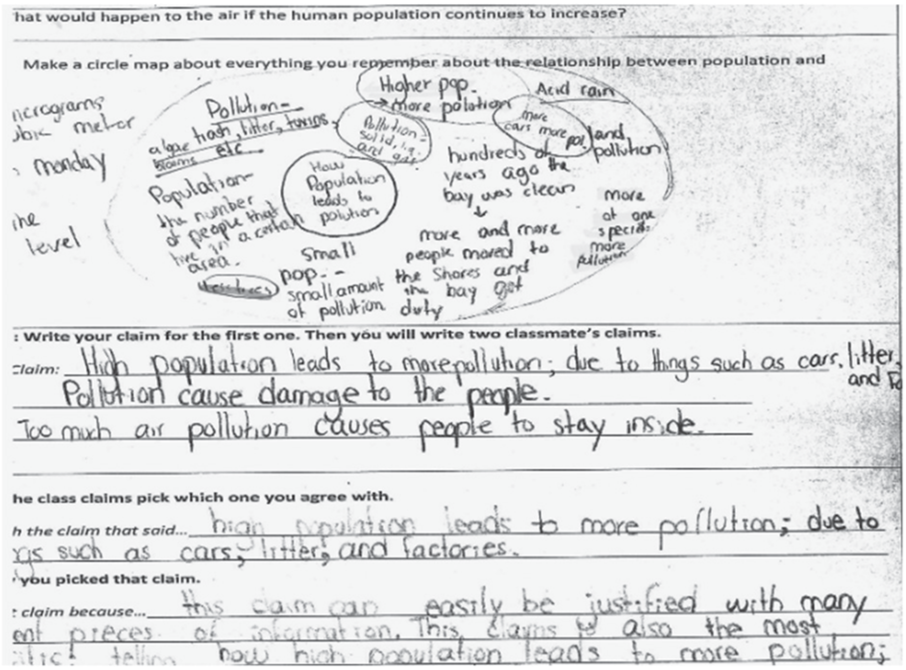
Changes in Choice of Writing Tasks

Before teachers implemented CA, their choices of writing tasks were not very systematic.

When asked about their instructional approaches, they did not describe any specific practice, nor did they mention reserving any time for writing instruction. In that first year, as we describe in our methods section, we made efforts to help the teachers learn to incorporate writing during instruction. We helped them develop ideas for instructional lessons on constructing and critiquing written explanations and arguments and then asked them to construct their own lessons. One of the lessons they designed is shown in Figure 2.

In this task, students were asked to formulate and choose the best explanation or "claim" made about a science phenomenon (i.e., population change). Although they did make efforts to encourage students to construct and critique each other's proposed explanations (in this case, their claims), the teachers had the whole class brainstorm together the "everything you remember" and "circle map" about the relationship between population and pollution. As shown below, the "claim" that they had students make really led logically to only one correct answer. Thus, although the teachers wanted students to critique each other's claims, there was little diversity in the claims and very little opportunity for students to disagree and argue.

By contrast, after the CA implementation, teachers independently continued using the claims, evidence, and reasoning approach and integrated it into their



hat would happen to the air if the human population continues to increase?

Make a circle map about everything you remember about the relationship between population and

: Write your claim for the first one. Then you will write two classmate's claims.

Claim: High population leads to more pollution; due to things such as cars, litter, and
Pollution cause damage to the people.
Too much air pollution causes people to stay inside.

he class claims pick which one you agree with.

h the claim that said... high population leads to more pollution; due to
gs such as cars, litter, and factories.

you picked that claim.

t claim because... this claim can easily be justified with many
ent pieces of information. This claims is also the most
tic! telling how high population leads to more pollution;

Figure 2. Population change task, developed during year 1 (2016).

usual practice. Now they focused more on creating tasks that allowed students to construct diverse explanations and critique them. For example, they had students conduct an investigation where light was shown through different filters to shine on objects with different colors. Rather than assigning traditional lab reports, as they described in earlier interviews, they enhanced their inquiries by asking students to write "scientific explanations" that they had to construct using a claims-evidence-reasoning framework. Figure 3 below shows an example. Since the students had collected their data, their findings led to a variety of responses. This activity created opportunities for students to construct, critique, and argue about explanations, practices which were not as well-supported by their choice of tasks before the CA.

While the CER format was promoted by the district, it is notable that the approach was not required and other science teachers in the school did not use it. Yet, Maggie and Kim adapted it as an approach to structure students' written work in the context of investigations that they were already using in instruction.

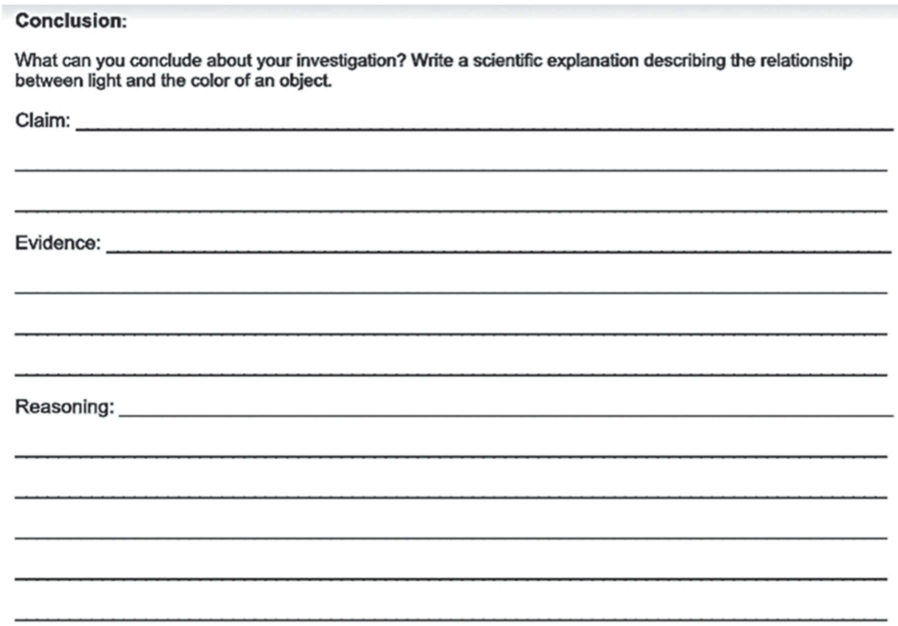
Discussion

In this study, we explored changes in two teachers' beliefs and choices of tasks before and after they implemented a CA focused on writing scientific explanations. Findings suggest that before implementing CA, Maggie and Kim expressed deficit beliefs about students and felt strongly about the limited role of writing in students' learning. Echoing findings from previous work by Peters-Burton et al. (2015) and Lewis et al. (2015), teachers' beliefs transformed after implementing CA regularly in their classrooms. Changes in their beliefs were also reflected in their choices of tasks. Before participating in the CA, the teachers expressed beliefs about the use of writing *for assessment*, whereas after the implementation they were more likely to express beliefs as valuable *for instruction.*

Although we found that changes in teachers' choice of tasks were consistent with the transformation in their beliefs, we acknowledge that other factors may have further motivated teachers to adopt new practices. For instance, the district's push to adopt the use of CER could have incentivized the teachers. We argue that the structural similarities between a CER and the tasks designed as part of the PD may have compelled the teachers to use the CER more. Given the scope of this study, we cannot draw conclusions about the causal relationship between CA and the teachers' changes in beliefs; however, our findings suggest that implementing CA and observing the qualitative differences in students' work allowed the teachers to see beyond their students' deficits. To elaborate, CA allowed both teachers to "apprentice" students in complex reasoning and practices (Brown et al., 1989) and were attuned to observe students' progress. Since the CA called for the teachers to gradually allow students to engage in sophisticated reasoning independently, they had opportunities to observe what students *could* do, fueling their motivation to design more challenging tasks.

Revisiting Guskey's model (1986; 1989), we suggest a hypothetical conceptual framework for how implementing a CA focused on writing in science could impact teachers' beliefs and choice of tasks (Figure 4). Based on our findings, we hypothesize that the implementation contributed to changes in the teachers' beliefs and influenced the tasks they chose. The fundamental question is *how* implementation of the CA could impact teachers' beliefs and practices. This is particularly important considering there was little evidence that the CA intervention itself was conclusively effective in making substantial statistically significant improvements to students' writing (Levin et al., in press).

Drawing from Guskey's model, we assert that students are the key players that guide teacher change when new practices are introduced. The CA provided the means for students to demonstrate their strengths and to highlight for teachers the potential of including cognitively demanding writing tasks. While the effect of the CA on students' construction and critique of explanations was underwhelming (see Levin et al., in press), we hypothesize that as teachers worked with us to design prompts, evaluate, and provide feedback to students, they noticed improvement in their students' writing that cultivated more asset-based beliefs about students and positive beliefs about writing in


Conclusion:

What can you conclude about your investigation? Write a scientific explanation describing the relationship between light and the color of an object.

Claim: ____

Evidence: ____

Reasoning: ____

Figure 3. Teacher-designed worksheet from Year 3 (2018).

science class. We suggest that by attending to the substance of the students' written work, teachers were *more sensitive* to their students' success qualitatively than our quantitative measures could pick up. A large body of work shows that teachers' beliefs are influenced by what they attend to in students' thinking (Robertson et al., 2016). We also propose that this attention to what the students were able to accomplish through the CA influenced the teachers' beliefs and consequently influenced their choice of writing tasks.

Implications for Research and for Teacher Education

Unlike quantitative research, in a qualitative case study, we do not seek external validity and attempt to make generalizations (Creswell & Creswell, 2017). Instead, we raise a hypothesis that merit greater research. We are currently following other teachers who are implementing similar interventions, and we hope to test and refine this hypothesis. It may hold up over many cases that a CA focused on engaging students in scientific practices through writing influences teachers' beliefs in general, or we may find that it influences different teachers in different ways, or that it doesn't influence some teachers' beliefs at all.

For teacher education, our results suggest that, in accordance with our adaptation of Guskey's model (1986; 1989), engaging in new and innovative practices can impact teachers' beliefs and their future practices. We do not propose that teacher education programs or teacher PD primarily focus on having teachers implement prescribed curricula. Rather, we encourage exploring instructional approaches like CA that provide opportunities for students to develop and demonstrate disciplinary knowledge and practices through gradual release of scaffolding. These opportunities for students to engage in independent practice may not only benefit students' learning, but it may also open doors for teachers to examine the substance of their students' works and strengths. In doing so, we should facilitate more opportunities for teachers to review and analyze students' work and provide feedback to their students.

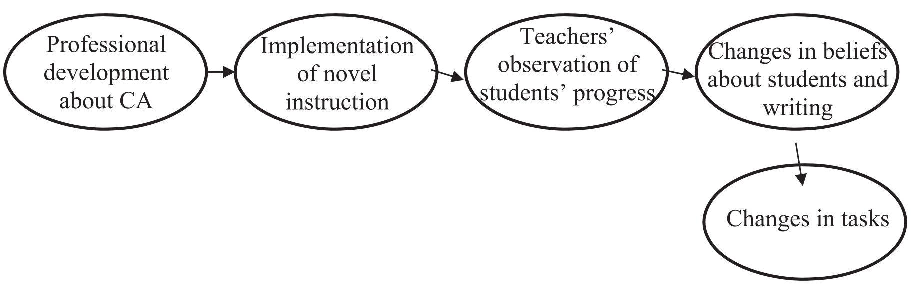


Figure 4. Adapted Guskey's model (1986; 1989).

References

Applebee, A., & Langer, J. (2011). A snapshot of writing instruction in middle schools and high schools. *English Journal, 100*(6), 14-27.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: W. H. Freeman and Company.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544-559. Retrieved from https://nsuworks.nova.edu/tqr/vol13/iss4/2

Brown, B. A., Ryoo, K., & Rodriguez, J. (2010). Pathway towards fluency: Using 'disaggregate instruction' to promote science literacy. *International Journal of Science Education, 32*(11), 1465-1493. https://doi.org/10.1080/09500690903117921

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18* (1), 32-42. https://doi.org/10.3102/0013189X018001032

Bryan, L. A. (2012). Research on science teacher beliefs. In B. J. T. Fraser, K. McRobbie, J. Campbell, & J. Barry (Eds.), *Second international handbook of science education: Vol. 24.* (pp. 427-295). New York, NY: Springer.

Creswell, J. (2005). *Qualitative inquiry and research design: Choosing among five traditions*([Nachdr.] ed.). Thousand Oaks, Calif.: Sage.

Creswell, J., & Creswell, J. (5th ed.). (2017). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks: SAGE Publications.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, *34*(3), 3-14. https://doi.org/10.3102/0013189X034003003

De La Paz, S., Monte-Sano, C., Felton, M., Croninger, R., Jackson, C., & Worland, K. (2017). A historical writing apprenticeship for adolescents: Integrating disciplinary learning with cognitive strategies. *Reading Research Quarterly, 52*(1), 31-52.

Drew, S., Olinghouse, N., Faggella-Luby, M., & Welsh, M. (2017). Framework for disciplinary writing in science grades 6-12: A national survey. *Journal of Educational Psychology, 109*(7), 935-955. https://doi.org/10.1037/edu0000186

Englert, R., & Conant, F. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483. https://doi.org/10.1207/S1532690XCI2004_1

Fang, Z. (1996). A review of research on teacher beliefs and practices. *Educational Research, 38*(1), 47-65. https://doi.org/10.1080/0013188960380104

Fives, H., & Buehl, M. M. (2012). Spring cleaning for the "messy" construct of teachers' beliefs: What are they? Which have been examined? What can they tell us? In K. R. Harris, S. Graham, T. Urdan, S. Graham, J. M. Royer, & M. Zeidner (Eds.), *APA handbooks in psychology. APA educational psychology handbook: Vol. 2. Individual differences and cultural and contextual factors* (pp. 471-499). Washington, DC: American Psychological Association.

Fives, H., & Gill, M. (2015). *International handbook of research on teachers' beliefs*: *Educational psychology handbook*. New York, NY: Routledge.

Gillespie, A. & Graham, S. (2014). A meta-analysis of writing interventions for students with learning disabilities. *Exceptional Children, 80*(4), 454-473. https://doi.org/10.1177/0014402914527238

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine.

Glesne, C., & Peshkin, A. (1991). *Becoming qualitative researchers*. New York, NY: Longman.

Gouvea, J. (2017). Insights from small-N studies. *CBE—Life Sciences Education*, *16*(3), 1-3. https://doi.org/10.1187/cbe.17-06-0110

Graham, S., & Perin, D. (2007). What we know, what we still need to know: Teaching adolescents to write. *Scientific Studies of Reading, 11*(4), 313-335. https://doi.org/10.1080/10888430701530664

Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher, 15*(5), 5-12. https://doi.org/10.3102/0013189X015005005

Guskey, T. R. (1989). Attitude and perceptual change in teachers. *International Journal of Educational Research, 13*(4), pp. 439- 45. https://doi.org/10.1016/0883-0355(89)90039-6

Harris, K., Graham, S., & Mason, L. (2006). Improving the writing, knowledge, and motivation of struggling young writers: Effects of self-regulated strategy development with and without peer support. *American Educational Research Journal, 43*(2), 295-337. http://doi.org/10.3102/00028312043002295

Kardash, C. A. M. (2000). Evaluation of an undergraduate research experience: perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, *92*(1), 191–201. https://doi.org/10.1037/0022-0663.92.1.191

Kiuhara, S., Graham, S., & Hawken, L. (2009). Teaching writing to high school students: A national survey. *Journal of Educational Psychology, 101*, 136–160. https://doi.org/10.1037/a0013097

Lee, O., Quinn, H., & Valdes, G. (2013). Science and language for English language learners in relation to next generation science standards and with implications for common core state standards for English language arts and mathematics. *Educational Researcher, 42*(4), 223-233. https://doi.org/10.3102/0013189X13480524

Levin, D.M., Chumbley, A.K., Jardine, H.E., Grosser-Clarkson, D., & Elby, A. (2018). Professed vs. enacted beliefs about responsive science teaching: Three cases from a practice-based middle level teacher certification program. In P. B. Howell, S. A. Faulkner, J. P. Jones, & J. Carpenter (Eds.)., *Preparing middle level educators for 21st century schools: Enduring beliefs, changing times, evolving practices*. Charlotte, NC: Information Age Publishing.

Levin, D.M., De La Paz, S., Lee, Y., & Escola, E.N. (in press). Use of cognitive apprenticeship models of instruction to support middle school students' construction and critique of written scientific explanations and arguments. *Learning Disabilities: A Multidisciplinary Journal.*

Lewis, E. B., Baker, D. R., & Helding, B. A. (2015). Science teaching reform through professional development: teachers' use of a scientific classroom discourse community model. *Science Education*, *99*(5), 896–931. https://doi.org/10.1002/sce.21170

Luft, J. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education*, *23*(5), 517–534. https://doi.org/10.1080/09500690121307

Maxwell, J. A. (3rd ed.). (2013). *Qualitative research design, an interactive approach* (pp. 87-120). Thousand Oaks, CA: Sage Publications.

McNeill, K. L., & Knight, A. K. (2013). Teachers' pedagogical content knowledge of scientific argumentation: The impact of professional development on k-12 teachers. *Science Education*, 97(6), 936–972. https://doi.org/10.1002/sce.21081

McNeill, K. L. & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In Lovett, M. & Shah, P. (Eds.), *Thinking with data* (pp. 233-265). New York, NY: Taylor & Francis Group, LLC.

National Center for Education Statistics. (2012). The Nation's Report Card: Writing 2011 (NCES 2012–470). Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Research Council. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Peters-Burton, E. E., Merz, S. A., Ramirez, E. M., & Saroughi, M. (2015). The effect of cognitive apprenticeship-based professional development on teacher self-efficacy of science teaching, motivation, knowledge calibration, and perceptions of inquiry-based teaching. *Journal of Science Teacher Education*, *26*(6), 525–548. https://doi.org/10.1007/s10972-015-9436-1

Robertson, A., Scherr, R., & Hammer, D. (2016). *Responsive teaching in science and mathematics* (Teaching and learning in science series). New York: Routledge, Taylor & Francis Group.

Saldaña, J. (3rd ed.). (2016). *The coding manual for qualitative researchers*. Los Angeles, California: SAGE.

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn by learning to write during the school science laboratory: Helping middle and high school students develop argumentative writing skills as they learn core ideas. *Science Education, 97*(5), 643-670. https://doi.org/10.1002/sce.21069

Schoenfeld, A. H. (2013). Reflections on problem solving theory and practice. *The Mathematics Enthusiast*, *10*(1), 3. Retrieved from https://scholarworks.umt.edu/tme/vol10/iss1/3

Yin, R. K. (2003). *Case study research: Design and methods*. Thousand Oaks, Calif: Sage Publications.

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