A Second-grade Teacher's Adaptive Teaching During an Integrated Science-literacy Unit

By: Melony Holyfield Allen, Catherine E. Matthews, Seth A. Parsons

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Abstract:

This case study explored the nature of one elementary school teacher's adaptive teaching during an integrated science and literacy unit. Data were collected during four consecutive weeks of instruction, weekly interactive planning sessions, 20 classroom observations, and 20 post-lesson interviews. Our analysis suggests that adaptations may be established during planning or emerge while teaching. This study also indicated that an adaptive teacher uses ongoing formative assessment to scaffold students' learning. A coding system that typifies how and why a teacher adapts instruction across disciplines can be used to examine adaptive teaching. Implications for teacher educators and researchers are discussed.

Keywords: Adaptive teaching | Teacher decision-making

Article:

1. Introduction

Marilyn Cochran-Smith (2003, 2005) argues that conceptualizations of effective teaching and teacher quality cannot be simplified to single measures such as student performance on standardized tests, as is often done in education discussions and governmental policy decision-making (Earley, 2000; Rothstein, 2010). Similarly, Kennedy (2010) posits that teacher characteristics cannot be equated to teacher quality. Such simplistic views do not take into account that teaching and learning are complex phenomena that are situated in specific contexts (Cochran-Smith, 2003, 2005; Kennedy, 2010; Putnam & Borko, 2000). Likewise, classroom teaching is unpredictable (Duffy, Miller, Parsons, & Meloth, 2009; Spillane, Reiser, & Reimar, 2002). For example, Eilam and Poyas (2006) explain, “Classrooms are highly dynamic, constantly changing, ill-structured, and characterized by concurrent interactions between multiple factors that combine inconsistently across case applications of the same nominal type” (p. 337). From these macro and micro levels of conceptualizing teachers' work, researchers have suggested that teachers who effectively navigate the complexity and unpredictability of classrooms are adaptive (Berliner, 1994; Corno, 2008; Darling-Hammond & Bransford, 2005; Fairbanks et al., 2010).

Nonetheless, little research has explicitly studied teachers' instructional adaptations as they engage in this complex and unpredictable work. The investigation reported here documented the nature of one second-grade teacher's adaptive teaching as she implemented an integrated guided inquiry-based science and literacy unit. Using case study methods, we examined how, when, and why this second-grade teacher engaged in adaptive teaching. An adaptation was defined as a deviation from the lesson plan associated with either the curriculum materials or the teacher's plan for instruction that demonstrated an application of professional knowledge in order to meet the needs of students or the demands of an instructional situation. Adaptations were noted during planning and while teaching. The teacher's rationales for adapting were documented during weekly interactive planning sessions and post-lesson interviews.

1.1. Theoretical frame

Perspectives of social constructivism informed this study. Based upon the work of Dewey (1938) and Vygotsky (1978), social constructivism posits that learners actively construct knowledge through social interactions within a specific context. Central to social constructivism are the ideas of Zone of Proximal Development (ZPD) and scaffolding. Vygotsky describes the ZPD as the sector between what a student can accomplish alone and what a student can accomplish with support. Scaffolding is the support provided that allows students to accomplish more than they could accomplish alone. One form of adaptive teaching is scaffolding; to scaffold students within their ZPDs, teachers adapt their instruction to the particular students they teach and the specific contexts in which they work. This perspective informed our research because we assumed a contextualized view of one teacher's instruction.

In addition, teacher adaptations are an important aspect of classroom instruction because social constructivists maintain that teachers and students co-construct classroom experiences (Vygotsky, 1978). Because students co-create classroom experiences through their reactions, questions, ideas, and understandings, the course of a lesson cannot be entirely preplanned; teachers must adapt their instruction based upon student participation in classroom discussions and activities (Sawyer, 2004). After instruction has been implemented, teachers use reflection, assessment data, curriculum materials, standards, and scope-and-sequence recommendations to plan future instruction. The curriculum materials used by the teacher in this particular study, *Seeds of Science/Roots of Reading (SS/RR),* are based upon social constructivist principles. Through the multimodal instructional model of these materials, “Do-it, Talk-it, Read-it, Write-it,” students participate in guided inquiry activities and discussions to develop evidence-based explanations and critical thinking skills (“What is it”, n.d.).

This theoretical orientation honors the complexity of classroom instruction: that teaching and learning are contextually situated phenomena (Cochran-Smith, 2003, 2005; Kennedy, 2010; Putnam & Borko, 2000). Similarly, our research assumes that classrooms are dilemma-ridden and unpredictable (Duffy et al., 2009;Eilam & Poyas, 2006; Spillane et al., 2002). What works in one situation or with one student will not necessarily work in a different situation or with a different student. To effectively operate within this complex and unpredictable environment, teachers must be able to adapt their instruction, responding to the students with whom they work in the situations in which they find themselves. Teachers must attend to the interactions among the dynamics of classroom community, tasks, materials, and students while effectively scaffolding their instruction to help students integrate and apply ideas (Harris & Rooks, 2010).

1.2. Background

Prior research on adaptive teaching (Duffy et al., 2008; Parsons, 2012) is grounded in theoretical foundations that suggest that adaptive teaching is a component of effective teaching (Darling-Hammond & Bransford, 2005; Lin, Schwartz, & Hatano, 2005). The current study built upon this work as well as prior work on the nature of inquiry-based instruction (National Research Council, 2012; Windschitl, 2003), teachers' use of curriculum materials (Brown, 2009; Remillard, 2005), and teachers' decision-making during planning (Borko, Roberts, & Shavelson, 2008; Hinnant, O'Brien, & Ghazarian, 2009). In the following sections, we review the literature on these topics.

1.2.1. Adaptive teaching as a characteristic of effective teachers

Teachers work with increasingly diverse students who are variable in their abilities, interests, linguistic backgrounds, and previous experiences. This increased diversity is the case in Australia (Burridge, 2009), Canada (Porter, 2004), China (Wong & Xiao, 2010), Germany (Werning, Loser, & Urban, 2008), Great Britain (Maylor, 2010), and the United States (Aud et al., 2012) as well as many other countries. Characteristics of increasingly diverse students can contribute to the unpredictability of teachers' work. If teachers are to meet the needs of all their students, then they must be able to make sound instructional decisions that allow for all students to learn and develop. Bransford, Darling-Hammond, and LePage (2005) asserted, “On a daily basis, teachers confront complex decisions that rely on many different kinds of knowledge and judgment and that can involve high-stakes outcomes for students' futures” (p. 1). To succeed within this dilemma-ridden environment, teachers must be adaptive. Randi and Corno (2000) indicated, “more and more, ‘good’ teaching is being characterized as flexible and responsive to different students and classrooms” (p. 680).

Two books published by the National Academy of Education (Darling-Hammond & Bransford, 2005; Snow, Griffin, & Burns, 2005) presented “adaptive expertise” as the pinnacle of teaching. Adaptive expertise strikes a balance between efficiency and innovation. Teachers must be efficient in that are able to apply research-based best practices, but they must also be innovative, so they can develop new strategies to use with students “for whom the existing routines are not enabling success” (Darling-Hammond & Bransford, 2005, p. 360).

Based upon their work in Chinese and U.S. classrooms, Lin et al. (2005) presented the theory of “adaptive metacognition.” They argued that: “Teachers…confront highly variable situations from student to student and class to class. One solution does not fill all, and teachers need metacognitive approaches that support adaptation and not just improved efficiency for completing recurrent cognitive tasks” (p. 245). This perspective further characterizes classroom instruction as unpredictable, thereby necessitating adaptations.

Research on exemplary teachers has found that effective teachers are adaptive. Pressley (2002) described Allington and Johnston's (2002) research on exemplary fourth-grade teachers: “Although they plan their instruction well, they also take advantage of teachable moments by providing many apt mini-lessons in response to student needs throughout the school day” (p. xiii). Summarizing Taylor and Pearson's (2002) project on effective schools and accomplished teachers, Duffy and Hoffman (2002) stated, “Instruction is a complex orchestration of techniques and materials that teachers creatively adapt from one instructional situation to another. Glossing over this complexity is misleading” (p. 385).

This body of literature, which includes theoretical articles and classroom studies, asserts that classrooms are unpredictable environments and that effective teachers must be adaptive in order to navigate this unpredictability.

1.2.2. Research on adaptive teaching

Although adaptive teaching is one component of effective instruction, little research has focused explicitly on teacher adaptations (Fairbanks et al., 2010). One line of research studied teachers' Adaptive Teaching Competency (ATC), which includes four teacher competencies that are related to student learning: subject knowledge, diagnosis, teaching methods, and classroom management (Vogt & Rogalla, 2009). This framework assumes that teachers use rich pedagogical content knowledge and ongoing diagnosis to flexibly implement instruction. Vogt and Rogalla conducted a quasi-experimental study in Switzerland where they coached the experimental group of teachers in the components of ATC. They found that the teachers who received the coaching scored higher in ratings of their ATC and their students had higher achievement gains than control teachers' students. Brühwiler and Blatchford (2011) used the ATC framework as their measure of quality teaching and found that among the 26 Swiss teachers they studied, ATC had a significant effect on students' learning.

These studies illustrate the importance of adaptive teaching and its interest to educational researchers outside of North America. However, these studies do not document how and why teachers adapt their instruction. Our research team embarked on a research agenda explicitly focused on studying how and why teachers adapted their instruction. This research is described below.

1.2.3. Our adaptive teaching research agenda

Adaptive teaching studies focus on teachers' application of professional knowledge in an instructional setting. Our understandings of adaptive teaching derive from a compilation of individual studies that have been conducted in similar contexts with replicated methodological procedures (Duffy et al., 2008; Miller et al., 2006; Parsons, 2012; Parsons, Davis, Scales, Williams, & Kear, 2010; Parsons, Williams, Burrowbridge, & Mauk, 2011). These replications allowed for comparisons and verification of findings while also deepening our understanding about how to best capture teachers' adaptations while teaching and their reasons for making adaptations. Using grounded theory (Glaser & Strauss, 1967), early studies of adaptive teaching allowed us to validate coding systems for adaptations teachers made and the associated rationales they offered, providing future researchers with a common typology to use to categorize teachers' adaptations and rationales (see Tables 1 and 2). However, all of these earlier studies documented adaptations teachers made only in the midst of teaching and only while teaching literacy. Teachers' adaptations made while planning or while teaching other subjects has not been studied.

Table 1. Adaptation codes.

1. The teacher modifies the lesson objective
2. The teacher changes means by which objectives are met
3. The teacher invents an example or an analogy
4. The teacher inserts a mini-lesson
5. Suggests a different perspective to students
6. Omits a planned activity or assignment
7. Changes the planned order of instruction

Table 2. Rationale codes.

A. Because the objectives are not met
B. To challenge or elaborate
C. To teach a specific strategy or skill
D. To help students make connections
E. Uses knowledge of student(s) to alter instruction
F. To check students' understanding
G. In anticipation of upcoming difficulty
H. To manage time

1.2.3.1. Early studies in our research on adaptive teaching

Miller et al. (2006) explored adaptive teaching by asking if literacy teachers' adaptations could be identified. Researchers were indeed able to identify literacy teachers' adaptations and found little variation in adaptations made by in-service and pre-service teachers. Four additional studies in 2007 examined adaptive teaching in literacy (Duffy et al., 2008). From this set of studies, seven adaptation codes and 10 rationale codes (see Tables 1 and 2) were developed.

1.2.3.2. Second phase of our research on adaptive teaching

In another set of studies (Parsons et al., 2010), researchers examined 24 literacy teachers teaching a total of 154 lessons. Researchers aimed to understand how and why teachers adapted their instruction. These studies identified 353 adaptations. Teachers most commonly adapted by inventing an example, analogy, or metaphor, and teachers most frequently reasoned that they adapted their instruction because the lesson objectives were not met. All of these studies took place in a school system that promoted prescribed literacy instruction. Researchers have speculated that prescribed literacy instruction might influence the frequency of adaptations and Parsons (2012) found that teachers adapted more frequently during more student-centered activities.

While our prior research found that literacy teachers made adaptations while teaching with the intentions of meeting students' instructional needs, these studies were limited to examining adaptations teachers made in the midst of literacy instruction. Consequently, the current research studied the nature of one teacher's adaptations made during planning and while teaching a guided inquiry-based science and literacy unit. Given the exploration of these new dimensions of adaptive teaching, we consulted the literature associated with the nature of inquiry-based science instruction, teachers' use of curriculum materials and instructional contexts, and teachers' decision-making during planning. In the following section, we explain how this literature informed the study described in this paper.

1.2.4. Inquiry-based science teaching

Historically, science education has embraced two major goals: (1) learning to do science (often called inquiry and now commonly referred to as scientific practices) and (2) learning science concepts or conceptual learning. The *Inquiry Synthesis Project* (Minner, Levy, & Century, 2010), a meta-analysis of 138 studies from 1984 to 2002, indicated that students who actively engaged in the learning process through scientific investigations were more likely to increase conceptual understanding than were students who experienced passive techniques.

Teaching for conceptual change continues to be at the heart of science education. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (National Research Council, 2012) will guide science instruction in the U.S. for the next decade. This report suggests that the nature of inquiry-based science instruction should integrate doing and learning through the following four aspects of scientific practice: (1) know, use, and interpret scientific explanations; (2) generate and evaluate scientific evidence and explanations; (3) understand the nature and development of scientific knowledge; and (4) participate productively in scientific practices and discourse (Duschl, Schweinggruber, & Shouse, 2007). The degree to which teachers incorporate these aspects of scientific practices into their instruction will seemingly influence the classroom environment and, therefore, how and why teachers adapt their teaching.

Windschitl (2003) suggested that there are four forms of scientific inquiry found in schools: (a) confirmation, (b) structured inquiry, (c) guided inquiry, and (d) open inquiry. Instruction, moving along this continuum, incorporates more aspects of scientific practice. For example, during structured inquiry, the questions and procedures are provided by the teacher, while in guided inquiry students design and implement procedures to answer questions posed by the teacher. In open inquiry, teachers may provide the subject matter but otherwise students generate scientific knowledge related to questions they identify using methods they choose.

Since the late 1980s, Biological Sciences Curriculum Studies' 5E Instructional Model (Bybee et al., 2006) has been used to facilitate inquiry instruction in elementary school classrooms across the U.S. This instructional model has also been used extensively in the development of new curriculum materials and professional development experiences. The 5Es consist of the following phases: engagement, exploration, explanation, elaboration, and evaluation.

Each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills. Once internalized, it also can inform the many instantaneous decisions that science teachers must make in classroom situations. (Bybee et al., 2006, p. 2)

This lesson plan model is largely synonymous with inquiry instruction in elementary science classrooms.

The *Seeds of Science/Roots of Reading* (*SS/RR*) curriculum implemented by our second-grade teacher does not use the 5E Instructional Model but rather uses a “Do-It, Talk-It, Read-It, Write-It” approach that “engages students in learning science concepts in depth, while explicitly teaching students to read, write, and discuss as scientists do” (“How it is Different”, n.d.).

SS/RR is an inquiry-based program of instruction. The Program Overview (n.d.) states, “Inquiry serves as one of the central strategies in the learning and teaching of science and literacy in the *SS/RR* program.”

1.2.5. Teachers, curriculum materials, and instructional contexts

Highly specified curriculum materials might limit teachers' autonomy about what and how to teach (Ede, 2006; Johnson, 1990; McNeil, 1986). Like Squire, MaKinster, Barnett, April, and

Barab (2003), we conceptualize teachers as co-makers of the curriculum in which they apply their professional knowledge to make decisions about the pedagogical approach and content that is represented in their planning and teaching. Brown (2009) defined teachers' pedagogical design capacity as their “ability to perceive and mobilize existing resources in order to craft instructional contexts” (p. 24). Others have indicated that contextual factors are equally important in how teachers design and enact curriculum materials (Remillard, 2000; Sherin & Drake, 2009; Squire et al., 2003). Our previous research supports both of these assertions. Therefore, we assume that (a) teachers shape the instructional context by drawing upon their content knowledge and pedagogical content knowledge and (b) teachers are influenced by the contexts in which they find themselves teaching and working.

We conducted this study in a school where the curriculum materials were not prescribed. The teacher in this study could adhere to the materials as written, adapt them in ways she deemed necessary, or choose not to use them at all. Such a context allowed our participant to make instructional decisions about what and how to teach. Curriculum materials are considered supports for teachers as they shift instructional practices (Kauffman, 2002). Davis and Krajcik (2005) argued that educative curriculum materials should help teachers “increase knowledge in specific instances of instructional decision making and assist them to develop more general knowledge that they can apply flexibly in new situations” (p. 3). In our study, the teacher was shifting her practice of teaching separate subjects toward an integrated teaching approach. The curriculum materials implemented during this study, *SS/RR*, are described below.

1.2.6. Seeds of Science/Roots of Reading (SS/RR) curriculum materials

SS/RR units, developed with funding from federal agencies, are designed to “capitalize on science-literacy synergies” (“Program Overview”, n.d.). *SS/RR*'s developers (Cervetti, Pearson, Barber, Hiebert, & Bravo 2007) argue that science and literacy share a synergistic relationship and that *SS/RR* activities aim to develop students' abilities to comprehend and engage in inquiry, use evidence to justify claims, and use the language of argumentation and concept specific vocabulary. Cervetti et al. (2007) reported that students made “significantly greater gains in science *and* literacy outcomes than students in comparison conditions” (p. 167). Teachers report that *SS/RR* curriculum materials are effective, assisting students to learn science and literacy by promoting student motivation, application of knowledge through hands-on activities, access to needed materials, and scaffolding of concepts (Wang & Herman, 2006).

In the *SS/RR* unit implemented in this study, “Designing Mixtures,” students explored the properties of various ingredients and applied their knowledge of properties to create various types of glues and sodas. Each lesson in the unit built off the previous lesson but was either focused on science or literacy. The primary instructional focus, either science or literacy, was noted in the teacher's manual of the curriculum materials. Students wrote recipes, learned about cause-and-effect relationships, and used summarizing as both a science inquiry and reading comprehension strategy. Through the texts provided with the curriculum materials, students learned reading comprehension strategies, nonfiction text features, and how to write procedural text. A detailed description of “Designing Mixtures” is provided in the Appendix.

1.2.7. Teacher decision-making during planning

Our previous adaptive teaching research was limited to the adaptations teachers made in the midst of instruction. The current study documented these adaptations as well as adaptations made during planning. The literature on teacher decision-making during planning informed this expansion of our research agenda. Scholars indicate that planning is a complicated process and that teachers' decisions during planning provide the foundation for their teaching (Borko et al., 2008; Henderson & Gornik, 2007). For example, during planning teachers must decide what and how to teach while taking into account factors such as standards promoted by government accountability systems (Meyen & Greer, 2009); available curriculum materials (Hewitt, 2006); and students' interests, backgrounds, and prior knowledge. Additionally, teachers must decide how to best support students' further growth (Hinnant et al., 2009).

In sum, theorists, teacher educators, and researchers describe classrooms as unpredictable environments and argue that teachers must be adaptive to navigate this unpredictability (Duffy et al., 2009; Spillane et al., 2002). Accordingly, adaptive teaching is viewed as a characteristic of effective teaching (Bransford et al., 2005; Lin et al., 2005; Randi & Corno, 2000). Nonetheless, few studies have examined how and why teachers adapt their instruction. Our research team has initiated a series of studies to investigate these phenomena. Our previous studies have examined the adaptations teachers make while teaching literacy. The current study builds upon this previous research by investigating a teacher's adaptations made during planning and while teaching an integrated inquiry-based science and literacy unit.

2. Method

This study utilized qualitative methods within a case study design (Yin, 2009) to examine and describe the nature of one teacher's adaptive teaching as she integrated science and literacy instruction. This in-depth case study complements existing reports of adaptive teaching that present frequency counts of teachers' adaptations during instruction (Duffy et al., 2008; Parsons et al., 2010). This design allowed us to capture and describe the teacher's adaptations, rationales, and the context in which they occurred.

2.1. Setting

This study occurred in a public, high-poverty, K–5 elementary school located in rural North Carolina, U.S. that was engaged in a partnership with our university. Throughout our partnership, we promoted and assisted teachers with integrating their science and literacy instruction. The second-grade classroom where this study was conducted had 23 students: 11 girls and 12 boys. Students ranged from seven to nine years old. There were six special needs students and eight academically gifted students in this class.

2.2. Participant

Ms. Hendrix (pseudonym), a young Caucasian woman in her fourth year of teaching, previously taught first and second grades. At the time of this study, she was in her second year of teaching second grade and her second year of teaching at this particular school. She served as an "on-site teacher educator" for our university, mentoring and supervising interns placed in her classroom. Ms. Hendrix has a strong science background and was interested in integrating science and literacy instruction. Ms. Hendrix attended two staff development sessions offered by our university that aimed to generate excitement about the notion of integrated science and literacy, involve teachers in integrating science and literacy, and assist teachers with their planning for such integration.

Ms. Hendrix was also involved in a school system, grant-funded professional development opportunity, "Teaching Educators About Math and Science" (TEAMS). She attended TEAMS meetings during the summers and the school year. A part of the TEAMS initiative included implementing science notebooks in classrooms. Ms. Hendrix was obligated to teach other teachers about her learning as a TEAMS participant and, therefore, coordinated a book club and led staff development sessions that focused on Klentschy's (2008)*Using Science Notebooks in Elementary Classrooms*.

In the U.S., the use of science notebooks with elementary school students has been associated with increased student achievement in science, mathematics, reading, and writing (Klentschy, Garrison, & Amaral, 1999). This increase in student achievement may be a result of teachers' ability to address students' gaps in understanding or misconceptions that become evident in their science notebooks (Nesbit, Hargrove, Harrelson, & Maxey, 2004). Science notebooks allow teachers to assess their students and allow students to perform as scientists. Using science notebooks, students record their observations and predictions and organize data with charts, graphs, and pictures. The goal is for students to ultimately make sense of what they are learning and engage in science investigations in an authentic way. Ms. Hendrix possessed well-developed professional knowledge related to the pedagogy and content of inquiry-based science. Teachers at Ms. Hendrix's school were allowed to make decisions about how to best use curriculum materials. Therefore, Ms. Hendrix was purposefully selected to participate in this study as a teacher who would likely engage in adaptive teaching.

2.3. Data collection

During a four-week period in which Ms. Hendrix taught all 20 lessons of the *SS/RR* "Designing Mixtures" unit, we observed Ms. Hendrix's daily instruction, conducted daily post-lesson interviews, and held weekly planning meetings. Fig. 1 displays how the data sources addressed the phenomena under study.

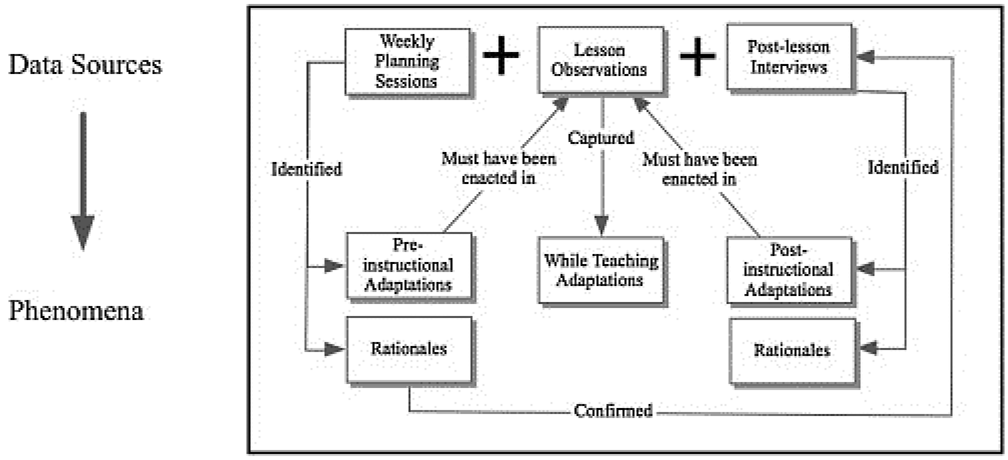

Fig. 1. Data sources for examining adaptive teaching.

During audiotaped weekly planning sessions, Ms. Hendrix's pre-instructional adaptations to the curriculum materials were identified. When she made a pre-instructional adaptation we asked for her rationale about why she made the change and noted her response. A pre-instructional adaptation was only included in the data analysis process if Ms. Hendrix enacted it while teaching and confirmed it again during the post-lesson interview. These methods allowed two opportunities for Ms. Hendrix and the researchers to clarify adaptations and rationales.

During lesson observations, a researcher scripted Ms. Hendrix's teaching, and when it appeared that she was adapting her instruction, it was noted. An adaptation while teaching was operationally defined as a deviation from the lesson plan associated with either the curriculum materials or the teacher's plan for instruction that demonstrated an application of professional knowledge in order to meet the needs of students or the demands of an instructional situation.

An interview was held immediately after each lesson to give Ms. Hendrix an opportunity to confirm adaptations, provide rationales for adaptations, and identify post-instructional adaptations. During the post-lesson interviews, we used our lesson observation script to guide our questions about the adaptations that Ms. Hendrix made. We described each adaptation we saw and the classroom events surrounding the adaptation. Then we asked, (1) “Was that a spontaneous change, (not planned)?; and (2) Why did you make that change?” At the end of each post-lesson interview, we asked, “Are there any changes that you will make for tomorrow's lesson as a result of anything that happened in today's lesson?” If the teacher responded positively, then we asked, “Why are you making that change?” Her responses were noted and then we confirmed post-instructional adaptations in the subsequent lesson. All post-lesson interviews were audiotaped and transcribed for analysis. The methods used to capture Ms. Hendrix's adaptations and associated rationales allowed researchers to accurately consider and richly describe the instructional circumstances throughout the process of data analysis, which is described below.

2.4. Data analysis

We prepared the data for analysis by displaying descriptions of confirmed adaptations and Ms. Hendrix's corresponding rationale on a chart (Miles & Huberman, 1994). The data chart (see Fig. 2 for an example of the displayed data) was organized by lesson and then by the phase of instruction (i.e., during planning or while teaching) when the adaptation occurred.

Lesson Number	Description of Adaptation	Rationale	Phase of Instruction		
			Planning		While Teaching
			Pre	Post	
2	Uses a pipette instead of a spoon to add water	To make sure the same amount of water is being mixed, so that it is a fair test	X		
3	Models how to shake their sticky test paper and discuss the concept of a fair test	They were all using different amount of glue. I want them to understand that little things can change your results. Things like how hard you shake or where you hold it, the kind of tray, paper, the amount of glue and beans can change the results. The earlier they learn about the fair test, the better and they know about fairness. It is important for them to learn that if you are going to test for something, then you have to have a standard.		X	
8	Introduces flavorings for sodas	I noticed students were interested and motivated so this was an opportunity for me to bring in some flavoring topics that they would later need			X

Fig. 2. Example of chart used to display data for analysis.

Preparing and organizing the data in this way provided a starting point for analysis. Using previous adaptive teaching codes (see Tables 1 and 2), two researchers from the adaptive teaching research team coded the adaptations and rationales together, a process called “researcher triangulation” (Merriam, 2009), to increase the reliability and validity of the coding process. While coding, researchers referenced the audiotaped planning sessions, lesson observation scripts, and original post-lesson interview transcripts to clarify adaptations and rationales and to consider the instructional circumstances surrounding the adaptations that were made. Additionally, Ms. Hendrix carefully examined the codes we assigned to all adaptations and rationales and was given an opportunity on several occasions to corroborate our findings and to make any suggested modifications about data analysis.

Since this study varied from previous adaptive teaching studies by examining a teacher's adaptations when using curriculum materials to integrate inquiry-based science and literacy instruction while teaching and during planning, we used the constant comparative method

(Glaser & Strauss, 1967) to remain open to the possibility of discovering new codes. However, new codes did not emerge from the data.

We compared the frequencies of the coded adaptation and rationale types made during different phases of instruction. Given the rigor of the data collection and analysis methods, as well as Ms. Hendrix's verification, our findings were validated and signify the nature of Ms. Hendrix's adaptive teaching as she implemented an integrated inquiry-based science and literacy unit.

3. Findings

Ms. Hendrix made 68 instructional adaptations. Sixty percent of her adaptations occurred while teaching (N = 41) and 40% of her adaptations occurred during planning (N = 27). Twenty-two pre-instructional adaptations were identified during weekly planning sessions while five post-instructional adaptations were identified during post-lesson interviews. Ms. Hendrix made more adaptations when the instructional focus was science (N = 44) than she did when the instructional focus was literacy (N = 24). Table 3 provides frequency counts of the adaptations Ms. Hendrix made while teaching and during planning. Frequency counts of the rationales she provided are highlighted in Table 4.

Table 3. Frequency of Adaptations.

Adaptation	Planned		While teaching	Total
	Pre-	Post-		
1. Modifies the lesson objective	2		1	3
2. Changes means by which objectives are met	13	2	11	26
3. Invents an example or analogy		2	12	14
4. Inserts a mini-lesson	4		9	13
5. Suggests a different perspective to students	1		5	6
6. Omits a planned activity or assignment	1		2	3
7. Changes the planned order of instruction	1	1	1	3
Total	22	5	41	68

Table 4. Frequency of rationales.

Rationale	Planned		While teaching	Total
	Pre-	Post-		
A. Because the objectives are not met	3	1	7	11
B. To challenge or elaborate	6	1	4	11
C. To teach a specific strategy or skill	4	2	7	13
D. To help students make connections	5	1	13	19
E. Uses knowledge of student(s) to alter instruction	1		3	4
F. To check students' understanding			4	4

G. In anticipation of upcoming difficulty	1		3	4
H. To manage time	2			2
Total	22	5	41	68

During planning, Ms. Hendrix most frequently adapted by "changing the means by which the lesson objectives were met" (*N* = 15). This generally meant that she modified the curriculum materials. Several different rationales were clearly articulated for these adaptations.

The adaptations she made while teaching centered around three codes: "inventing an example, analogy, or metaphor" (*N* = 12); "changing the means by which objectives were met" (*N* = 11); and "inserting a mini-lesson" (*N* = 9).

The frequency counts (Tables 3 and 4) provide a holistic picture of how and why she adapted her integrated science and literacy instruction. To complement this macro view, an intricate and detailed account of how and why Ms. Hendrix adapted her instruction is provided. First, we describe how and why she adapted during planning. Then, we provide a description of Ms. Hendrix's adaptations and articulated rationales she made while teaching.

3.1. Adaptations made during planning

Ms. Hendrix adapted in a variety of ways with different rationales for adaptations. She changed the means by which the objectives were met most frequently by modifying the curriculum materials. For example, the curriculum materials suggested that the teacher maintain a class content wall chart as a place to record and display students' learning throughout the implementation of the unit. However, Ms. Hendrix decided that she would require students to record individual statements in their science journals instead of directing "only a few students to write statements for the class content wall." She decided to make this change because she wanted to offer students a more challenging task than the one suggested in *SS/RR*.

During planning for another lesson, Ms. Hendrix decided to remove a poster from students' view that summarized the properties of glue. She stated, "Students need to think about and process the properties of glue." In another instance, Ms. Hendrix changed the suggested order of the activities in *SS/RR*. The lesson aimed for students to learn that scientists design glue for particular purposes and that the properties of glue determine how the glue is used. New ingredients for students' glue mixtures were introduced in this lesson and included flour, gelatin, cornstarch, and corn syrup. During planning for this lesson, Ms. Hendrix explained,

The manual wants me to have a whole class discussion about the ingredients, but I don't think they (students) have enough background knowledge about gelatin or corn syrup so I want them to have experience with it before we talk about it. After that, they will be able to incorporate those property words into our conversation.

Modifying the curriculum materials in this way allowed Ms. Hendrix to build students' background knowledge so they could connect it to the whole group discussion.

During planning, Ms. Hendrix frequently changed the means by which the objectives were met, and these changes were sometimes connected to a larger goal that she held for students' science learning. For instance, one lesson aimed for students to learn that ingredients can change a glue's properties and that science involves tests to find out about such properties. Ms. Hendrix planned to teach students to use pipettes, rather than spoons to add drops of water to glue mixtures as suggested by *SS/RR*. This decision was rooted in her goal of developing students' understanding of a fair test. Spoons could not be used to accurately measure the drops of water that would be added to the glues. Ms. Hendrix aimed “to make sure the same amount of water was being mixed, so that it was a fair test.” Using the pipettes offered students a more precise way to measure the liquid.

During planning for another lesson that engaged students in creating glue mixtures and designing “sticky tests,” Ms. Hendrix noticed students' inconsistencies in the amount of glue used to perform a sticky test. In a post-instructional planning session, Ms. Hendrix decided that she would model how students should shake their sticky-test paper and decided to explicitly discuss the concept of a fair test with the class. She “wanted them [students] to understand that little things can change your results. It is important for them to learn that if you are going to test for something, then you have to have a standard.”

The majority of the adaptations that Ms. Hendrix made during planning consisted of changing the means by which the objectives were met and these adaptations were most frequently associated with science lessons. Ms. Hendrix also planned mini-lessons as adaptations that incorporated facets of literacy. For example, during planning Ms. Hendrix anticipated students' difficulty with the concept of cause and effect for a lesson that addressed both literacy and science objectives. The objectives for this lesson included that students learn about the effects of ingredients and that when determining the effects of ingredients, look for evidence of change. Since Ms. Hendrix anticipated students' difficulty in meeting the objectives of this lesson, she scaffolded their learning by creating a cause and effect mini-lesson that she taught before launching into the curriculum materials. She began the mini-lesson by asking, “What do you know about cause and effect?” Then she presented various “effects” and had students respond by identifying the “cause.” Ms. Hendrix was particularly concerned with presenting “effects” that were related to “students' everyday lives.”

This lesson in the curriculum materials also promoted a similar connection to students' lives. However,*SS/RR* curriculum materials recommended that the teacher take a more explicit approach to teaching about cause and effect through direct instruction. Yet, Ms. Hendrix decided that the most appropriate approach for her students was to allow them to think about and reflect upon what they already knew so that she could better connect their existing knowledge to new knowledge. She explained why she planned this mini-lesson:

When I teach cause and effect in literacy, I have found that it is sometimes hard for students to make that connection. For some kids if they can flip it around, it is like it almost helps them see it better. Like they know why there are mud puddles, “Why are there mud puddles outside?” “There are mud puddles outside because it rained” but they can't do “because it rained there are mud puddles.” I have noticed this during literacy, and this strategy helps some of them.

Ms. Hendrix exercised autonomy during planning by most frequently modifying the curriculum materials in ways that allowed her to meet her students' instructional needs. However, she most often adapted her instruction while teaching and most of her adaptations while teaching were made during science lessons.

3.2. Adaptations made while teaching

Capitalizing on opportunities to scaffold students' learning, Ms. Hendrix frequently adapted her instruction by providing examples to help students make connections. For instance, when students read about flavored jellybeans, Ms. Hendrix introduced the idea of flavorings for sodas. She said that she “noticed students were interested and motivated so this was an opportunity for me to bring in some flavoring topics that they [students] would later need.” In another lesson, she responded to students' lack of reading fluency, which impacted their reading comprehension. She pointed out punctuation marks in the passage, and modeled an example of how to use them as guides for fluency and then led the class in echo-reading the passage.

When students displayed difficulty with listing properties of different kinds of glue, she provided concrete examples of glue with various visual properties so students could draw from these examples as a way to help them consider the varying properties that glues may have.

During a first lesson of the unit, a student hesitated to share a prediction. Ms. Hendrix perceived this event as the student's “fear of being wrong” and, therefore, changed the means by which the lesson objective was met by incorporating a discussion about the essence of a prediction. She explained to students, “A prediction is not right or wrong. It is just what you think.” This explanation oversimplifies the thinking that students must do when they predict. Predicting is an important science and reading skill in which one considers the most likely outcome based on patterns of evidence. When predictions are actually tested, some outcomes are as predicted and other outcomes are not as predicted. While Ms. Hendrix did not highlight this important feature of predicting in this particular adaptation, we found the focus of using evidence was connected to many other adaptations that she made in other lessons.

When she adapted to incorporate opportunities for students to learn about using evidence, she frequently changed the means by which the objectives were met. For example, she required students to compare and contrast properties of their glues in hopes that they would make better decisions about a new glue recipe. However, students were unable to articulate their evidence for the changes they made to their glue recipes, so she decided to guide them through the thinking process. She probed students with questions such as “How is your glue like mine?”; “Do you want your glue to have this property?"; "What ingredient did you use that caused your glue to have that property?" Then she modeled for students how to arrange this information into a statement that used evidence about what ingredients they would use in their glue recipes. For example, she stated, "I need a thick glue. Isabelle used a lot of flour and not too much water, so I think I will need more flour in my recipe." Then she concluded for students that she used evidence from the properties of Isabelle's glue to make a prediction that was then correct about what was needed for her glue.

On several occasions, she changed the means by which objectives were met by leading discussions or providing explicit instruction. A pattern that emerged from these adaptations indicated that she frequently aimed at providing students with a glimpse into what it means to be a scientist, to do science. For example, with an adaptation in which she led a discussion about how food scientists develop flavors, she reasoned, "talking to them [students] about being a scientist is the big picture."

In the midst of another lesson, Ms. Hendrix recognized students' difficulty with understanding the purpose of documenting notes while collecting data. Therefore, she provided explicit instruction in which she explained the importance of accurately recording notes and then provided a format for students to use in their science notebook. On another occasion, students' sticky-test results varied in ways that Ms. Hendrix had not anticipated and students experienced difficulty in drawing substantial conclusions. She made sure that students not only formulated their own conclusions based on evidence from their data but also understood that there could be multiple variables affecting the data. She led the class in a discussion about using a control and standard procedure when conducting tests and then using the data to question other scientists' results. When asked to provide her rationale for this particular adaptation, she stated,

I never anticipated the results being that scattered. I don't think students this age think about multiple variables. I think they would just assume that someone just did something they weren't supposed to. I wanted them to see there could be more than one thing affecting our test. My goal was not to take over everything they recognized about the data and make them see it my way, but I wanted them to have their own thoughts about it.

Threaded across the mini-lessons that she inserted was the notion of having students use data as evidence and use the language of argumentation. Her attempts to expose students to authentic science and practices of science also appeared to hold true for the mini-lessons. For example, when students offered two different perspectives about what made a good glue, Ms. Hendrix focused students' attention on using their data to decide about the necessary properties of a good glue. The students shared individual data in small groups and decided whose glue was the strongest glue in the group. Each student was required to use data when justifying a claim. In this instance, Ms. Hendrix halted her instruction, redirected students' thinking to give them an opportunity to engage in using the data in their language of argumentation. When asked about her reason for this adaptation, she indicated that she wanted to assist students in understanding that “we don't always have to agree, especially in science. We each have our own records and we each have our own way of interpreting things and you have to decide as a scientist how you are going to interpret what happened.” She further explained that she has “encouraged them all year long to write what *they* think, what *they* see, not what they think I want them to write.”

Ms. Hendrix made many adaptations while teaching including providing an example, metaphor, or analogy; changing the means by which the lesson objectives are met; and inserting a mini-lesson. The adaptations that she made seemed to be filtered by the ways in which she views science. She provided many opportunities for students to develop an understanding of how to engage in the authentic practices of science that included fair testing in experimental procedures, operationally defining variables such as the strength or stickiness of a glue, communicating and sharing results, as well as considering alternative explanations for results.

4. Discussion

This study explored the nature of one teacher's adaptive teaching as she implemented an integrated guided inquiry-based science and literacy unit. This teacher adapted her instruction in a variety of ways both during planning and while teaching. Her adaptations often served as scaffolds for students: when she adapted to provide more background knowledge on glue ingredients, when she inserted a mini-lesson on cause and effect before examining the effects of different ingredients, and when she noticed students' influent reading and engaged in echo-reading with the class. Adaptations also served to challenge students (i.e., work within their ZPDs). For example, Ms. Hendrix removed a poster from students' view (removed a scaffold) to compel them to “think about and process” the properties of glue. Likewise, she chose to use pipettes instead of a spoon to dispense liquid, so students would have to consider the concept of fair test. In these ways, Ms. Hendrix used ongoing formative assessment and as a result her adaptive teaching created opportunities for her students to actively refine their understanding and learning.

Ms. Hendrix articulated a variety of rationales for her adaptations. She adapted to encourage independent thinking: “I wanted them to interpret the data…rather than someone else”; she adapted to clarify concepts; she adapted because students “did not understand”; she adapted to capitalize on student motivation; and she frequently adapted to encourage students to think like scientists: “I wanted them to see there could be more than one thing affecting our test.” These findings empirically support the many researchers who have discussed the unpredictability of classroom instruction (Berliner, 1994; Bransford et al., 2005; Duffy et al., 2009; Eilam & Poyas, 2006; Spillane et al., 2002) and also illustrate the deep thinking involved in classroom instruction.

This research adds to the literature by studying teacher adaptations more comprehensively (i.e., while planning and during instruction) and in a different context (i.e., a different school district and during an integrated science-literacy unit). An important finding in this research is that, even with an explicit mindfulness to not force adaptations into existing codes, no new codes resulted from this study. We hypothesize that no new codes emerged because of the rigorous process used initially to create the coding systems. In our early studies, five doctoral students documented adaptations in different settings. To analyze these data, each researcher read documented adaptations and rationales aloud, one at a time, and the five researchers used constant comparative analysis (Glaser & Strauss, 1967) to create and refine the coding systems through extensive discussion and recoding of the data.

Subsequently, the entire research team conducted additional research on adaptive teaching and used the initially created coding systems and constant comparative analysis to continue to refine the coding systems. Typology codes for adaptations and rationales that were developed from 430 adaptation and rationale pairs from more than 180 classroom observations of 27 different teachers representing each elementary grade, kindergarten through fifth grade, have withstood the rigorous process used to identify how and why elementary school teachers adapt their instruction.

Because no new codes emerged from this study, despite the fact that we focused on a different content discipline (science versus literacy) in a more open inquiry instructional environment as opposed to a scripted instructional environment, we are confident the codes that have been developed will allow researchers to document how and why adaptive teaching occurs. As such, researchers will be able to hone in on particular aspects of adaptive teaching in varied contexts to better understand the types of contexts that allow for or promote adaptive teaching. Researchers can also begin looking for the types of adaptations and rationales that appear to be most robust. Furthermore, these coding systems supplement Adaptive Teaching Competency studies conducted by Brühwiler and Blatchford (2011) and Vogt and Rogalla (2009) by looking closely and identifying how and why teachers adapt their teaching.

Ms. Hendrix's adaptations closely matched the adaptations identified in our previous studies of adaptive teaching (see Fig. 3). One notable exception is that Ms. Hendrix adapted by “inserting a mini-lesson” more frequently (22%) than in previous studies (10%). Codes for rationales were less aligned between Ms. Hendrix and our previous studies (see Fig. 4). Ms. Hendrix provided the rationale “because the objectives were not met” less often (17%) than teachers in previous studies (27%). Similarly, she adapted “using knowledge of students” less frequently (7%) than teachers in previous studies (14%). However, Ms. Hendrix adapted “to help students make connections” more frequently (32%) than teachers in previous studies (18%). She also offered the rationale “to teach a specific strategy or skill” more often (17%) than educators in previous studies (7%).

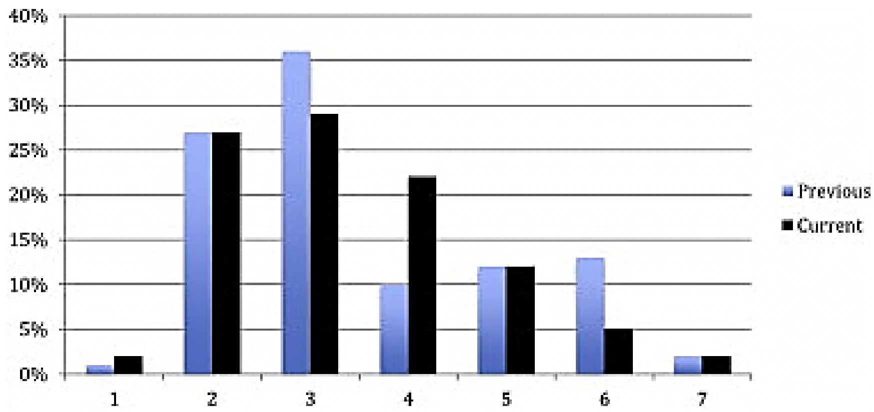

Fig. 3. Percentage of adaptation codes used while teaching in our previous studies versus the current study. 1. The teacher modifies the lesson objective; 2. The teacher changes means by which objectives are met; 3. The teacher invents an example or an analogy; 4. The teacher inserts a mini-lesson; 5. Suggests a different perspective to students; 6. Omits a planned activity or assignment; 7. Changes the planned order of instruction.

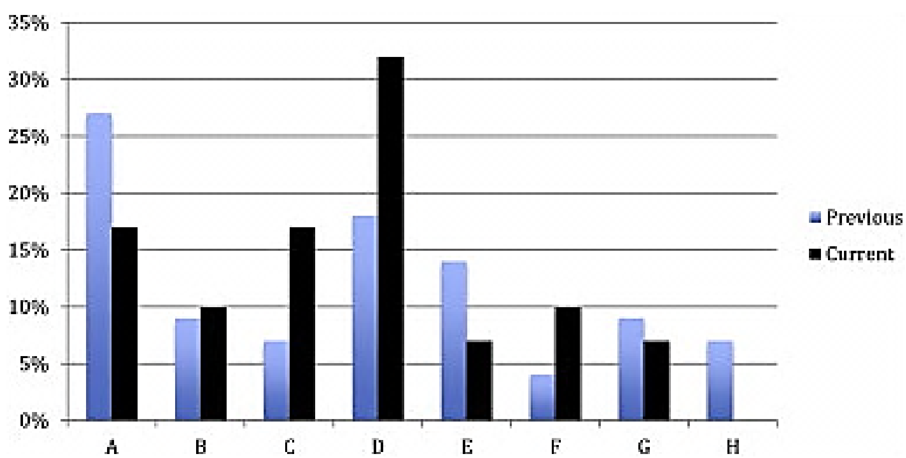

Fig. 4. Percentage of rationale codes for adaptations made while teaching in our previous studies versus the current study. A. Because the objectives are not met; B. To challenge or elaborate; C. To teach a specific strategy or skill; D. To help students make connections; E. Uses knowledge of student(s) to alter instruction; F. To check students' understanding; G. In anticipation of upcoming difficulty; H. To manage time.

These comparisons need to be interpreted with caution because the current study is a case study of one teacher in one grade level whereas the corpus of previous data is a collection of case studies in more than 20 classrooms, grades K‑5. Therefore, differences found in this study may be due to this particular teacher's preferences or tendencies in instructional delivery. More important, from our perspective, is that in this new context, observing a teacher teaching different subject matter, we found that our codes adequately captured this teacher's adaptations. It seems, then, that our research methods of analysis to capture this important aspect of instruction, adaptive teaching, have resulted in a valid and reliable way to typify instructional adaptations. That is not to say that coding adaptations and rationales is without ambiguity. Thus, we suggest that at least two researchers code adaptations and rationales, and present any analysis for validation by the teacher, as we have done in this study.

We found that Ms. Hendrix made more adaptations when the instructional focus, as identified in the curriculum materials, was science (N = 44) than she did when the instructional focus was literacy (N = 24). Ms. Hendrix's tendency to adapt her instruction more frequently while teaching science may have occurred because her students had better-developed literacy skills than science skills. Elementary school children in the U.S. are exposed to many more hours of literacy instruction than science instruction (McMurrer, 2008). Thus, more adaptations to scaffold students' learning may be needed while teaching science. Or, it may be that Ms. Hendrix's expectations for her students' science learning are unusually high and so she must make many more adaptations for that higher order learning to occur. Harris and Rooks' (2010) assert that effectively scaffolding instruction helps students integrate and apply ideas. Despite the reasons that more adaptions were made when science was the instructional focus, it was clear that Ms. Hendrix used ongoing formative assessment to scaffold her instruction.

We also expect that Ms. Hendrix's exceptional background and interest in science played a role in the nature of the adaptations she made when science was the instructional focus. Our social constructivist lens led to these speculations. We assume that the teacher's and the students' backgrounds and the nature of their interactions influence the teacher's instruction (Vygotsky, 1978). Given these findings, it is clear that while science teacher educators continue to promote and offer guidance to assist teachers in developing their abilities to deliver inquiry-based instruction, it is also imperative to attend to teachers' development of adaptive teaching.

Given that Ms. Hendrix often made adaptations to the curriculum materials in ways that allowed her students to engage in the practices of real scientists, which is also a key feature of *SS/RR*, it is clear, then, that teacher educators should also attend to developing teachers' abilities to critically evaluate curriculum materials and make decisions about how to implement and adapt curriculum materials to best meet the situated and contextualized needs of their students and instructional contexts. One way to do this may be to require teacher candidates to adapt curriculum materials with a particular classroom in mind. For example, if we understand that science teachers who use curriculum materials tend to change the means by which objectives are met, then we need to help our pre-service and in-service teachers think about how they would most effectively change the means of meeting lesson objectives and then enact those changes.

Realizing that Ms. Hendrix adapted by making changes to the curriculum materials corroborates what others have reported about teachers' use of curriculum materials. Specifically, her adaptations to the curriculum materials illustrated her pedagogical design capacity (Brown, 2009). She was knowledgeable of the overall goals of the curriculum materials and able to draw on her professional knowledge and make adaptations that were intended to improve instruction for her students. This finding, however, raises a question about whether similar adaptations and rationales would be made to curriculum materials by teachers who are not provided with materials such as the ones used in this study. How would the nature of Ms. Hendrix's adaptive teaching compare with elementary teachers' adaptive teaching who develop and implement their own unique units of integrated science and literacy? What would be the nature of adaptive teaching with teachers who resist integrating science and literacy instruction? How would adaptive teaching look with teachers who possess science identities that do not align with the provided curriculum materials?

Another unique aspect of this study is the documentation of adaptations that occurred during planning. Ms. Hendrix did make adaptations to the curriculum materials as she was planning and reflecting on her instruction. These findings corroborate previous studies that show how complicated teachers' planning can be and that teachers must be thoughtful in managing a variety of factors such as accountability standards and curriculum materials (Hewitt, 2006; Hinnant et al., 2009; Meyen & Greer, 2009). A methodological difficulty, and a limitation of this study, is that because planning and reflection are not actions that take place at specified times, capturing adaptations made during planning and reflection is difficult. Continued study and creative research designs will help uncover teacher adaptations made during planning.

Social constructivist perspectives indicate that teaching and learning is contextual (Dewey, 1938; Vygotsky, 1978). Accordingly, it is likely that context plays an important role in teachers' adaptive teaching. In order to build a greater understanding about how context may influence the adaptations made by elementary science and literacy teachers, future studies need to be conducted in varying contexts. Multiple case designs that examine both elementary science and literacy teachers who work in various contexts will reveal additional insight about the nature of the relationship between adaptive teaching and context.

This study focused on Ms. Hendrix's adaptations. We believe that many of the adaptations were connected to larger goals that Ms. Hendrix held for her personal teaching and for her students' learning. This emerging idea was further supported by an unsolicited email from Ms. Hendrix in which she discussed her thoughts about how to best extend this unit of instruction. She considered requiring students to further explore the properties of soda and then generate a prioritized list of their preferred soda properties. However, she rejected this idea and suggested an alternative that seemed to incorporate her personal aims for teaching in which she could better motivate students to value and engage in learning. She wrote:

No, the kids wouldn't really get into that assignment (creating a list) as much because it would be too much like writing⋯but they would enjoy creating an advertisement for their soda depicting its properties there and some could even write a few persuasive sentences to go with that even though that isn't exactly second grade curriculum.

In our view, she designed a more open-ended task that students would complete with a more authentic purpose for writing, which is likely to promote students' valuing of and engagement in both science and writing (Parsons, 2008).

An important next step to consider is whether or not adaptive teachers positively impact student outcomes. Researchers and teacher educators appear to assume that adaptive teaching will lead to increased student learning, and, indeed, this relationship may seem intuitive to educators. However, data demonstrating this relationship would help researchers and teacher educators work with policymakers, administrators, and curriculum developers to support teacher professionalism, especially autonomy and support for professional growth.

Appendix A

Overview of Designing Mixtures from the Seeds of Science, Roots of Reading Website, http://www.seedsofscience.org/curriculum/grades2_3_overview.htm.

Summary

“Designing Mixtures” immerses students in learning about properties of substances, dissolving, the design process, mixtures, and other key physical science concepts. The unit has two investigations‒each with 10 sessions. Five student books engage students in doing, talking, reading, and writing about the science concepts. About half of the sessions in the unit have a literacy focus. As students read the books, they work to master the reading comprehension skill of accessing and applying prior knowledge, they write procedural text, and learn to use nonfiction text features, such as illustrations, captions, and labels.

Investigation one ‐ investigating ingredients

During the first investigation, students read *What If Rain Boots Were Made of Paper?* and discuss what materials different objects are made of. They conduct tests to determine which ingredient makes mixtures the most sticky, and use that evidence to make their own glue mixtures. The class records new scientific terms on a Science/Everyday Word chart, explore and discuss procedural text, and play a giving instructions game. Students notice text features as they read *Solving Dissolving*, a book that introduces students to the concept of solubility, and then test four possible soda ingredients to find those that are soluble in water and taste good. They discuss the role of cause and effect in making mixtures and then search through the Handbook of Interesting Ingredients reference book to compare their ideas about the effects of sugar and flour on mixtures to what other scientists have found.

Investigation two ‐ making mixtures

Students read *Jelly Bean Scientist*, a book about a food scientist who designs new jelly bean flavors. They collect more information about possible flavors for their sodas and use this information and their test results to create their soda recipes. Students create their first sodas and consider how their sodas compare to the properties of good soda. Then they refine and write their soda recipes. By following their partners' soda recipes to create a second, improved soda, students experience firsthand the value of clear procedural text. Students go on to read *Jess Makes Hair Gel*, a book about a boy who uses a design process to make hair gel. They use this to guide their next design challenge‒creating a strong glue. They search for evidence of ingredients that will help make a strong glue, in the *Handbook of Interesting Ingredients*, and through firsthand investigations. They evaluate the evidence and use it to make and refine glue mixtures. The unit ends when students write a recipe for strong glue based on all of the evidence they have gathered.

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