Linking the Microscopic View of Chemistry to Real-Life Experiences: Intertextuality in a High-School Science Classroom

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ABSTRACT: Chemistry learning involves establishing conceptual relationships among macroscopic, microscopic, and symbolic representations. Employing the notion of intertextuality to conceptualize these relationships, this study investigates how class members interactionally construct meanings of chemical representations by connecting them to real-life experiences and how the teachers' content knowledge shapes their ways to coconstruct intertextual links with students. Multiple sources of data were collected over 7 weeks with a participation of 25 eleventh graders, an experienced teacher, and a student teacher. An examination of classroom discourse shows that the intertextual links between the microscopic view of chemistry and students' real-life experiences could be initiated by students and instigated by the teachers. The teachers applied several discursive strategies to scaffold students building meaningful links based on their prior knowledge and experiences. Additionally, the experienced teacher with stronger content knowledge tended to present links in both dialogic and monologic discourses. Yet, the relatively limited content knowledge did not necessarily constrain the student teacher's interactions with students. The findings of this study provide a backdrop for further research to explore how chemistry is learned and taught in a class through the social constructivist lens. *Sci Ed* **87:**868–891, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/sce.10090

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INTRODUCTION

> *Chemistry, . . . , is a mix of a molecular engineering, based on extrapolations from the macroscopic to the microscopic, and a science, coming to grasp directly with the microscopic.*
> Hoffman and Laszlo, 1991, p. 9

Chemistry is a microscopic science. Chemical processes are paradigmatically represented by molecules and explained from a microscopic perspective. Various types of microscopic representations, such as structural formulas and ball-and-stick models, are cultural tools for chemists to conduct inquiry (Nye, 1993). Instead of using different representations interchangeably, chemists schematically choose appropriate symbols and signs to generate hypothesis, present data, make predictions, and convince other scientific community members in their daily practices (Hoffman & Laszlo, 1991; Kozma et al., 2000).

However, given the important role of representations in chemistry, many studies showed that students are not able to understand microscopic representations as chemists do (e.g. Ben-Zvi, Eylon, & Silberstein, 1986, 1987, 1988; Kozma & Russell, 1997; Krajcik, 1991; Nakhleh, 1992). Students' difficulties in interpreting representations (Ben-Zvi, Eylon, & Silberstein, 1986), providing verbal explanations for chemical processes (Kozma & Russell, 1997), and making translations between different types of representations (Keig & Rubba, 1993) indicate a lack of links among chemical phenomena, representations, and relevant concepts (Kozma, 2000a). Inspired by a social constructivist view of learning (Vygotsky, 1978), Kozma et al. (2000) suggested that chemistry curricula should guide students to use multiple representations visually and verbally in conjunction with associated physical phenomena in a classroom. A learning environment needs to explicitly demonstrate the conceptual relationships among representations at the macroscopic, molecular, and symbolic levels in a problem-solving or inquiry context. Through social and discursive practices, students have opportunities to conceptually move back and forth among three levels and cognitively interact with various types of representations in a meaningful way.

However, as students' learning difficulties in understanding chemical representations have been well known and a social constructivist perspective has been proposed, some questions remain unanswered. How are microscopic representations introduced, used, and practiced in a science classroom? How are conceptual links among life experiences, chemical representations, and conceptual entities presented and constructed by members in a science class through their discursive practices? How does the teacher's content knowledge shape his or her ways to coconstruct links with students? These questions are the focus of this study. To answer these questions and reveal the social and interactional nature of meaning-making process in an eleventh-grade science class, this study employs the notion of intertextuality to conceptualize this meaning-making process and examines classroom discourse in detail.

According to Halliday and Hasan (1985), text is defined as functional language which "may be either spoken or written, or indeed in any other medium of expression that we like to think of" (p. 10). From this perspective, chemical representations at different levels (i.e., macroscopic, microscopic, and symbolic), students' real-life experience, and classroom events can be viewed as texts (Santa Barbara Classroom Discourse Group, 1992). When students construct understandings about chemical concepts, they might coordinate within and across different representations and life experience. The links among representations, real-life experiences, and classroom events made by students can be considered as intertextual relationships. Defined as "the juxtaposition of different texts" (Bloome &

Egan-Robertson, 1993, p. 305), intertextuality has been viewed as a central process for people to make meanings of unfamiliar texts (Lemke, 1990). As the relationships among chemical representations are usually discussed within a framework of the conceptual change model (e.g., Gabel, 1998), this study aims to enrich our understandings about chemistry learning through a social constructivist lens and uses intertextuality to conceptualize how class members interactionally make meanings of chemical representations by linking them to real-life experiences.

THEORETICAL FRAMEWORK

Researchers and educators in chemistry education have been discussing the three levels of representations in chemistry: macroscopic, microscopic, and symbolic levels (Gabel, 1998; Gabel, Samuel, & Hunn, 1987; Johnstone, 1982, 1993). At the macroscopic level, chemistry is observable as melting butter or a burning candle. To better explain these phenomena, chemists develop concepts and models of atoms and molecules. At the microscopic or molecular level, a burning candle becomes a chemical process in which carbon atoms of the wax react with oxygen molecules in the air and carbon dioxide molecules are produced. Another way to represent this process is using a chemical equation with symbols, formulas, and numbers, such as $C(s) + O_2(g) \rightarrow CO_2(g)$. As shown in this example, chemists represent sensory experiences by atoms and molecules, and translate them into symbols and formulas. Examining the evolution of the chemists' way of seeing and drawing, Hoffmann and Laszlo (1991) argued that microscopic representations currently used in chemistry have evolved from phenomenological analogies of sensory experiences at the macroscopic level. However, understanding microscopic and symbolic representations is especially difficult for students (e.g., Ben-Zvi, Eylon, & Silberstein, 1986, 1987, 1988; Gabel et al., 1987). Students' difficulties have been attributed to several factors, such as the aperceptual nature of atoms and molecules (Ben-Zvi, Eylon, & Silberstein, 1986), students' incomplete or inappropriate mental models (Kozma et al., 1996; Williamson & Abraham, 1995), and discrepancies between school science and students' real-life experience (Osborne & Freyberg, 1985).

Various instructional strategies, tools, and curriculum have been developed to ease students' difficulties (Gabel, 1998; Krajcik, 1991) and most of them emphasize the importance of challenging and changing students' alternative conceptions and incomplete mental models. As sociocultural factors that mediate learning become more prominent, on the basis of the historical development of chemical representations and the research on how scientists use representations for scientific investigation and social communication (Latour, 1987; Lynch & Woolgar, 1990), Kozma and his colleagues (1997, 2000) argued for a different view of learning chemistry that focuses on students' development of representational competencies in social contexts. These representational competencies include generating representations purposely, using representations to make explanations, using representations in a social context to communicate understandings, and making links across representations (Kozma et al., 2000). Therefore to develop students' understandings of chemistry, a chemistry curriculum should guide them to use multiple representations in conjunction with associated physical phenomena. A learning environment, including the teacher, curriculum materials, and technological tools, should explicitly demonstrate the relationships among macroscopic, microscopic, and symbolic levels in an inquiry context. Through social and discursive practices, students conceptually move back and forth among three levels and have opportunities to cognitively interact with various types of representations in a meaningful way (Kozma, 2000a). Building on Kozma's view of learning chemistry, this study employs intertextuality to theorize the relationships among chemical representations at different levels.

Intertextuality and Understanding of Chemistry

According to social semiotics, meaning of a text is not built-in but made by connecting the text to other similar or relevant texts. As Lemke (1990) suggested, “everything makes sense only against the background of other things like it” (p. 204). A central process of making meaning of a text is through making connections across different texts (Short, 1992). In this sense, a chemical representation could become more understandable to students when it is linked to other relevant texts that students already knew, including representations they learned earlier and experiences they had. Thus, intertextuality could be a cognitive resource or a learning strategy for students to construct meanings of new representations.

Then in what conditions does intertextuality happen? Bloome and Egan-Robertson (1993) indicated that “the social construction of intertextuality occurs within a cultural ideology that influences which texts may be juxtaposed and how those texts might be juxtaposed, by whom, where, and when” (p. 330); that is, every community has its meaning-making practices and people from different communities tend to have different ways to make intertextual links among texts. Kozma et al. (2000) described two types of intertextual relationships made by chemists when they used symbolic and microscopic representations in laboratories. One relationship focuses on the surface features of chemical representations and substances that chemists study. Chemists identify and manipulate these features so that the symbolic and molecular representations could be mapped onto the substances at a macroscopic level. The intertextual links between substances and representations are established during the mapping process. A second intertextual relationship happens among symbolic and molecular representations, and involves a semiotic, rhetorical process in which representations are referents of aperceptual entities (e.g., atoms and molecules) and processes (e.g., chemical equilibrium). Kozma et al. (2000) identified the second type of intertextual relationship by analyzing chemists’ discursive practices with the juxtaposition of multiple representations. Both types of intertextual relationships are socially significant within the professional community of chemists (Kozma et al., 2000). Linking chemical substances and entities to representations allows these substances and entities to become objects of the conversation and investigation, and creates a chemical reality which otherwise does not exist (Latour, 1987).

Additionally, intertextual links among chemical representations at different levels are observable. These links could be found in chemists’ discursive practices as they schematically choose appropriate symbols and signs to generate hypothesis, present data, and make predictions about the chemical phenomena that are the focus of their investigation (Kozma et al., 2000). As Kozma (2000a) stated, “the use and understanding of a range of representations is not only a significant part of what chemists do---in a profound sense it is chemistry” (p. 15). Understandings of chemistry tie to the situated use of multiple representations across tasks and contexts. In a science classroom, therefore, conceptual relationships among chemical representations should not be only constructed within a student’s mind, but also observable through social interactions among class members, textbooks, and instructional resources. Namely, the development of conceptual understandings in chemistry is embedded in discursive and social interactions through which students are encultured into practices similar to what chemists do (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Resnick, 1987).

Although making interetextual links among three levels of representations is so crucial to chemistry learning, little is understood about whether these links are meaningful for students and how teachers use intertextuality as an instructional strategy to help students learn chemistry. Before I provide a detailed account of the data collection process, I would like to review more educational studies to define the intertextual links that could be built in science classrooms.

Intertextual Links Between School Chemistry and Real Situations

Intertextual links could be made between students' real-life experience and the macroscopic aspect of chemistry. In this study, real-life experiences refer to the ones that students have outside the school. Studies in the area of students' alternative conceptions have indicated that isolating the school science from students' real-life could make students develop two unconnected knowledge systems related to science: one is used to solve science problems in schools, and the other is used for their daily lives (e.g., Osborne & Freyberg, 1985). Although chemical processes at the macroscopic level are visible and relatively easier to be understood, in most chemistry curricula, these processes are extracted from real situations and usually designed as laboratory activities. In these activities, students are asked to follow given procedures instead of experiencing an iterative process of scientific inquiry. It is not surprising that most students are not able to apply their scientific knowledge learned in schools to real situations, because they do not have opportunities to do so in schools. Additionally, the same phrase may share different meanings in students' daily life and their science classroom. For example, "organic" is commonly used to describe a type of food that is cultivated naturally without using artificial insecticides or hormones. However, in chemistry, "organic" refers to a type of compounds containing carbon atoms. Thus, to learn science, students must appropriate their use of language and reconstruct meanings for terms that are commonly used in their cultural and linguistic practices outside the school.

To fill the gap between students' daily experiences and learning experiences in the science classroom, the first intertextual link that could be constructed in classroom settings is between real situations and the chemistry content at the macroscopic level. In fact, the process of building this type of links has been discussed as "contextualization" in science education that means to situate the learning context in students' real-life experience (Krajcik, Czerniak, & Berger, 1999). For example, informed by the social constructivist learning model, the project-based science includes contextualization as a key feature of this approach for students to make meaning of the school science (Marx et al., 1997). A contextualized driving question, on which a project is centered, is anchored in an important real situation (Cognition and Technology Group at Vanderbilt, 1990). It provides opportunities for students to see how the school science is related to their lives and how the scientific knowledge is applied in real situations.

Compared with the first type of link, constructing intertextual links between real situations and the chemistry content at the microscopic and symbolic levels have not received much attention outside the area of chemistry education, although it has been documented that most students do not understand atoms, molecules, and chemical symbols. Therefore, this study focuses on the construction of this second type of links in a science classroom.

According to the history of chemistry, chemists first simplified real situations into chemical processes and developed atomic and molecular models to make explanations (Hoffman & Laszlo, 1991; Nye, 1993). In general, chemical representations were developed through the sequence of visible phenomena, chemical reactions, atomic and molecular models, and symbols/formulas. As some researchers assume that students' development of understanding is similar to the historical development of science (e.g., Wiser, 1995), the links between real-life experiences (e.g., visual phenomena) and the chemistry content at the microscopic and symbolic levels (e.g., molecular models and formulas) would be difficult to build without mediators, such as simplified chemical processes or common names of chemicals. Thus one objective of this study is to deepen our understanding of in what ways phenomena in real-life experiences, chemical molecules/structures, and symbols are intertextually linked and related to each other in the classroom settings and whether some of the representations are used as mediators. By exploring the nature of this type of link, this study could provide insight into how to help students understand chemical symbols and molecules through class interactions.

Class Discourse and Learning Community

While most studies in the area of chemistry education adapt theoretical assumptions from cognitive psychological theories, the ethnographic aspect of this classroom-based study could contribute to understandings of the social and interactional nature of teaching and learning in chemistry. The qualitative data collected for this study provide rich information about contexts, social interactions, and cultural practices that constitute membership in a classroom learning community (Tuyay, Jennings, & Dixon, 1995). Community members create particular ways of talking, thinking, and interacting, which shape and are shaped by the communicative processes of class discourse. These class discourse processes are rule-driven (Bloome & Egan-Robertson, 1993) to allow and exclude what and how scientific knowledge is practiced, constructed, and intertexually connected through class interactions (Cobb & Yachkel, 1996; Kelly & Chen, 1999; Kelly & Crawford, 1997; Moje, 1995).

When constructing scientific knowledge in a class, members not only pursue individual meanings to enhance their individual cognition, but they also construct social meanings to become members of a group. For example, in Roth and Bowen (1995), over a period of 7 weeks, students gradually adopted more and more graphical representations in their reports. The development from less to more abstract representations was indeed accelerated by the teacher or peer requests to present their data in a more convincing way. Roth and Bowen attributed students' representational competence, e.g., translating or mathematizating their physical experiences into graphical representations and using graphing as a strategy to solve problems, to "cultural accomplishment" (p. 98), because through interactions within and between small groups the learning community created a culture that encouraged students to use graphs in their practices. Similarly, for chemists within a professional community for knowledge building, using various representations to present their thinking process and communicate with colleagues is not only a way to further understandings as individuals, but also a way to confirm their membership (Kozma et al., 2000). Thus, viewing a class as a cultural community allows educational researchers to generate in-depth descriptions and alternative interpretations of what happens inside a classroom.

Examining classroom discourse and related social interactions could be a way to understand a class as a community (Rex, 1999). By focusing on students' discourse as particular semantic relationships within the classroom settings, Lemke (1990) indicated that intertexts of oral and written texts construct ways of making social meanings. Therefore, analyzing oral and written discourse within the class learning community is an avenue to investigate how meanings of chemical representations were socially constructed in a chemistry class. Through a close examination of classroom discourse, I identify various intertextual links made by class members, analyze how and why they made these links, and discuss how these links were socially meaningful and recognized by class members.

METHODS

In order to investigate what types of intertextual links were established in the class through social and discursive practices, and how the teachers' content knowledge shaped the links students made, ethnographic data were collected over 7 weeks. In this section, I describe the context of this study and then provide a detailed account of data collection and analysis.

Context

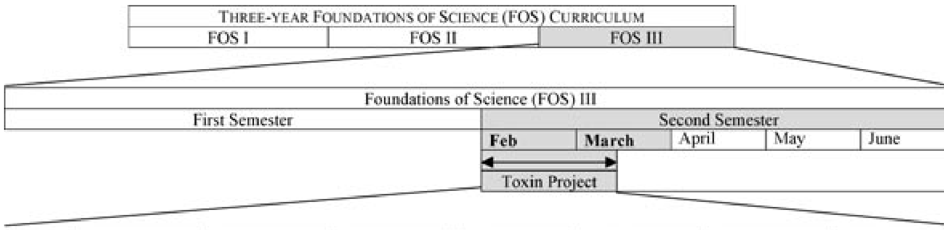
This study was conducted at a small public high school in a university town in the Midwest. There was a focus on the arts (drawing, painting, photography, music, and dance) at the school. The school curriculum was solid academically, although it was not high-powered and no advanced placement (AP) courses were offered. The teachers in the science program have been working with educational researchers from a local university to develop and implement a 3-year, integrated, project-based science curriculum (Blumenfeld et al., 1995; Marx et al., 1997) called Foundations of Science (FOS) (Heubel-Drake et al., 1995). FOS was intended to replace separated earth science, biology, and chemistry courses at the ninth, tenth, and eleventh grades. Throughout the year, students studied scientific subject matter by investigating broad questions and creating artifacts. Four essential features of FOS curriculum were (1) project-based science, (2) integrated curriculum, (3) real science, local topics, and (4) regular use of technology. Projects were designed as a driving force for what content was taught. The curriculum was "authentic" (Brown, Collins, & Duguid, 1989; Resnick, 1987) in that the teachers believed that "science is taught as it is practiced in the real world" (Heubel-Drake et al., 1995). FOS also emphasized the practical application of science in the community, so local topics and real issues were brought into the classroom to be discussed and investigated. Technology was used on a daily basis; students had access to the Internet, the school network, and several pieces of commercial software.

Data for this study were collected from an eleventh-grade science classroom of 25 students (2 Asian, 2 African, and 21 Caucasian Americans) who had previous experiences with the instructional approach in their freshman and sophomore years. The students represented a range of racial, academic, and socioeconomic characteristics that corresponded to district demographics, although the majority of students were White and middle to upper-middle class.

The Toxin Project

This study focused on a cycle of activity—a complete set of activities, actions, or lessons around a single topic or a specific theme (Green & Meyer, 1991). The notion "cycle of activity" was used to indicate a complete series of thematic activities initiated and enacted by class members (Floriani, 1993). Through these activities, class members interactionally constructed their academic and cultural knowledge with common thematic content. The cycle of activity from which data were collected was a 7-week project named "Toxin Unit." Figure 1 situates this cycle of activity in a larger class history.

During this cycle of activity, students worked with one or two other classmates and each small group conducted an investigation of a known toxin from a list provided by their teachers. Classroom activities of this cycle or unit were centered around a driving question: "Is my drinking water safe?" To answer this question, they were given lectures of relevant chemical concepts, searched information from the web, watched videos of water treatment and environmental science, did lab activities of solubility and water purification, built physical and computational models, and designed webpages for final presentations (see Figure 1). Chemical concepts covered by this unit were VSEPR (Valence-Shell Electron Pair Repulsion) theory, covalent bonds, IUPAC (International Union of Pure and Applied Chemistry) nomenclature of organic compounds, molecular structures, and polarity of bonds and molecules. Throughout the project, several local topics and environmental issues were raised and discussed. For example, students watched video about the local water treatment and engaged in discussions about some toxic chemicals that could be found in their houses.



Week	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Day	1(M), 2(W), 3(Th)	4(M), 5(W), **6(F)**	**7(M)**, 8(W), 9(F)	10(M), 11(W)	**12(M)**, 13(W)	14(M), 15(W), 16(F)	17(M), 18(W), 19(F)
Events	• Introduce the project • Watch water treatment video • Foul water lab • Watch movie: a civil action	• Review foul water lab • Discuss the movie and related issues • Lecture: ionic and covalent bonds • eChem I • **Lecture: naming alkanes**	• eChem II • **Lecture: naming hydrocarbons** • Manipulate physical models • eChem III • Lecture: cyclic compounds and functional groups • Watch video: Michigan at risk • Quiz	• Review quiz • Watch video: Michigan at risk • Toxin investigation • Lecture: EN, polarity, solubility • Solubility lab	• Review solubility lab • Review polarity and solubility • **Toxin in my house** • Lecture: TV method • Lecture: VSPER theory • Web hunt: VSPER theory	• Discuss web evaluation criteria • Watch video: Silence of spring • Demo: creating a webpage • Web page design	• Web page design • Discuss evaluation criteria of independent study • Peer critique of web pages

Figure 1. The Toxin Project situated in and across time (M: Monday; W: Wednesday; Th: Thursday; F: Friday).

Teachers

Two teachers were coteaching the class. The experienced teacher, Mark, majored in chemistry, and had 10-year teaching experience and 5-year experience with the FOS program. The student teacher, Maggie, was an undergraduate student majoring in biology and minoring in chemistry. She was assigned to teach at this school for 4 months to fulfill certification requirements. She had no instructional experience with project-based science prior to teaching this Toxin Unit. During the cycle of activity, Maggie took the main role of teaching in the class. The experienced teacher sometimes contributed his opinions about some issues or his understanding of the content to class discussions without interrupting the student teacher's instruction. During the time of my class observation, he had never shown his dissatisfaction at what she taught or how she taught in front of the class. Nor did he act in front of her students in ways that might be interpreted as undermining Maggie's authority as a teacher. Students trusted the instruction and answers that Maggie gave, and never asked for Mark's permission or acknowledgement for the activities that Maggie had them to do. They treated her as a coteacher rather than an inexperienced student teacher.

Data Collection

Before collecting data for this study, I visited Mark's science class weekly and attended teachers' meetings several times. Through the 7-week data collection, I attended every class period including watching a movie outside the school on Day 3. I participated in the class as a researcher conducting this study, as a computer specialist, and as a content specialist for the Toxin Unit. I interacted with the students for their content questions and computer problems. I also attended teachers' meetings and was involved in the project planning.

I collected multiple sources of data for the study. I took field notes during each of the class periods that I attended to capture the major events of the day and to note particular episodes related to constructing meanings for chemistry. A Hi-8 video camera recorded the classroom activity. These recordings are the primary data source for this study's transcriptions of the toxin cycle of activity and evidence for my analytical claims.

Since FOS was an integrated and interdisciplinary science curriculum, teachers did not assign a specific textbook as the main source of information for this course. Rather, they integrated the scientific information collected from multiple resources, including journal articles, the internet and textbooks, to write worksheets, handouts, and develop the curriculum. I collected these curriculum materials during teachers' meetings and the class periods. I used these materials to understand how teachers implemented the FOS curriculum and what they considered the content of the curriculum.

Data Transcription and Analysis

Several analytic steps were taken to understand how the teachers and students made the science content meaningful through linking it to real situations. First, the video recordings of class activities were transcribed. During transcription, I identified chemical concepts covered during this cycle of activity, the events of each day, and the length of events. In this study, an event is defined as a bounded set of activities about a common theme on a given day. The event could contain one activity or a series of socially and academically linked activities that comprise subevents (Lin, 1993). This level of transcription provided an overview of the cycle of activity and made a range of events visible. Second, event maps of the 7-week cycle of activity were created to demonstrate that events were thematically tied to each other within the Toxin Unit (See Figure 2 for event maps of Day 6, 7, and 12). Further, I located and coded the subevents involving explicit links between chemistry and real situations made by class members on maps. Third, discourse segments of these subevents were transcribed and analyzed. The selections of segments were guided by my research questions. The common terms, chemical terminology, and chemical representations used by students and teachers were coded.

<table>
<tr><th>min</th><th>Day 6</th><th>Day 7</th><th>Day 12</th></tr>
<tr><td>5</td><td>Previewing today's activities</td><td rowspan="10">Group time: Using a computer program to build virtual 3D models and practice naming rules of alkanes</td><td>Previewing today's activities</td></tr>
<tr><td>10</td><td rowspan="3">Class discussion: reviewing ionic and covalent bonds</td><td rowspan="2">Class discussion: reviewing solubility lab</td></tr>
<tr><td>15</td></tr>
<tr><td>20</td><td rowspan="8">Group time: manipulating 3D models to investigate polarity of molecules</td></tr>
<tr><td>25</td><td>Class discussion: homework</td></tr>
<tr><td>30</td><td>Lecture: Defining alkanes</td></tr>
<tr><td>35</td><td rowspan="3">Lecture: Nomenclature of alkanes
*(Segment 1: ethanol)**</td></tr>
<tr><td>40</td></tr>
<tr><td>45</td></tr>
<tr><td>50</td><td rowspan="3">Student activity: Practicing the nomenclature of alkanes</td></tr>
<tr><td>55</td><td rowspan="2">Lecture: Defining and naming alkenes and alkynes</td></tr>
<tr><td>60</td><td rowspan="2">Class discussion: polarity and solubility of toxins</td></tr>
<tr><td>65</td><td rowspan="6"></td><td>Student activity: Practice naming</td></tr>
<tr><td>70</td><td rowspan="3">Student activity: Manipulating 3D physical models</td><td rowspan="4">Class discussion: Toxin in my house
*(Segment 2 & 4: Toxin in my house)**</td></tr>
<tr><td>75</td></tr>
<tr><td>80</td></tr>
<tr><td>85</td><td rowspan="2">Lecture: Introducing functional groups *(Segment 3: Fish smell)**</td></tr>
<tr><td>90</td><td></td></tr>
</table>

Figure 2. Event Map—Events and approximate time spend on Day 6, 7, and 12. The discourse segments selected for analyses are located in the highlighted events.

The curriculum materials and field notes that were collected to describe the implementation of FOS curriculum were not coded and analyzed in detail; rather, they were used to map patterns of classroom instruction and display the events of the day and particular episodes related to my research questions. The data from these two resources offered evidence for triangulating the assertions I generated from the classroom video data. I generated assertions from the transcripts of segments by searching the data corpus. Then I established an evidentiary warrant for the assertions and verified them by confirming and disconfirming evidence provided by the data corpus (Erickson, 1986).

FINDINGS

This section presents analyses of how intertextual links between real situations and the chemistry content were coconstructed by class members through social and discursive practices. Part I focuses on how the intertextual links between real situations and the content at the *microscopic* level were built in the class, and Part II illustrates how the student teacher and the experienced teacher used different instructional strategies to construct links with and for students.

Part I: Linking the Real World to the Content at the Microscopic Level

To illustrate how the links were built in the class, in this part, I present three excerpts of class interactions on Day 6, 12, and 7. These three excerpts are selected to demonstrate patterns that emerged from the ethnographic data corpus. The first excerpt on Day 6 shows how an intertextual link was initiated and completed by the class members. It provides a detailed account of how a link was constructed through a student-initiated class interaction. The second excerpt on Day 12 is taken from a class discussion of homework. It reveals how teachers instigated links selectively while interacting with students' responses. The third excerpt on Day 7 demonstrates a link constructed solely by the teachers. It allows me to examine what content knowledge was involved in the construction of a link. This excerpt also indicates what were the other texts that teachers considered relevant to the interpretation of molecular and symbolic representations in chemistry.

Excerpt 1: A Student-Initiated Link. The first excerpt is taken from a lecture on the nomenclature of alkanes on the sixth day of the Toxin Unit (the event map see Figure 2). Prior to this event, the student teacher, Maggie, reviewed bonding theory, discussed homework with the class, and introduced the definition of alkanes. During this event, Maggie showed students a chart of alkanes with chemical names and structures. This excerpt occurred right after Maggie had given a brief description of the chart. I selected this excerpt to demonstrate how an intertextual link was initiated by a student and how the initiation was recognized by the class members.

This excerpt (Table 1) shows how Jack, as a student, initiated this interaction by raising a question about how ethanol was relevant to what he learned about alkanes. Ethanol was something he heard outside the class and used in real situations (2 and 4). Maggie signaled that this question of ethanol could be socially meaningful to all class members by saying "let's think about ethanol" (5). She used the pronoun "us" to redirect this Jack–teacher dialogue to a whole-class discussion. She then asked a question regarding the number of carbon atoms (5), which was built on information she had given prior to Jack's question. She had said that the number of carbon atoms and the type of compounds determine a compound's name. Although she did not explicitly use the term, atom, her first question (5) assumed that the students recognized that ethanol contains some carbon atoms. Given

TABLE 1
Day 6—A Student-Initiated Link (Excerpt 1)

Interactions	Experienced Teacher	Student Teacher	Student
1		Jack	(Jack raises his hand.)
2			Jack: I just come up with this idea, ethanol, that's what the wxxx perform stuff that can run cars.
3		Okay, ethanol.	
4			Jack: Is there anything to do with this sort of . . .
5		Okay, let's think about ethanol. How many carbons do you think ethanol has?	
6			Student: I have six.
7		Well, do you recognize anything in ethanol that's on this chart?	
8			Evan: Two for eth (he shows two figures).
9		It has two carbons. And do you recognize the ending O L at all?	
10			Students: Alcohol
11		Alcohol. Okay, we'll get into that a little more on Monday, and how to actually name alcohols. But you know just from today, you already know that has two carbons.	

her introduction of the earlier information, there was a known and socially acknowledged answer for her current question (5). A student's incorrect response (6) indicated that the students might not know ethanol has carbon atoms or they did not see the relationship between the prefix and the number of carbon atoms. She then explicitly linked the name "ethanol" to the prefixes shown on the chart (7). Evan's correct response (8) showed that he recognized this relationship by saying "eth for two." In response to Maggie's further question (9) about the meaning of the ending, "ol," more than one student showed their recognition of using a chemical name to identify structure-related information (10). At the time, some students had gotten the rule between the chemical name of a compound and its chemical characteristics. Maggie's conclusion (11) further confirmed the rule by indicating that students could have no understanding of alcohol, but they had to learn to use the prefix to identify the number of carbon atoms that could be applied for chemical names they learned from their daily lives.

In this excerpt, Jack brought his understanding about an organic compound within a real world context into the school classroom. Maggie's response signaled that what he presented was socially acceptable within the history of what counted as appropriate chemistry information in the classroom. Furthermore, she used the compound, ethanol, as an example to show students how a chemical name commonly used in their daily lives could inform them about its structure, such as the number of carbon atoms and the type of compounds. When she said "let's think about ethanol," she moved the name "ethanol" from the context of Jack's experience to the context of a science class. Her first question regarding the number of carbon atoms further connected this "ethanol" to the chemistry content at the microscopic level that ethanol was something made up of carbon atoms.

During this cycle of activities, students often volunteered their ideas about organic compounds within a real world context. The student teacher, Maggie, took the opportunities by using these compounds as examples to show them how a chemical name commonly used in their daily lives informed them about its structure, such as the number of carbon atoms and the type of compounds. A common chemical name became a mediator intertextually linking students' life experiences and the chemistry content at the microscopic level when it was meaningful in both contexts. Because a student-initiated link revealed what students have known about the content, it provided a context for the class members to build meanings on their prior knowledge and concrete experiences. Through discursive practices, the teachers strategically linked a chemical term to the content by guiding students to rethink the relationship between the number of carbon atoms and the nomenclature of organic compounds. Even though some students may not share a common experience or may not realize what a specific term meant in chemistry, they acknowledged that the chemistry content could be connected to their daily lives.

This first excerpt has shown how a link was initiated by a student and established through a class discussion. However, not all students' questions initiated the construction of links. The following excerpt reveals how the teacher selected students' responses as initiations and chose specific links to make.

Excerpt 2: A Teacher Instigated Link-Making. This excerpt is taken from a class discussion on Day 12 (see Table 2), and the topic of this discussion was "Toxins in my house." Before the day, students had to fill out a "Home Hazardous Products Survey" as homework. This class discussion was based on the compounds that students found in their houses.

In this excerpt, although the student teacher repeated the student's response "lime salt" (3), she did not write it on the board, nor did she ask further questions about it, as she did to Ted (5). Her response to ammonia chloride provided an explanation of why she ignored lime salt (10 and 12). Rather than putting it on the list immediately, she asked a question to the whole class as to whether ammonia chloride was organic or nonorganic (10). Her response (12) showed that to be a compound that would be put on the list or be discussed, it should be an organic toxin or at least a toxin. In this cycle of activity, all lectures were related to organic chemistry (see Figure 1), so her response in this interaction reemphasized that the chemical compounds which were socially meaningful in this interaction (and in this cycle of activity) were organic toxins. Therefore, as an inorganic nontoxin, lime salt was and should be ignored by the teacher and the class. As shown from turn 9 to turn 15, Jerry gave and then changed his answers three times. Receiving the teacher's signal that the organic toxin would be a legitimate answer in the class, he seemed to repair his first response and bought in organic prefixes to his second and third responses. Thus, the teacher and students interactively chose and ignored to understand specific chemical compounds and coconstructed meanings of "organic."

Additionally, an intertextual link could be seen between ammonia chloride and cleaners. To help students decide whether ammonia chloride was organic or not, the student teacher told students what atoms are in it (10). Rather than using atoms' names (i.e., nitrogen, hydrogen, and chlorine), she described these atoms as symbols (i.e., N, H, and Cl). Thus, at the microscopic/symbolic levels, ammonia chloride was represented as a combination of atoms and symbols. The link between the content and real situations was completed by the student teacher's conclusion (19) of ammonia chloride as an ingredient of cleaners. In this excerpt, ammonia chloride was used as a name across contexts, which mediated the construction of a link by allowing the teacher to move it from the context of real situations to the context of the science class.

As shown in the excerpt 1 and 2, while links could be initiated by students and selectively constructed through the class interactions, the content knowledge at the microscopic/symbolic levels was mainly provided or prompted by the teacher. In the first excerpt, the student teacher's questions guided students to treat "ethanol" as a compound with two carbon atoms. Her response in the excerpt 2 defined what counted as an organic compound and determined what atoms ammonia chloride consists of. By presenting a link constructed solely by the teachers, in the next excerpt, I analyze what content knowledge was involved in the process of making a link.

TABLE 2
Day 12—Links That Were Chosen to Be Made (Excerpt 2)

Interactions	Experienced Teacher	Student Teacher	Student
1		What's something that you found in your house?	
2			Student: Lime salt.
3		Lime salt?	
4			Students: xxxx Students: Shut up. Ted: Iso-propanol.
5		Iso-propanol (she writes the name on the board). What's iso-propanol? Where did you find that, Ted?	
6			Ted: I found that on the furniture polish.
7		Okay, so Ted found isopropanol on furniture polish. Jerry.	
8	Shh...		
9			Jerry: I found hum... ammonia chloride xxxxxxx.
10		Ammonia chloride. Is ammonia chloride toxic? Is ammonia chloride... that's ammonia, which is N and Hs, right? And Cl. Would that be organic? Would that be an organic toxin or nonorganic toxin?	
11			Students: Nonorganic.

Continued

TABLE 2
Day 12—Links That Were Chosen to Be Made (Excerpt 2) *(Continued)*

Interactions	Experienced Teacher	Student Teacher	Student
12		It would be an inorganic, because it doesn't have any carbon in it. Okay? But it is a toxin, and we put it up. What was it again?	
13			Jerry: Ammonia methyl, uh . . .
14		Ohh. That was methyl ammonia.	
15			Jerry: It's dimethyl.
16		So dimethyl ammonia chloride (she looks at Jerry and waits for his confirming.)	
17			Allan: What is that?
18			(Jerry turns to Allan and explains to him.)
19		A lot of people probably got some kinds of ammonia chlorite or ammonia chloride. Those are really common in things like uhh . . . toilet bowl cleaner, and lots of combination bleach cleaners. Something with ammonia chloride in it is really common.	

Excerpt 3: A Connection Constructed by the Teacher. This excerpt is taken from a lecture of functional groups of organic compounds on Day 7. After the student teacher introduced the functional groups of halocarbon, alcohol, ether, aldehyde, ketone, and ester, Mark, the experienced teacher gave the following talk (Table 3).

Instead of constructing links through dialogic interactions with students, the teachers made links by describing processes, showing structures, and presenting relevant information in monologic discourse. To show students "how these [compounds with functional groups] actually work together," the experienced teacher integrated chemical terminology (i.e., aldehyde, carboxylic acid, and ketone) into a daily experience. He transformed the fish smell and lemon to chemical compounds, and deodorization became a chemical process. To make all links in this talk visible, I further transcribe this excerpt to Figure 3. It demonstrates how multiple texts were juxtaposed as the experienced teacher moved back and forth between the real situation and chemistry content. This example created a context for students to rethink the functional groups they just learned and emphasized that chemistry at the three levels (i.e., the macroscopic, microscopic, and symbolic levels) was part of their daily life (3).

As shown in Figure 3, these links could have not been built without content knowledge elements (i.e., aldehyde, citrate acid, and carboxylic acid). The experienced teacher must realize the chemical characteristics of these functional groups and relevant links prior to giving the talk. The links demonstrated in Figure 3 indeed are similar to those made by chemists in Kozma et al. (2000). The teacher used representations as referents of aperceptual

TABLE 3
Day 7—A Link Constructed by the Teacher: Fish Smell and Lemon (Excerpt 3)

Interactions	Experienced Teacher	Student Teacher	Student
1	I'm gonna show you how these [functional groups] actually work together. If you . . . let's say you're about to eat some fish. And fish has that funky smell that funky smell is an aldehyde. And . . . that funky smell you take a piece of lemon which has . . . which has citrate acid in it. It's a carboxylic acid. It's citrate acid.		
2		So this is the lemon. (She circles the general formula of carboxylic acid, and writes "citrate acid" next to it.)	
3	It's the lemon, and you pour on to the fish smell which is the aldehyde. And those things together break the aldehyde down into I think a ketone, and which doesn't smell as much. So you know, I mean you are constantly doing these types of reactions . . . umh . . . without even thinking about it. And you're changing one compound into another compound to solve the particular problem. That's just an example what's going on there.		

entities (e.g., acid, aldehyde and ketone) and semantically combined these representations to describe an invisible, chemical process (e.g., breaking the aldehyde down into a ketone).

Additionally, based on his understanding of students' prior knowledge and experiences, he assumed that students had experience with pouring lemon juice on a fish, because his talk would have been socially meaningless if students did not recognized either fish smell or functional groups. Thus, by creating these links, the experienced teacher demonstrated his content knowledge of the topics and pedagogical knowledge of what students already knew and how to teach the content meaningfully. To illustrate how the teachers' content could shape the ways of making links, in the Part II, I present the fourth excerpt and discuss how the student teacher and the experienced teacher constructed links differently.

Part II: The Content Knowledge and the Ways of Making Links

Excerpt 3 and Figure 3 have shown that the construction of links involved both the teacher's content and pedagogical knowledge. To further explore this issue, I selected the fourth excerpt.

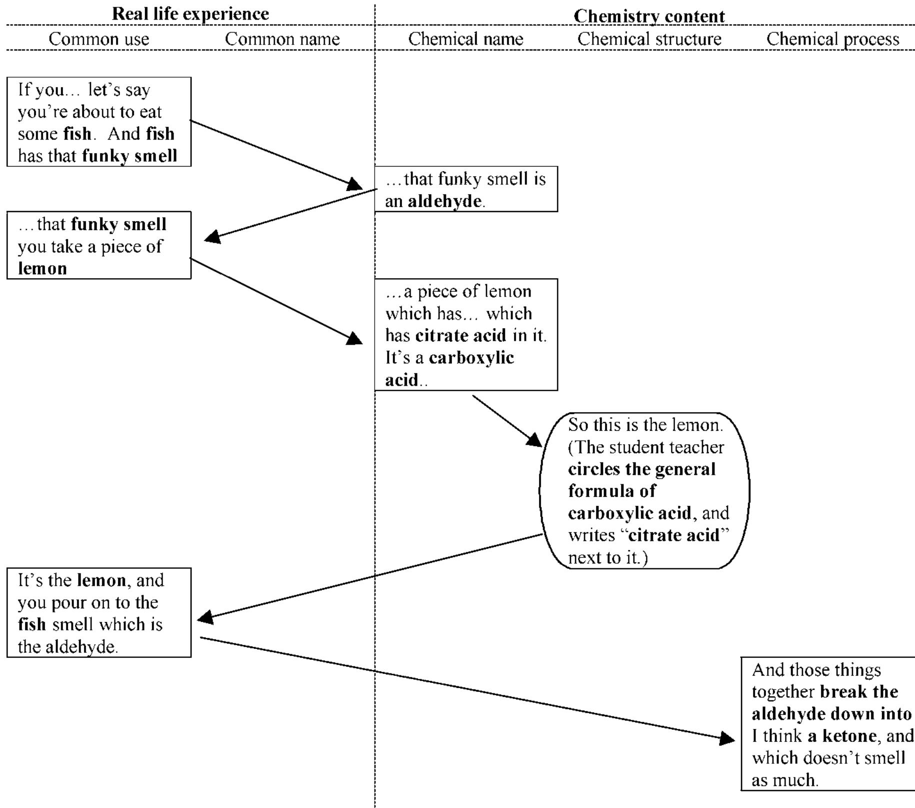


Figure 3. The juxtaposition of multiple texts done by the experienced teacher and the student teacher in the Fish Smell and Lemon excerpt. Boxes contain the experienced teacher's discourse. The oval contains the description provided and the action taken by the student teacher.

Excerpt 4: Toxin in My House. This discourse segment follows excerpt 2 (Table 4); both of the segments are taken from the same event on Day 12 (see the event map in Figure 2). After the student teacher concluded that ammonia chloride was a common ingredient of cleaners (see Tables 2 and 4 (19)), she asked Andy about the toxin he found in his house—mono ethanol amine in oven cleaner. The experienced teacher then intervened in the dialogue between the student teacher and Andy by saying that mono ethyl amine and dimethyl ammonia chloride were almost the same compound. He explained that both dimethyl and ethyl contained two carbon atoms, and that amine was one kind of ammonia compound.

The experienced teacher's intervention began with the comment (27), "which is very interesting." Rather than initiating the intervention with a complete sentence, he used "which" to slot into and continue the dialogue between the student teacher and Andy. The use of "which" made his intervention part of their dialogue rather than an interruption. As mentioned previously, during the time of class observation, he never interrupted class instruction in ways that may have undermined the student teacher's teaching authority. Continuing and becoming a part of the class discourse were strategies he frequently used.

In response to the student teacher's question (28), Mark, the experienced teacher, first explained the chemical meaning of dimethyl (29). His explanation made an intertextual link to what students had already learned about naming rules and subgroups. By including

TABLE 4
Day 12—Toxin in My House (Excerpt 4)

Interactions	Experienced Teacher	Student Teacher	Student
19		A lot of people probably got some kinds of ammonia chlorite or ammonia chloride. Those are really common in things like uhh . . . toilet bowl cleaner, and lots of combination bleach cleaners. Something with ammonia chloride in it is really common. So Andy, what did you find in your house?	
20			Andy: Mono ethanol amine
21		Mono ethan ol amine? (She writes it on the board.)	
22			Andy: Yeah. It was in oven cleaner.
23		And what was that in?	
24			Andy: Oven cleaner.
25		Oven cleaner?	
26			Andy: Right
27	Which is very interesting. It's probably the same thing, almost.		
28		Is this? (she points to dimethyl ammonia chloride)	
29	Yeah. Because dimethyl, what does dimethyl mean? It means 2 methyls, which means two carbons, right? What is ethyl?		(Some students nod.)
30			Allan: One . . . two carbons
31	Two carbons. Right. Amine is another way of saying ammonia, so it's another some kinds of the ammonia compound.		

several small questions, his explanation showed his assumptions that students understood that di meant 2 and methyl was a subgroup with only one carbon atom. When he said "right?" he was looking for students' confirmation, which could be verbal or nonverbal expressions, such as nodding. His explanation was more like a review of what students already learned, so he expected the answers to his questions to be known by the class. Allan's response further validated the teacher's assumption that students could recognize the structural similarity between dimethyl and ethyl. In contrast with his treatment of dimethyl, his explanation of amine (31) did not contain any questions. He directly provided a description of how amine was related to ammonia knowing that for students ammonia was a socially recognizable compound and amine was first mentioned by a class member. Thus, in this excerpt, the experienced teacher applied different instructional strategies of questioning and explaining based on his recognition of students' prior knowledge regarding naming rules and molecular structures. To introduce the compounds that were not socially recognized by the class, he used descriptions or lecturing. Furthermore, he made intertextual links to what students had already learned by using a series of interactive questions. The student teacher applied a similar strategy in the first excerpt by prompting students to read the structure-related information from ethanol.

In this fourth excerpt, the student teacher and the experienced teacher demonstrated their content knowledge through discursive practices. From chemical names of two compounds (dimethyl ammonia chloride and mono ethanol amine), the experienced teacher saw the similarity of their molecular structures. His explanations (29 and 31) illustrated his understanding of molecular structures, naming rules, and the relationship between them. Yet the student teacher's response (28) showed that she did not recognize the relationship when Mark first made a comment about these two compounds (27). At the time, she did not identify the similarity of structures between them as Mark did.

Figure 4 synthesizes the second and fourth segments and certain elements of the links constructed during these interactions become visible. It can be observed that the information related to the content was mainly provided by the two teachers. In addition, the experienced teacher's explanations were all located in the chemistry domain. As he did in excerpt 3 (see Figure 3), the experienced teacher tended to extend the chemistry content into what students had not yet learned through describing or presenting various links between real situations and the content at the microscopic level. His explanations and descriptions contained many chemical terms and required considerable content knowledge. The student teacher also provided relevant information and/or encouraged students to generate meanings related to the chemistry content. For example, Figure 5 showed how the link was constructed in the excerpt 1. By questioning students to interpret chemical meanings from the name "ethanol," Maggie illustrated how to read a structure from a chemical name. However, compared with the experienced teacher, she tended to construct intertextual links with students by building on what students had already learned. She applied content knowledge to shape students' ways of constructing links with the class. Her response in the fourth excerpt could also be interpreted as a lack of content knowledge about the relationship between ammonia and amine. Therefore, with more understanding of the chemistry content, the experienced teacher made links with the class through presenting information or asking a series of questions by oral discourse; on the other hand, the student teacher with presumably less content and pedagogical knowledge mainly used questioning to build links with the class.

CONCLUSIONS

Recent studies in science education have increasingly turned to a concern with the use of language in scientific practices (e.g., Hogan, Nastasi, & Pressley, 2000; Kelly & Chen,

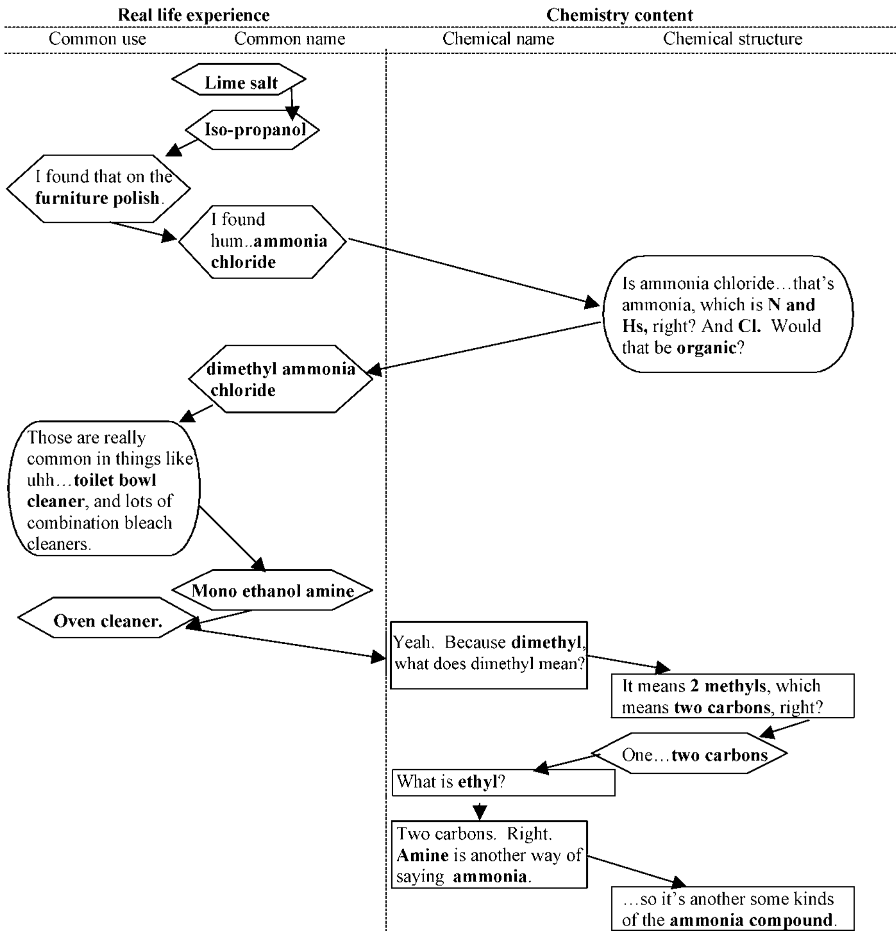


Figure 4. The juxtaposition of multiple texts done by the class members in the Toxin in My House excerpt. Boxes contain the experienced teacher's discourse. Ovals contain the student teacher's discourse. Students' responses are shown in hexagons.

1999; Kozma, 2000b). Kozma (2000b) indicated that the use of language in chemistry serve educational functions. While the participants in Kozma's studies (2000b) were chemists and college students, this study illustrates how students and teachers at the high school level coconstruct meanings of chemical representations through classroom discourse. Students' final artifacts demonstrate that they took up this "link-making" as a way of presenting and learning chemistry knowledge. Figure 6 shows one student group's web page in which they gave an introduction their toxin—acetone. In this page, they provided a detailed description of the chemical structure of acetone and explained how this structure causes the polarity of this compound. They then tied the information of polarity to solubility and biological effects on the human body. This page included conceptual information of the three levels of chemistry and revealed that the students' thinking of chemistry could move back and forth among phenomena (i.e., biological effects and solubility), representations (i.e., the structure and formula), and concepts (i.e., the relationship between polarity and structure). At the conceptual level, therefore, oral and written discourses could be used to make interpretations of chemical representations. Through the use of language, students in the study came to learn the conceptual knowledge embedded in symbolic and molecular representations.

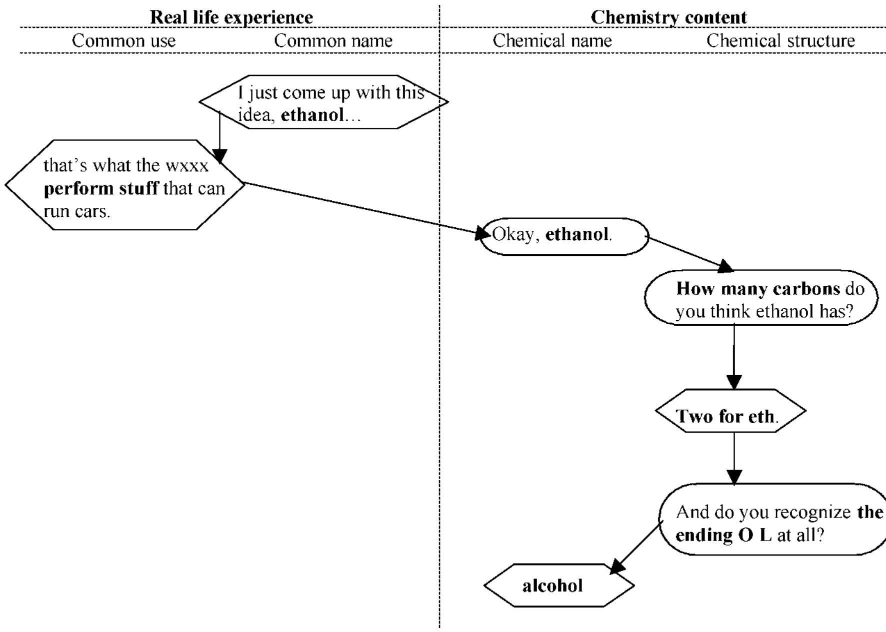


Figure 5. The juxtaposition of multiple texts done by the class members in the Ethanol excerpt. Ovals contain the student teacher's discourse. Students' questions and responses are shown in hexagons.

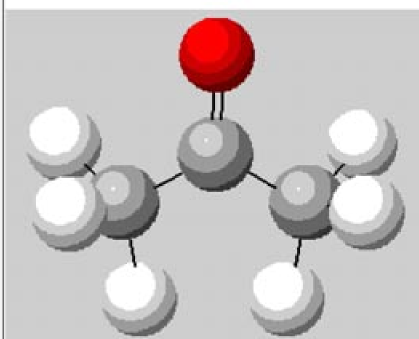
Although students are capable to make links among three levels, students' understanding is usually constrained by available resources including linguistic resources provided by teachers (Kozma, 2000b). The findings show that teachers' scaffolds were crucial to support students' conceptions to move beyond the perceptual experiences. The close examination of class discourse suggests that although links could be coconstructed by the teachers and students, the chemistry terms and content at the microscopic level were mainly provided or guided by the teachers. The intertextual links created by students were usually weak and focused on mapping common names and common uses of substances to chemical structure, which is similar to the first type of intertextual link in Kozma et al. (2000). As shown in Figures 4 and 5, students did not actively mention any information located in the chemistry domain unless they were prompted by the teachers. Without explicit instruction, students might have not been able to make these links. In excerpts 1, 2, and 4, the teachers' questions contained important conceptual information and implied possible relationships among chemical representations that became a linguistic scaffold to support the meaning-making process. Therefore, because of the abstract and content-based nature of chemical representations, teachers' scaffolds are crucial to facilitate the construction of links between chemical representations and observable phenomena.

Additionally, this study shows that at the social level, making intertextual links could become a specified way of language use (Lemke, 1988) and be promoted by the design of the curriculum. Instead of learning microscopic representations through teachers' lecture or textbooks, students were encouraged to collect information from multiple sources. Not only did class members contextualize the science content in their familiar settings, they valued the information gathered from textbooks, dictionaries, life experiences, and websites. The learning community created a socially accepted way to bring their life experiences into the classroom context to make the content meaningful. In doing so, chemistry was learned and taught against the mystique of science (Lemke, 1990). The classroom discourse mixed

The **CHEMICAL PROPERTIES** of acetone are:

Solubilty: It dissolves in water, and is often used as a solvent

Covalent bonding/3D Structure:



This is a ball-and-stick diagram of the molecule C_3H_6O, otherwise known as ACETONE. The grey balls represent Carbon atoms, the white balls are Hydrogen and the red ball is Oxygen. The black sticks represent bonds: single sticks represent single bonds, and double sticks represent double bonds. Therefore, there are single bonds among the Carbon and Hydrogen atoms, and among the Carbon atoms. There is one double bond in Acetone- between the Carbon and Oxygen atoms. The Carbon-Hydrogen bonds are non-polar bonds, the Carbon-Carbon bonds are neutral, and the CArbon=Oxygen bond is polar. The Carbon-Oxygen bond has stongest electronegativity value, therefore Acetone is slightly polar because the non-polar bonds among the other atoms contribute to eliminating some of the polar bond's electronegativity.

Polarity: Acetone is borderline between polar and nonpolar. In an experiment we performed, we found that non-polar substances dissolved in the acetone. In solubility, like substances dissolve like substances, and so we concluded that acetone was non-polar. However, acetone also partly dissolves in water due to it's 3-D structure as shown above, and is not strongly polar or non-polar.

Effects on the Human Body: Because Acetone can be polar and non-polar it effects many systems in the body. For example, fat is non-polar and so Acetone can attack the fat cells in your body. If you are exposed to acetone it goes into your bloodstream and is then carried to all the organs in your body. I f it is a small amount the liver breaks it down to chemicals that are not harmful and uses these chemicals to make energy for normal body functions.

Figure 6. One student group's web page of their toxin acetone.

colloquial and academic language, and the chemistry content discussed in the classroom was not contrary to common sense. By transforming the information from real-life experiences into scientific knowledge, students learned to know that science is not a special kind of truth. The "authentic" feature of the curriculum may contribute to the establishment of the social norms, as the teachers emphasized the practical application and local issues of science in the community (Heubel-Drake et al., 1995).

However, although the culture of the class in this study invited students' daily experiences, teachers did not further include these related experiences into the interactional space (Heras, 1993) of class discussions. When the student teacher moved a chemical name from Jack's experience into the context of the class in the first excerpt, this process involved re-contextualization (Lemke, 1990). She isolated the compound "ethanol" as a chemical name from Jack's experience and recontextualized it in the context of the science class without discussing it within Jack's context or providing implications of why this compound was used as a way that Jack described. She might consider that Jack's experiences might not be socially recognized by other class members, so she chose to discuss it as a chemical compound. Yet, if making links and contextualization become ways of understanding science, the questions of whose context counts as "the" context of a class and how class members construct social meanings through integrating multiple contexts outside the school should not be overlooked.

Teachers' content knowledge shapes the discursive nature of scaffoldings. Carlsen (1992) indicated that insufficient content knowledge led teachers to control classroom conversion rather than encouraging an interactive dialogue between the teacher and students. The findings of this study further show that teachers' content knowledge influenced their choices of discursive strategies; however, it may not necessarily constrain the interactions between the teacher and students. In this study, although the student teacher did not have sufficient content knowledge to extend students' understanding through presenting more links in real situations, she still promoted students to generate questions and relate the content to experiences through oral discourse.

The findings of this study provide a backdrop for further research to explore how students use intertextual links as a way of learning, how students learn from links that are built by different instructional strategies, and how chemistry is learned and taught in a class through the social constructivist lens.

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