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Investigating and Theorizing Discourse During Analogy Writing in Chemistry

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Abstract: Explanations of the role of analogies in learning science at a cognitive level are made in terms of creating bridges between new information and students’ prior knowledge. In this empirical study of learning with analogies in an 11th grade chemistry class, we explore an alternative explanation at the “social” level where analogy shapes classroom discourse. Students in the study developed analogies within small groups and with their teacher. These classroom interactions were monitored to identify changes in discourse that took place through these activities. Beginning from socio-cultural perspectives and hybridity, we investigated classroom discourse during analogical activities. From our analyses, we theorized a merged discourse that explains how the analog discourse becomes intertwined with the target discourse generating a transitional state where meanings, signs, symbols and practices are in flux. Three categories were developed that capture how students intertwined the analog and target discourses—merged words, merged utterances/sentences, and merged practices.

Key words: merged discourse; science classroom discourse; analogy; role-play; hybridity

Introduction

The field of research on science teaching and learning using instructional analogies is well established (Aubusson, Harrison, & Ritchie, 2006). In science education, the research focus has been on how analogies are used for instruction by students, teachers, textbook authors, how best use is made of analogies for instruction, and on the use of analogies in achieving conceptual change (Aubusson et al., 2006). Early studies on the role of analogy in learning tended to come from cognitive science (e.g., Gentner, 1983). Podolefsky and Finkelstein (2007) have critiqued cognitive perspectives on learning with analogies for focusing on individual cognition in laboratory settings and ignoring how learning occurs in naturalistic settings. More recently, Hubber, Tytler and Haslam (2010) argued that analogies may contribute to the range of multimodal representations used by students to explain scientific phenomena. They proposed that rather than analogy working only at a cognitive level, it may serve as one form of representation amongst others including gestures, diagrams and discourse. Furthermore, Treagust and Duit (2008) have called for a multi-perspective approach to science education research in general. We propose that socio-cultural perspectives on learning with analogies can complement studies from cognitive science and those from conceptual change by focusing on how social interaction, culture, and discourse help to shape individual learning. In this study, we investigated discourse during analogy-writing activities in a chemistry class through a unique theoretical framework informed by cultural theories. Two analogical activities, a neurotransmission role-play and a

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1 In this discussion analogy is a similarity made between familiar objects, or the analog concept, and scientific concepts or theories, referred to as the target concept. The process of drawing similarity between the analog concept and the target concept is called mapping (Duit, 1991). Analogies can also take on the form of role plays (Aubusson & Fogwill, 2006).
stoichiometry analogy, formed key activities for our investigations. The study addresses the need for research focusing on the influence of analogy on social interaction and discourse as identified by Coll, France and Taylor (2005) as well as the need for differing perspectives in science-education research (cf. Treagust & Duit, 2008) on analogy.

In the next section, we review literature on analogies in science education identifying the main contributions and need for further research. We then present our theoretical framework that is informed by socio-cultural perspectives and cultural theory. The design of the study follows with a thick description of the context of the school and classroom in which we conducted the research. Against this backdrop, we canvas two claims from the results of the study. The warrants for these claims are used to theorize what we call *merged discourse* in the discussion. Merged discourse accounts for the findings of the study and provides a way of theorizing discourse during analogy-writing activities. We conclude by providing suggestions for future research.

**Research on Learning and Teaching Science With Analogies**

Research on analogies has shown that there are benefits and potential pitfalls to their use in science instruction (Aubusson, Harrison, & Ritchie, 2006; Dagher, 1995; Duit, 1991). Specific conditions must be met in order to produce desirable rather than deleterious results from the use of analogies (Glynn, 1996; Harrison & Treagust, 2000). In order for analogies to be of use, the analog concept must be something that is part of students’ lived experiences. Teachers must make clear that analogies are representations of target concepts and not the target itself, as students often take it to be. For example, in the popular water-in-pipes analogy for electric current, students can come to think of electrical wiring as being like a water conduit—that is, a hollow pipe through which electrons flow. In addition, mapping similarities and differences between target and analog becomes most important. Students must see that the analogy eventually breaks down and is no longer sufficient as a representation of the target concept. Work conducted by Harrison and Treagust (2006) suggests that multiple models are required to represent fully a target concept due to the limitations of single analogies.

Analogies have also been described as double-edged swords as they can lead to alternative conceptions and misrepresentation (Aubusson, Harrison, & Ritchie, 2006; Zook, 1991). Zook (1991) proposed a model for predicting the relative potential for analogical misrepresentation; that is, the extent to which unsuitable features of an analog concept may be mapped to the target concept. His model identified two loci that influence misrepresentation: 1) who generates the analog concept; and 2) the mapping of similar attributes between the analog and target. The model shows that students have little difficulty in choosing an appropriate analog concept but find the mapping process difficult. The corollary to this is that students find teacher analog concepts difficult to relate to, but easier to map to the target concept. Zook’s work pointed to different outcomes from instructional analogies depending on the locus of the analog concept (i.e., teacher choice or student choice). Educational research has identified various outcomes from these two loci of analog concepts.

Treagust, Chittleborough, and Mamiala (2003) reported one example of a teacher’s use of analogies for teaching stoichiometry (the reacting quantities in chemical reactions). The teacher likened the concept of limiting reagents (i.e., the reagent consumed completely in a reaction) to a dance where one male dancer pairs with two female dancers to represent a reaction with a stoichiometric ratio of 1:2 in the reactants. Analysis of discourse revealed that the analogy generated interest amongst students and that “the symbolic representation of the equation and the analogy helped to develop the submicroscopic representation of the limiting reagent concept”
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(Treagust, et al., 2003, p.1360). These multiple forms of explanation (i.e., macroscopic, symbolic and submicroscopic) were regarded as most likely to lead to comprehensive understanding of chemical concepts.

Aubusson and Fogwill (2006) studied teachers’ and students’ use of simulation role-play (or analogical role-play), in science classrooms. These researchers defined simulation role-plays as analytical activities because the actors did not represent other people as in other forms of role-play. During simulation role-plays in science classrooms, the actors represent scientific concepts like electrons or food during digestion. According to Aubusson and Fogwill (2006), simulation role-play can contribute to enabling students to generate deeper understanding, to simulate theory, to bring student understanding of concepts to the fore, and for students to share different views through social interaction. In addition to these benefits, they added that engaging in role-plays encourages scientific thinking through analogical reasoning and fosters discussion and learning in subsequent lessons.

Spontaneous student-generated analogies are different from instructional analogies as students develop them without external stimulus provided by teachers or researchers. Studies by Cosgrove (1995), May, Hammer, and Roy (2006), and Ritchie (1998) reported spontaneous student-generated analogies in elementary science classrooms, identifying positive learning outcomes for students. Spontaneous student-generated analogies are rare in high school settings (Coll, 2006; Harrison & De Jong, 2005). For example, Harrison and De Jong’s study identified that a student generated only 1 out of 10 analogies in two hours of lesson observation. The low occurrence of spontaneous student-generated analogies proves a challenge for researchers, as prolonged periods of study in naturalistic settings may not yield viable data. Some researchers (e.g., Pittman, 1999; Wong, 1993) have investigated student-generated analogies where instructors (teachers or researchers/participants) have asked students to construct analogies. These analogies are not spontaneous because the participants were required to use analogies by the instructors. However, this has allowed researchers to understand part of the process through which students generate analogies and overcome the problem of their low occurrence in naturalistic settings. The studies reported so far in this review have tended to focus on classroom use of analogies and ways to teach effectively with analogies.

Gentner’s (1983) cognitive theory has been influential in understanding how analogy functions to generate meaning. Despite the influence of cognitive theories on analogy research, cognitive studies on analogy have been critiqued for reliance on laboratory-style investigations that focus on individual cognition rather than emphasizing social interaction in naturalistic settings (Podolefsky & Finkelstein, 2007). Podolefsky and Finkelstein argued that cognitive theories might not apply wholly when interpreting students’ use and understanding of analogy in naturalistic settings. Their argument is consistent with views taken in other educational research. For example, Van Boxtel (2004) argued that studies focusing on individual cognitive process ignore the contextual, situated nature of learning. Only by focusing research on social interaction and discourse can the situated nature of learning be accessed. He claimed that the role analogy may play in shaping social interaction is not well documented. We hold the view that studies in natural settings focusing on interaction and discourse can complement our understanding of analogies derived from individual cognitive studies. Yerrick, Doster, Nugent, Parke and Crawley (2003) provided one participant-observer study of pre-service teachers’ interpretation and argumentation through using instructional analogies. Through fine-grained analysis of small-group discourse, they found that students used analogies to introduce and debate prior knowledge and experience, to negotiate a social climate for substantive scientific discourse and the analogies
allowed for joint construction of knowledge. Their study demonstrated that analogies could play a role in shaping classroom discourse and social interaction.

Few studies have focused on how analogies influence classroom discourse. Even though Yerrick et al. (2003) provided some insights into social aspects of learning, the study focused on pre-service teachers and not high school students in naturalistic settings. More studies are required that investigate how high-school students generate analogies in chemistry (Coll, 2006). Such studies could contribute new insights to the existing literature based on individual cognition.

**Theoretical Framework**

*A Socio-cultural Perspective for Investigating Learning With Analogies*

Coll et al. (2005) have suggested that research from socio-cultural perspectives can lead to understanding of individual cognition through analysis of “social and cultural contexts from which [individual cognition is]…derived” (p. 189). Socio-cultural theory is heavily imbued with a focus on the social interactions following Vygotskian lines of thought (Lemke, 2001). From such a perspective, learning science involves being socialized into scientific ways of reasoning and acting (Jakobsson, Mäkitalo, & Säljö, 2009) and “engaging in a community of practice, marked by one’s growing ability to use the discourse of that community and enact identities valued within that community” (Basu & Calabrese Barton, 2009, p. 7; emphasis added).

Discourse can be used in two ways (Lemke, 1995). The first usage noted by Lemke refers to a social activity of making meaning with symbols and language within particular settings. Here, settings can be classrooms, churches, workshops or any other place where particular kinds of activities are performed and sets of values amongst the participants are shared. The second usage refers to social habits produced by a community. From a socio-cultural perspective, then, learning school chemistry involves developing the capacity to use the symbols, practices, language, concepts, and social habits pertaining to chemistry.

One dominant line of socio-cultural research in science education has involved the investigation of the experiences of linguistically and culturally diverse students in mainstream science classes (Carter, 2008). Characterizing such studies is the exploration and investigation of the struggle against Eurocentrism in science education by students of non-Western backgrounds (Lewis & Aikenhead, 2001). For example, Mutegi (2011) studied how African American students experience the “Science for All” agenda that drives the US curriculum. Such research focuses on the social and historical contexts of linguistically and culturally diverse groups of students and their experiences of (Western) school science. A broader perspective that is applicable to students that are not typically considered as marginalized (i.e., from linguistic or cultural minorities) was offered by Roth (2008). He suggested that the experiences of all students can be understood from socio-cultural perspectives because the linguistic and cultural practices of their everyday lives differ somewhat from those of the science classroom. We take up Roth’s proposal in our study as outlined in the next section where we consider cultural interpretations of science education research from the perspectives of hybridity and Third Space.

*Cultural perspectives for investigating classroom interactions.*

In this study, we coupled socio-cultural perspectives with the cultural constructs of hybridity and Third Space (Bhabha, 1994; Wallace, 2004) to interpret classroom interactions and
discourse as cultural encounters (Roth, 2008) where students’ everyday discourses interact with the chemical world of the classroom. Science has been described as a form of culture because it consists of “…its own creeds, language, material practices, perceptions, theories, and beliefs” (Roth & Lawless, 2002, p. 1). In this way, culture equates to the practices and traditions of communities (Rogoff, 2003), including scientific and classroom communities. We adopted the concept of hybridity as “…suitable for understanding … science as a culture within and different from other aspects of everyday life” (Roth, 2008, p. 894). Roth refers to this as “Diaspora in the native tongue” (p. 910). That is, some students’ out-of-school lives differ enough from the science class that their experience of engaging in science is like cultural difference of people displaced from their home country and culture. From this view, we interpreted students’ experiences of the science classroom as cultural experiences where their everyday discourses and the science discourse of the classroom can interact as they construct analogies. Roth proposed that: “Confronted with differences, individuals continuously engage in cultural bricolage, taking from here and there to make do, producing … new, heterogeneous, creolized forms of knowledgeability and practice” (p. 894). Through bricolage, cultural hybridity can result.

**Hybridity and Third Space in cultural studies and educational research.**

Hybridity and Third Space have been used as ways of describing both culture in the post-colonial world (e.g., Bhabha, 1994) and desirable classroom environments (e.g., Gutiérrez, Baquedano-López, Alvarez & Chiu, 1999; Mojé, et al., 2004; Wallace, 2004). Bhabha invokes a Third Space in cultural studies to explain cultural hybridity. According to Bhabha, due to hybridity, the meanings and symbols of culture have “…no primordial unity or fixity; … even signs could be appropriated, translated, rehistoricized and read anew” (p. 37). Classroom studies that adopt Third Space and hybridity as theoretical constructs share the common theme that a first space (teacher/school discourse) interacts with a second space (students’ everyday discourses/everyday language practices) to produce a hybrid Third Space (e.g., Gutiérrez et al., 1999). To simplify subsequent discussion of these differing perspectives, we herein refer to the latter (i.e., hybrid Third Space) as the “synthesis perspective.” According to Bell, Bell and Michell (2001), definitions can be of two types, descriptive (or conventional meaning) and stipulative (or author defined meaning). A key difference between Bhabha’s conceptualization of hybridity and its use in education research is that he presents a stipulative definition of hybridity while the synthesis view represents a descriptive definition. That is, Bhabha uses hybridity to transcend binary ways of thinking. Thus there can be no first and second space from his conceptualization. In contrast, the use of hybridity in educational research (e.g., Gutiérrez et al., 1999) follows conventional concepts of hybridity as the synthesis of antecedent categories designated as the first space and second space.

**Interpreting classroom discourse through hybridity and Third Space.**

In our study, we proceeded openly with the differing perspectives of hybridity presented in the previous section. We investigated classroom discourse by looking for fluidity of meanings where signs are translated and appropriated in different ways (i.e., a to-ing and fro-ing between discourses; cf. Bhabha, 1994) while also looking for instances where antecedent categories might come together. Regarding the latter, for example, Wallace (2004) identified children’s hybridization of language and multiple classroom discourses when investigating the literacy practices of a grade 10, U.S. science classroom. In her study, students had been investigating the
effects of vinegar on the shell of submerged eggs. One student uttered: “I think the vinegar began pickling the egg making it absorb the water. Then the syrup caused the egg to push out the water due to the pressure of the syrup” (p. 909). In her analysis of this text, Wallace indicated that this student’s use of authoritative language such as pressure is hybridized with the student’s own meaning/s such as pickling and push out. We investigated classroom discourse during analogy-writing activities by identifying similar instances where students hybridize canonical science with their everyday discourse.

Research Design

The aim of this study was to investigate discourse during analogy-writing activities in a high school chemistry class. The research question that guided the study was: Under what circumstances does hybridization of everyday and chemical discourse occur during analogy-writing activities? We adopted an instrumental case study design (Stake, 2005). Instrumental case studies can contribute to theory building and focus on the interests of the researcher while the case plays a supportive role (Stake, 2003).

School Setting and Classroom Context

The study was conducted in Bellocchi’s 11th grade chemistry class at City High School, a large coeducational high school from a North Queensland city in Australia. The class consisted of 19 students, comprised of 11 males and 8 females. The distribution of student achievement in their 11th grade Chemistry assessment was: 4As, 2Bs, 9Cs, 3Ds, and 1E. Results were based on a scale of A-E with A being the highest level, C being a pass grade and D and E representing fail grades. Chemistry was scheduled for five, 40-minute lessons each week. Essentially, the Chemistry program covered basic chemical concepts at the beginning of 11th grade. These included writing formulae and naming chemical compounds, studying the relationships between physical and chemical properties of matter, and understanding the structure and bonding of materials. During the study period, two contexts formed the organizing principles for Chemistry: 1) Chemistry of Drugs- organic chemistry (including nerve signaling); and 2) Chemistry of Fires and Explosions- quantitative chemistry (including stoichiometry and limiting reagents).

The Teacher’s Use of Instructional Analogies and Role Play

The teacher had been using a range of instructional analogies, both pre-planned analogies and spontaneous analogies, since his first year of teaching (See Ritchie, Bellocchi, Pöltl & Wearmouth, 2006). The teacher presented instruction on the use of analogies and discussed the limitations of any particular analogy that was planned for his instruction following similar lines to structured approaches for teaching with analogies (e.g., FAR guide\(^2\); Treagust, Harrison, & Venville, 1998). The teaching and learning episodes described in this study represent components of larger instructional sequences on the chemical concepts relating to stoichiometry and organic chemistry. While the instructional sequences during the study period focused on the development of a range of chemical concepts relating to organic chemistry and quantitative chemistry, our detailed investigation focused on two analogical activities within this context. Specifically, these were a neurotransmission role play and a stoichiometry analogy. Database searches (i.e., Scopus

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\(^2\) The FAR guide stands for Focus, Action, Reflection and it is designed to scaffold a teacher’s instruction when planning to use analogies.
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& Google™ Scholar) indicated that no studies have reported the use of analogical role-play in teaching and learning of nerve signaling. A review of student difficulties with chemical concepts indicates that reaction stoichiometry is one of the more problematic chemical concepts (Dori & Hamieri, 2003). Stoichiometry is a key chemical concept pertaining to the quantitative relationships inherent in chemical formulae and chemical equations (Schmidt, 1997).

The teacher used two types of analogy in the study. First, an activity based on a teacher-generated role play for neurotransmission was implemented during the Drugs unit. This activity involved students representing a series of neurons by standing in a line. The students each held paper balls that represented neurotransmitters. They passed these to the adjacent person to represent the transmission of a signal between neurons. Then, in subsequent lessons, student groups developed their own role plays to model the inhibition of nerve signals by the neurotransmitter gammaamino butyric acid (GABA). The binding of GABA to its receptor site on an ion channel was explained through a lock and key metaphor to indicate the specificity of the binding. The second analogy activity involved a teacher-generated stoichiometry analogy (Reported in Coll, 2008) as part of the Fire unit. In this activity, the teacher represented a chemical reaction with a recipe for making a ham sandwich. Students were invited to participate and assigned the symbols ‘H’ and ‘B’ to the ham and bread and students co-wrote the recipe for the sandwich (HB₂) with the teacher as follows:

\[ H + 2B \rightarrow HB_2. \]

The analogy was then used to model a range of stoichiometric calculations (e.g., mole to mass, limiting reagents) before presenting the concepts again purely through chemical symbols and terminology. Students participated throughout the entire process of analogy construction and evaluation. In subsequent lessons, student groups developed their own stoichiometry analogies. Briefly, instruction for the two analogical activities (i.e., role play and stoichiometry analogy) followed a similar format. The role play and stoichiometry analogy were taught in such a way as to address the problem of analogical misrepresentation identified by Zook (1991). Zook indicated high levels of misrepresentations of mappings between analog and target concept when teachers choose the analog. For this reason, Alberto facilitated the mapping process with students. To overcome the second problem noted by Zook; that is, that students find teacher analog concepts of low relevance, students were invited to develop their own analogies.

Data Sources and Analysis

In this case study design, three student groups (Fergie’s group, Max’s group, and Trev’s group) were chosen to participate in the study from a total of five groups in the class (see Table 1).

[Table 1 About Here]

Together, the three groups represented the majority of the class (i.e., 13 out of 19 students). The groups were chosen based on having provided informed consent to participate in the study, on the students’ willingness to participate, and because these three groups of students participated actively in all classroom activities (based on classroom observations made prior to the period of the study). Thus, the groups were likely to engage in interactions that were focused on the schoolwork and align with our research interests. The number of participants is significant
for a case study design as it represented the majority of the class and produced a significant amount of data (i.e., 260 hours of audio recordings).

Data sources were generated from video and audio recordings (using 5 MP3 recorders) of student group interactions, interviews, artifacts (e.g., written analogies), and responses to written questions about the construction of analogies. The open-ended written questions asked students to explain how their groups arrived at the particular analogies they had chosen. Interviews were conducted by stimulating recall of classroom episodes by presenting students with video or audio recordings of lessons or transcripts derived from these, the next available day after recording. Interview questions were open-ended and based on points of interest to the researchers derived from analysis of lesson video and audio recordings and transcripts. General orientation questions were used to ask students to explain how they developed their analogies. Interviews then moved to more specific questions targeting phenomena observed in student interactions. These took the form of “In this part of the lesson you used the word [a word], can you tell me more about it?”

Classroom transactions were recorded by video and audio throughout the 17-week study period. During this time, we analyzed all lessons before and following the student role-play activity (2 lessons) and the stoichiometry analogy activity (2 lessons). This consisted of 17 lessons preceding and 25 lessons subsequent to the role play, and 15 lessons preceding and 17 lessons following the stoichiometry analogy. Lessons before the role-play and analogy lessons were recorded to establish baseline data of classroom discourse. In total, there were 4 lessons allocated to analogy-writing activities out the 78 lessons recorded. The 74 lessons in which analogies were not generated involved a range of classroom activities. The activities included teacher lectures, practical laboratory exercises, and quantitative and qualitative problem solving. For some activities, such as practical laboratory exercises, and quantitative and qualitative problem-solving activities, students worked in groups. An example of this was a stoichiometry group-challenge where student groups competed to be the fastest to solve a complex stoichiometry problem. The stoichiometry challenge took place during one lesson subsequent to the stoichiometry analogy activity. In other lessons, students tended to work in dyads or triads. We monitored all student interactions during these lessons searching for evidence of hybridity.

Two studies that have focused on analogical discourse are those by Treagust et al. (2003) and Yerrick et al. (2003). In a similar way, we conducted a fine-grained analysis focused on the content of classroom talk and processes that produce it (Yerrick, et al., 2003). As our interest was in the content of student talk, we used transcript conventions sparingly. Transcripts were marked with ‘…’ to indicate pauses where each ‘.’ represents a one second pause. Curly brackets {} were used to insert our comments into the transcript when providing context or explanations for the reader. In cases where we report lengthy extracts, turns that did not have bearing on our interpretations and analyses were omitted and replaced with the missing numbers (e.g., 25-30). Our fine-grained analysis began with identification of hybridization of everyday discourse and chemical discourse (Wallace, 2004) and for fluidity of meanings, signs, symbols, and practices (Bhabha, 1994). We began by listening and reviewing all audio and video material and artifacts either on the day of the lesson or within a few days after observations for each student group. Audio and video data that offered insights relevant to our research question were immediately transcribed. Starting from the hybridization of everyday and chemical discourse, we coded the data sources. As common themes emerged from each student group, comparisons of the three student groups allowed the refinement of our coding categories; for each group, transcripts and artifacts were re-coded based on the new themes (Roth, 2005).
Findings

We present two claims in this study: 1) hybridization was identified only in analogical activities; 2) hybridization occurred between the analog discourse and target discourse. The warrants supporting our claims are presented through exemplary extracts from lesson transcripts, interview transcripts, analogy written-question responses, and student artifacts (i.e., written analogies).

Claim 1: Hybridization was identified only during analogical activities

Hybridization of students’ everyday discourses with chemical discourse was only observed in lessons where they constructed analogies. Thus, of the 78 lessons observed in this study, 4 lessons contained hybridized discourse. Samples of hybridized discourse from these lessons are discussed in Claim 2. Everyday discourses did feature in the other observed lessons. For example, during one episode when the class was solving stoichiometry problems, Trev’s group was working on a solution to a problem. As Trev was looking over Mal’s shoulder, he noted that Mal had incorrectly spelt the word “whether.” Trev intervenes as seen in Extract 1 to correct Mal’s spelling. This led to a brief exchange with a play on the word whether as also meaning a sheep.

Extract 1

<table>
<thead>
<tr>
<th>Turn</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Trev: Shouldn’t that whether have a ‘H’ after the w?</td>
</tr>
<tr>
<td>38</td>
<td>Mal: Trev let’s not worry about grammar in chemistry</td>
</tr>
<tr>
<td>39</td>
<td>Louise: But yes it should</td>
</tr>
<tr>
<td>40</td>
<td>Trev: Cool</td>
</tr>
<tr>
<td>41</td>
<td>Mal: A wether is a male sheep</td>
</tr>
<tr>
<td>42</td>
<td>Trev: No that’s a ram</td>
</tr>
</tbody>
</table>

(Trev’s group Stoichiometry problem solving)

The full exchange consists of 6 turns relating to the sheep. The discussion on the spelling ends after Turn 42 and the topic of sheep does not feature again in the remainder of the exchanges. Similarly, Fergie’s group was answering questions about nerve-signal inhibition by movement of ions (Extract 2). Fergie used the word inhabit in Turn 45 instead of inhibit as Sara points out in Turn 46. This triggers Sara’s memory of a song that contains the phrase lose your inhibition (Turn 48). The girls discuss the song but the song does not feature in their responses to the questions they are writing or in subsequent lessons.
Although reference is made in this transcript to a song containing the word inhibition, this does not represent a case of hybridization as reported by Wallace (2004) because the students are not using the pop-culture reference to explain or discuss chemical concepts. In this excerpt, the introduction of the song by Sara serves in the process of clarification of the meaning of the word ‘inhibition’ (Turns 51-52).

When student groups engaged in practical laboratory activities and answering written chemical-problems, their conversation was focused on the chemical concepts or processes and their everyday discourses were not invoked in these activities for solving problems or interpreting science concepts.

Claim 2: Hybridization occurred between the analog discourse and target discourse

For the neurotransmission role-play, students generally took on the roles of neuron structures (e.g., ion channels that control the passage of ions into and out of the neuron membrane) and ions (cations and anions that are involved in changing the polarity of neurons).

The target concept represented by Fergie’s group in their role-play was that nerve signals cease when GABA binds to receptors on nerve cells thereby opening chloride-ion channels. This allows negatively-charged chloride ions to enter the nerve cell making the interior negatively charged relative to the exterior and thereby inhibiting the signal transmission. Students in Fergie’s group enacted ions (Fergie, Garima and Pete), GABA (Sara) and a chloride-ion channel (Liz). Garima and Pete smiled and danced to convey their role as positive ions in the neuron. In the role-play script, Fergie enters the role play with the line “…I am a very negative perso-ion, I flood the neuron cell with negative charge, and hence I depress other ions in the cell” (Fergie, Role-Play Script p. 3). Garima and Pete respond in the play by frowning and ceasing their dance. We will proceed with interpretation of these actions and roles of the students and then we will explore the word perso-ion in depth.

When the analog concept (“…I depress other ions in the cell”) was mapped onto the target concept, it mapped as the positive ions turning into negative ions. This does not
occur in neurotransmission and thus represents a mapping of surface features of the analog rather than mapping of deeper relational structures. Although the group’s role play reflected the lock and key metaphor used by the teacher in a previous lesson (See Research Design), to an extent, Fergie claimed during an interview that other factors affected their role play. One factor was that she had been in situations where people with negative emotions transferred their negativity to others around them. This phenomenon of spreading emotions between individuals is called emotional contagion (Hatfield, Cacioppo & Rapson, 1994). Fergie also made reference to Emo subculture and depression during the interview as a source for the analog:

Like when I walked into the inside the cell or the neuron I came up with the whole thing like yeah we can pretend like its depressing like we were gonna pretend we were Emo …. (Fergie, Interview 1).

Emo (derived from emotional music) is a relatively new subculture believed to have developed in the U.S. from the 1980s Emo music scene that was characterized by emotionally turbulent themes (Bailey, 2005). Recently, attention has turned to this subculture in relation to teen suicide and depression (Definis-Gojanovic, Gugic & Sutlovic, 2009). In the role play, Fergie’s group represented negative emotional-contagion and linked this to the movement of ions in cells, thereby hybridizing societal discourses of Emo and emotional contagion with chemical discourse. Trev’s group also referred to Emo subculture in the analog concept for their stoichiometry analogy (based on an Emo hair-style recipe) suggesting that knowledge of this subculture was not limited to Fergie’s group.

Extract 3 stands in contrast to Extracts 1 and 2 presented in Claim 1 as here we see the students to-ing and fro-ing between everyday discourse and chemical discourse as students construct meaning about nerve signaling. This extract was taken from a lesson where students were planning their role play. In Extract 3, there is a to-ing and fro-ing between analog terms such as key and lock and the respective target concepts such as GABA and channel in Turns 40-48.

### Extract 3

<table>
<thead>
<tr>
<th>Turn #</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Fergie: Yep you’re the key I can be the chloride ion a-aaand Liz what do you wanna be?</td>
</tr>
<tr>
<td>40</td>
<td>Sara: The chloride the channel</td>
</tr>
<tr>
<td>41</td>
<td>Liz: I wanna be the lock</td>
</tr>
<tr>
<td>42</td>
<td>Fergie: That’s the door</td>
</tr>
<tr>
<td>43</td>
<td>Sara: Yeah that’s the door {the chloride channel}</td>
</tr>
<tr>
<td>44</td>
<td>Fergie: OK you’re the lock</td>
</tr>
<tr>
<td>45</td>
<td>Sara: Ehehehe</td>
</tr>
<tr>
<td>46</td>
<td>Liz: Are you the key?</td>
</tr>
<tr>
<td>47</td>
<td>Sara: Yes I’m the key eehh</td>
</tr>
<tr>
<td>48</td>
<td>Fergie: GABA slash key {reads what she is writing}. (Fergie’s group, role-play rehearsal)</td>
</tr>
</tbody>
</table>
As the students negotiate the roles each will take in the role play, they refer to *lock*, *key*, and *door* that were all terms used by the teacher in his explanation of neurotransmission to the class. The words ‘lock’ and ‘door’ are used interchangeably in the exchange to signify GABA and the chloride-ion channel. This to-ing and fro-ing indicates that in the context of the interactions there was no fixity in the meanings of words. Thus, “key” has no unitary meaning as it is also used here to refer to GABA.

There is a to-ing and fro-ing between the two discourses in Turns 39–44 where the meaning of the terms remains tacit and fluid. For example, in Turn 40 Sara refers to the chloride channel and in the ensuing turns, key and door are used to represent it. In Turn 48 Fergie shows her understanding of the relational structure of the key and the GABA molecule when she utters, “GABA slash key” (i.e., GABA/key). By engaging in cultural bricolage, the students hybridized the everyday discourse of unlocking doors with the chemical discourse of neurotransmission. The exchanges in Extract 3 demonstrate the students’ correct conceptual understanding of the role of GABA in opening the chloride channels in the same way that a key opens a door.

Another case of hybridization in Fergie’s group involved the creation of a new word *perso-ion* (pronounced as persion). The word represented the student, or person, in the role-play (*perso-*) and their role as ions (*ion*). For example, the role-play script read: “Garima {indicating the person’s line}: I am K⁺, I am sooo happy, I am a very positive perso-ion.” Fergie’s word *perso-ion* was classified as a special case of hybridization as it involved creating a Portmanteau word from *person* and *ion*. Fergie explained the word during an interview as follows:

… I started writing person and thought if I add an ‘i’ in it can be persion ha-ha. So I wrote perso and put slash ion and knew what to say. So … we can sort of merge the person in which is giving the analogy effect like people could understand ‘cause we’re people but at the same time we can explain that we’re also ions demonstrating like as people what ions would do. So that’s why we named it persion. (Fergie & Garima role-play interview 1)

Here, Fergie explained the hybrid nature of perso-ion by stating that the word created an “analogy effect” so students in the class “could understand” that the behavior of positive ions in nerve cells was being represented through the actors’ actions (smiling, dancing) and utterances (e.g., “I am sooo happy”). Her comments demonstrated that for Fergie, perso-ion signified that her group members in the play were enacting what ions do in nerve cells. Fergie’s mappings became clearer through further analysis of the role-play script. In the actor introductions, the person with a positive attitude (signified by ‘happy’) mapped to the target ‘positively charged ion’. The analogy created was, happy (positive):person::positive charge:cation. In the role-play, the actors conveyed their happiness through smiling and dancing around. During interviews with Fergie’s group, Alberto asked whether the group had encountered Portmanteau words or used such words before the role play activity. The students were able to identify other hybrid words from everyday discourse including *liger* (i.e., lion-tiger), and *brunch* (breakfast-lunch). Thus,

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3 Portmanteau words are words made by combining two other words. For example, *brunch* is the Portmanteau of *breakfast* and *lunch*.
not only did the word perso-ion represent hybridization at the level of the words person and ion, but it also represented the everyday discourse of generating Portmanteau words (e.g., brunch, liger etc.) when one wishes to signify a combination of two entities into one.

A second instance of a hybridized word was observed in Trev’s group. His group based their role-play on the same concepts as Fergie’s group. The analog in their role-play was a bar scene where Ned acted as a bouncer at the door (together representing the chloride ion channel), Louise acted as an alluring young woman (the GABA molecule) and Ana and Mal were underagers (the chloride ions) who slipped past the bouncer when Louise lured him away from the door. In this way, the group had represented the binding of the GABA molecule (alluring woman) to the chloride-ion channel (bouncer) allowing the chloride ions (underagers) into the cell (bar). This description illustrates the relational structure of the analog with respect to the target. Trev narrated the story. Extract 4 presents an excerpt from the planning lesson during which students constructed their role plays. In Turn 6 and in preceding turns, the students had jokingly and purposively mispronounced GABA to sound like a bar (i.e., GAYBAR).

*Extract 4*

<table>
<thead>
<tr>
<th>Turn #</th>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>Ana: I want to take you to the GAYBAR GAYBAR {sings}</td>
</tr>
<tr>
<td>07</td>
<td>Trev: So opening the chloride ion thing</td>
</tr>
<tr>
<td>08</td>
<td>Louise: So someone</td>
</tr>
<tr>
<td>09</td>
<td>Trev: deactivates it</td>
</tr>
<tr>
<td>10-11</td>
<td>Louise: someone being the GABA…</td>
</tr>
<tr>
<td>12</td>
<td>Louise: and then someone being the… the like the protein like I dunno somehow put</td>
</tr>
<tr>
<td>15-18</td>
<td>Trev: Have something like the um oh! have someone like being the um the receptor thing and then one of you two goes to get by the receptor and then one of you guys can be the GAYBAR the GABA and come in and be all like all like alluring and allure him away and then like the chloride ions can get through</td>
</tr>
<tr>
<td>20-22</td>
<td>Trev: Or… no ay just what does it do {reading info sheet} it bonds with it and then it opens yeah. You can have two chloride ions</td>
</tr>
<tr>
<td>23</td>
<td>Louise: …so I’m the GAYBAR GABA so I hook and yeah like bond onto the receptor you move over allowing the chloride ions coming in which makes it more negative which switches off or makes it harder to fire</td>
</tr>
</tbody>
</table>

(Trev’s group preparing role-play)

Language use such as the hybrid word *gay-bar* is not uncommon amongst Western societies. For instance, the city of Philadelphia used the Portmanteau word *gayborhood* when advertising a section of the city as the official gay, lesbian, bisexual and trans-gender sensitive neighborhood (Williams, 2007). The hybridization of the acronym GABA with the word *gay-bar* is similar to the hybridized word perso-ion
developed by Fergie. In the developments seen in Extract 4, this led the students to generating a role play based on underagers trying to enter a bar. In Turn 24, Louise adopted the role suggested by Trev, in Turn 19, by moving toward Ned (the bouncer) and pretending to flirt with him to lure him from the door. Her role reflects societal discourses of entering nightclubs and bars by sweet-talking the bouncer at the door. In Grazian’s (2008) ethnographic study of urban nightlife in Philadelphia, for example, he claims “…for underage nightlife consumers, access [to nightclub entry] remains a paramount concern, which often encourages pandering to sexist expectations of male bouncers and security guards” (p.102). This is seen in Turn 19 where Trev suggested that one group member should act like the GABA molecule and “…be all like alluring and allure [sic] him (the bouncer/ion channel) away.” Here, Trev’s bricolage produced hybridization as he ascribed the human property of being alluring to the GABA molecule thereby hybridizing the analog and target discourses in his utterance. That is, the subject of his utterance was the GABA molecule that belongs to the target discourse. The notion of being alluring pertains to the analog discourse representing an everyday way of behaving in nightclub and bar contexts. Similar to the exchanges from Fergie’s group in Extract 3, Trev’s group demonstrated their conceptual understanding by correctly mapping the alluring girl that distracts the bouncer to the GABA molecule causing the chloride ion to open.

The generation of the words GAYBAR and perso-ion by Fergie and Trev’s groups also mirrors science culture in that scientific neologisms have been derived in similar ways. For example, Dawkins (1976) coined the noun meme to label the unit of cultural transmission and imitation of ideas, habits, skills, stories, information or behavior. He describes the coinage of meme as borrowing from the Greek root mimeme that sounds “a bit like gene” (p.192). Subsequently, meme has been hybridized with “complexes” to produce memeplexes (Blackmore, 2003). The examples of meme and memeplexes are within-discipline (i.e., science-science hybrids) examples because the two words that have been combined both pertain to science discourse. Examples exist where different disciplines have come together and new words have been coined resulting in the development of a new disciplinary discourse. One example is the discipline of Econophysics where the word phynance has been coined (Stauffer, 2000). Both Econophysics (from economics and physics) and phynance (from physics and finance) are hybridizations similar to the ones we reported in Claim 2 where new language has arisen from the combination of two different discursive communities. In our study, analogy provided an opportunity for students to engage in the coining of new words in a way that is similar to the coinage of words in new interdisciplinary fields like Econophysics. We are not claiming that the words GAYBAR and perso-ion meet the specifications for neologisms in science. What we argue here is that the process of combining words to create new words that describe new objects or concepts is similar in the students’ analogical activities to other cultural practices including science.

Other cases of hybridization were observed in Max’s group. In his group’s stoichiometry analogy script relating to making a guitar, they wrote “The body [of the guitar]... is like a molecule and the strings individual elements.” In this sentence, the students indicate the analogical relationship between the guitar body that is made of parts (head, neck, sound box) by stating that it is “like” a molecule. In the second part of the sentence, they refer to the strings as elements without making explicit the analogical
relationship by stating “…the strings individual elements.” The mappings between elements of the analog concept and target concept in the sentences written by Max’s groups demonstrate correct conceptual understanding of the concepts of molecules, elements and their relationships to one another in a chemical reaction. This is because elements are parts of molecules as strings are parts of a guitar.

Max generated a hybridized sentence that ended with “a molecule in our guitar formula” in his response to the analogy written-question asking how his group had developed their analogy. In his hybrid sentence, Max referred to the guitar, his analog, in terms of molecules and formula; words that belong to the target discourse of the analogy. In his sentence, Max used the words to describe the analog, guitar. The sentence written by Max and his groups’ written analogy represented hybridization of everyday discourse with chemical discourse because the context of guitars was personally relevant to one of the group members (i.e., Craig) who was a member of a band.

Max’s group generated a second hybrid sentence when writing a quantitative problem related to their guitar analogy. Their analogy required that for every guitar body, six strings were needed to make one guitar. Max’s group phrased a written question as follows: “How many of each reactants [sic] will be needed to make 2 Acoustic Guitars?” In this question, the word reactants, which pertains to the chemical discourse, is used to signify the parts of the guitar (i.e., the body and strings). The use of the word reactants in the question demonstrates conceptual understanding due to the correct mapping between the parts of the guitar and elements in a reaction (i.e., the reactants) that combine to form molecules. Another significant aspect of the hybridization in artifacts from Max’s group was that like the word perso-ion, it was part of the written artifacts and not just part of the natural language during student interactions. This indicated that hybridization was not limited to spoken language.

As part of his instruction to students for preparing their stoichiometry analogies, the teacher asked students to assign letter symbols to the analog concepts chosen by the students. This involved hybridization of chemical practice with the analog concept; that is, assigning symbols to the analog concept as one would for elements and compounds. While brainstorming possible analog concepts for chemical stoichiometry, Trev’s group considered using a set of molecular model kits at the back of the classroom as their analog. The models were made from colored Styrofoam™ balls. Ana had suggested they could use the models and Trev and Louise began to elaborate the analogy by looking at the number of Styrofoam™ balls that make up one model molecule. In doing so, they started to assign each ball a color and then created an equation to describe the number of different colored balls that made up the model. For example, they assigned yellow balls the symbol “y” as shown in turn 1 in Extract 5:

**Extract 5**

<table>
<thead>
<tr>
<th>Turn # Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>128 Trev: So four ‘y’ plus two ‘b’ equals oh yeah oh</td>
</tr>
<tr>
<td>129 Louise: Equals one ‘p’?…</td>
</tr>
</tbody>
</table>

(Trev’s Group Stoichiometry Analogy Activity)
Use of letters to represent chemical elements is the usual practice in chemistry. Through bricolage, the students used the chemical practice, as required by their teacher, to refer to their tentative Styrofoam-model analog.

Negative cases were also identified in this study where students were discussing the analogy and role play and did not generate hybridizations. For example, Fergie’s group brainstormed a large number of potential analog concepts before deciding on a Milo™ (a drink flavoring) analog for their stoichiometry analogy. During their brainstorming, there were sequences of utterances where only the discourse of the analog was observed. This was also observed in the turns preceding Extract 5 from Trev’s group as they constructed their equations for the Styrofoam™ models. However, these negative cases tended to precede or follow the hybridizations we have reported.

During a lesson subsequent to the stoichiometry-analogy lessons, student groups participated in a stoichiometry challenge. This activity involved a problem-solving challenge where students were required to solve a complex stoichiometry question. The fastest group to submit a correct response received a prize. Analysis of student responses to this challenge indicated that Fergie’s and Trev’s groups correctly completed the challenge. Max’s group did not submit a response to the challenge, thus we could not evaluate the group’s understanding of the concept. It is not possible to conclude from this one activity whether the analogy activities and the hybrid discourses the groups generated had an effect on the students’ abilities to solve the challenge problem. Nevertheless, this result provides some indication that the majority of the class could demonstrate competence with the target concept.

Summary of Findings

The results reported in Claim 1 indicated that students’ everyday discourses did feature during lessons where students collaboratively solved chemical problems. However, in such lessons everyday discourses did not become hybridized with chemical discourse; the everyday discourse featured in side conversations and did not contribute to completing the class activities. In Claim 2, we reported that through analogy-writing activities, everyday discourses and chemical discourse became hybridized and resulted in the generation of new ways of talking and writing about chemistry. Thus, the 4 lessons involving analogy-writing activities were unique among the 78 lessons where we observed the hybridization of everyday and chemical discourse. As well as reporting the way in which hybrid discourse developed during interactions centered on analogy-writing activities, we found some evidence that students demonstrated conceptual understanding of target concepts. While this was not the focus of our study, in most cases hybridized utterances and sentences corresponded with correct conceptual understanding with only one case of an incorrect mapping being noted with Fergie’s group in relation to positive ions becoming negative ions.

Roth (2008) proposed that some students in science class could be thought of in terms of diaspora from their everyday lives immersed in the culture of science. In this study, we reported how students were afforded opportunities to draw on cultural resources and discourses with which they were competent in their everyday lives, and use these to choose and map analog concepts to the target concepts during analogy-writing activities. This resulted in bricolage as students borrowed words, meanings and practices
from everyday discourse and science discourse leading to the development of hybridized
discourse. In summary, hybridization of discourse was observed only during analogical
activities and did not extend beyond these; the hybridizations resulted from bricolage of
everyday discourses (represented in the analog concepts) with chemical discourse; and
there were three types of hybridization observed. Specifically, these were the
hybridization of words (i.e., perso-ion & GAYBAR), the hybridization of utterances and
sentences (e.g., “guitar formula”), and the hybridization of practices (e.g., assigning
symbols to the analog concept). We observed that everyday discourse and culture became
hybridized with science discourse and culture when students drew upon subcultures (e.g.,
Emo) and practices (e.g., Portmanteau words, scientific neologisms) during their analogy-
writing activities. Thus, analogy provided opportunities for students to use competencies
in other discourses to construct meanings in their chemistry class.

Interpreting Discourse During Analogy-Writing Activities

We began our interpretive efforts in this study with openness to the different
interpretations of hybridity used in cultural theory and educational research. Through our
analyses we identified the fluidity in meanings of signs and symbols that resonate with
Bhabha’s (1994) characterization of cultural hybridity. However, we could also clearly
identify that this fluidity in meanings and symbols, and the resultant hybridization, arose
only during analogical activities. Analogy is defined as the mapping of similarities
between an analog and a target. Thus, in this respect, what we observed was in line with
educational perspectives on hybridity that construct it as the coming together of
antecedents to produce a hybrid (i.e., the synthesis perspective). However, we also note a
difference here because the conventional meaning of hybrid as the combination of
antecedent categories or conditions to generate a new, synthesized condition, does not
adequately explain our observations. If a hybrid is produced that results in synthesis, then
the new condition (i.e., the hybrid) should be identifiable over time—like the word brunch
that is now a common part of English language. The situated nature of the hybrids we
observed during analogical activities suggests that we have identified something that is
not captured by either Bhabha’s perspective or the synthesis perspective. We have come
to understand the findings of our study differently from these perspectives. To be clear,
we do not refute hybridity theory; rather, our position has shifted in light of our study and
we now theorize the findings.

In bringing everyday discourse together with chemical discourse, analogies foster
bricolage through the generation of liminal spaces where new ways of interacting and
new discourse arises. The result is a discursive transition state characterized by fluidity in
meanings and where symbols, language and practices are not fixed— we call this merged
discourse.

Toward a Theory of Merged Discourse

We theorize merged discourse to explain that during analogical activities,
discourse can proceed in such a way that elements of the analog discourse and target
discourse are substituted to produce words, utterances, sentences and practices where
everyday ways of talking and culture are used interchangeably with science discourse and
culture. Analog discourse refers to symbols, language and practices as they pertain to
everyday discourse in an analogy. We found that students drew upon societal norms and
subcultures (e.g., entry into nightclubs, Emo) as well as personal interests (e.g., the guitar
analogy) to select their analog concepts. As such, this reinforced the notion that the
analog concepts drew on everyday discourse and these became merged with the target
discourse during analogy activities. Target discourse refers to the symbolic practices, and
physical practices of science (i.e., chemistry). Merged discourse represents a mutual
relationship formed between the analog discourse and the target discourse where there is
no synthesis achieved between the two antecedent discourses (i.e., analog and target).
The word *merge* can suggest a unity or synthesis produced from separate entities such as
is the case with coining new Portmanteau words like *brunch*. We present stipulative
definitions for the words *merged, merging* and *merge*. That is, we use them to refer to a
coming together of discourses not a synthesis. Given that merged discourse was situated
within analogical activities, we propose that it represents a transition state in discourse
where meaning is fluid and where the analog and target discourse temporarily intertwine.
Meanings of words (e.g., GABA) become interchangeable with their analog counterparts
(i.e., key) and guitars can be referred to in chemical terms by describing them as
molecules. We theorize merged discourse as a transition state because, as observed in our
study, it was situated within analogy activities where discourse moved between the
analog and target. Once the analogy-writing activities were completed the students exited
the transitional state and returned to speaking by using chemical discourse (e.g.,
terminology, practices) or using everyday talk in ways that were unrelated to the goals of
classroom work.

*New Analytical Tools for Investigating Discourse in Analogy-Writing Activities*

In addition to the theorization of merged discourse, we developed three categories
of discourse during analogy-writing activities from our data: 1) merged words (e.g.,
perso-ion, GAYBAR); 2) merged sentences/utterances (e.g., molecule in our guitar
formula); and 3) merged practices (e.g., Y for yellow ball, B for blue ball, generating
neologisms). As students had written hybridizations as well as spoken them, the category
merged utterances/ sentences was generated to account for the different modalities
through which students merged the analog discourse with the target discourse.

We identified three instances in this study where the students used the merged
words GAYBAR and perso-ion in merged utterances (e.g., Turn 19 in Extract 4). No
other examples of similar interrelationships between our three categories of merged
discourse were identified in the data; therefore, we cannot make conclusive statements
about the extent to which our categories may be interrelated or discrete. Merged
discourse serves to theorize how the three categories we observed had arisen in the
students’ utterances and writing through an intertwining of the two discourses. We
propose that these three categories can be used to code transcripts of classroom discourse
as ways of identifying the generation of merged discourse.

In relation to existing research on analogies, studies reviewed by Aubusson,
Harrison and Ritchie (2006) have tended to take strong cognitive perspectives leading to
concept-centered views of analogical reasoning and focused on learning as the acquisition
of science concepts through elimination of alternative conceptions (i.e., conceptual
change). Re-reading this body of research through the theoretical framework adopted in this study, conceptual change can be perceived as the colonization of student ideas by scientific ideas. Roth (2008) proposed a different view on how learning may occur from cultural processes as follows:

Diaspora, finding oneself away from the familiar resources that characterize the home, provides for the possibility of learning by incorporating other (different) discursive and material practices into those one already knowledgeably deploys. (p. 907)

Through merged discourse we account for learning from the perspective of diaspora as students drew on resources from everyday discourses to construct meaning about neurotransmission and stoichiometry during analogy-writing activities. Rather than observing colonization of ideas in our study, the discourse we have reported is better represented through the notion of bricolage where students borrowed and imported concepts, words, meanings, and practices from one culture into another as they constructed meaning.

The focus of our study was to investigate how analogy-writing activities influenced classroom discourse rather than on the development of conceptual understanding. However, we observed that students demonstrated understanding of the concept of stoichiometry in both the analogy-writing activities and in the stoichiometry challenge. In relation to merged discourse, we propose that learning occurs when students enter a transitional state where everyday discourses and chemical discourse merge. While in the transitional state, students construct merged words, merged sentences or utterances, and merged practices, that reflect the mappings of elements of the analog concept on the target concept. Once the chemical discourse is appropriated, students abandon the merged discourse and any reference to everyday discourse. Monitoring the merged discourse generated by students could allow teachers to monitor the mapping process and to ascertain whether appropriate elements of the analog discourse have been merged with the target discourse.

**Contribution of This Study to the Research Literature on Analogies in Science Education**

Our study makes a significant and unique contribution to research on analogical processes in science education through empirical investigation of the social dimension of learning with analogies and theorizing how discourse during analogy-writing activities is produced through a cultural lens. No studies we have reviewed have interpreted discourse during analogy-writing activities through a theoretical framework similar to ours. By focusing on discourse during analogical and other forms of classroom activities, we were able to identify and theorize the nature of analogical discourse from what is externalized (through talk) by students as they engage in collaborative analogical activities in situ. We have also demonstrated that analogy can be used as a way of including students’ out-of-school lives for instruction through integration of pop-culture, subcultures and language conventions such as the generation of neologisms and Portmanteau words. Learning with analogies from the perspective of merged discourse occurs when people construct merged words, utterances, sentences or practices where the specific elements (words, characteristics, practices) of the analog are used interchangeably for the target and *vice versa*.
versa. In doing so, the participants may move from everyday discourse, to a transitional state of merged discourse and then enter chemical discourse.

**Future Directions**

Merged discourse may in future help to explain how the social dimension of learning with analogy influences the understanding of analogies and target concepts, from a social, discursive perspective rather than an individual, cognitive perspective. Analytically, our three categories (i.e., merged words, utterances/sentences, practices) provide means for tracking analogical processes in natural conversation and writing. This is significant because, as Treagust and Duit (2008) have shown, the majority of conceptual change research has used interview techniques, tests, and to a lesser extent, think-aloud protocols for investigating student conceptions. Our approach combines cultural perspectives on learning with investigations of natural conversations during analogy-writing activities, thereby offering different theoretical and methodological insights into the development of student conceptions in chemistry. Thus, we offer a means of studying learning-in-the making rather that a way of measuring inputs and outputs of instruction by interviews, tests and think-aloud protocols. This may inform current understanding of the mapping process in analogical reasoning as a discursive phenomenon. Together, these developments can enhance our understanding of the function of analogies in shaping science-classroom discourse and can complement our interpretations and analytic endeavors based on mappings of similar relations in the analog and target as derived from cognitive theory. Furthermore, while socio-cultural perspectives on learning tend to focus on how students appropriate the dominant classroom discourse of science (cf. Basu & Calabrese Barton, 2009), in this study we have outlined how, through the construction of analogies, students generated new discourse and cultural practices. Our findings could extend sociocultural perspective’s of learning beyond the concept of learning as the appropriation of the practices of a community to include learning as the generation of new practices through the merging or hybridization of different discourses.

Further study is required to scrutinize and refine merged discourse. We have presented the scope of our theorization by confining it to the context for this study where students constructed analogies in a chemistry class. However, we anticipate that our three categories of merged discourse will also be identified in studies of modeling activities where elements of language from the model and the target concept will become merged. This is because analogy has been classified as one form of modeling (Harrison & Treagust, 2000) with other categories including physical models and symbolic models. As modeling activities bring together a model and a target in a similar way, to analogies, we expect that discourse would be produced that is similar to what we have reported in this study.

Our theorization of merged discourse remains refutable; if observations of classroom discourse during analogy-writing activities do not yield the generation of merged words, utterances, sentences, or practices, then there is reason to revisit our theory. Alternatively, if discourses combine in such a way that they persist beyond the originating activity, then we would need to revisit the notion that merged discourse represents a transition state. If merged discourse is observed in other activities (e.g.,
modeling) that draw together scientific discourse with other forms of discourse, then our conceptualization of merged discourse as the intertwining of analog and target discourse would need to be broadened to include these new cases. On the other hand, if merged discourse cannot explain discourse in studies of modeling activities this could serve to delimit our theorization to just explaining analogical discourse.

Limitations of This Study

One limitation of our study was the case study design as this reduced our ability to generalize merged discourse beyond this context. Further research is required in different settings (e.g., classrooms, different science concepts, different teachers) from the one in this study to elaborate the analytic categories; merged words, utterances/sentences, practices, and merged discourse. For example, research is needed to determine whether merged discourse can explain interactions where students are not familiar with the target concept when they design analogies. In our study, students had received instruction on the target concept through analogies prior to developing their own. By studying spontaneous student analogies or ones where the student is yet unfamiliar with the target concept, it is possible to determine the extent to which the teaching in our study affected the interactions we observed. Other studies could be conducted where two different teachers use different approaches (one involving analogy) to teach the same science concepts, or alternatively, where the same teacher teaches two classes with and without analogies. This would allow us to establish whether merged discourse was an artifact of the teacher’s instruction or whether it is ubiquitous. To this end, we are encouraged, however, as upon analyzing the text produced by two science educators (cf. Aubusson & Fogwill, 2006) we identified cases of merged discourse in sentences they constructed when discussing research on role play in chemistry classrooms. The text produced by these authors was generated before our study.

One of the strengths of our study, toward the potential generalizability of merged discourse, was that we observed the phenomenon in three independent student-groups. This provides greater support for our theory than if we had observed merged discourse in only one or two of the student groups. Furthermore, the examples provided of the words Econophysics and phynance that result from the development of interdisciplinary fields when two different discursive communities (i.e., economics and physics) become integrated are supportive of our theorization to some extent. The examples of Portmanteau words like phynance and memes that we have identified in the literature are similar only to our merged word category. Further research focusing on naturalistic conversations that take place in emerging interdisciplinary fields (e.g., Econophysics) could strengthen our theorization of merged discourse, particularly if evidence is identified of merged utterances, merged sentences, or merged practices. At the time of this study, we could not identify extensive research literature into the discourses that emerge from interdisciplinary communities. Perhaps our study can provide a scaffold for similar research into the new discourses emerging from these fields. Thus, merged discourse could have transferability beyond this study. Finally, by analyzing classroom discourse during other forms of modeling activities, we could further elaborate or delimit our theorization and categories of merged discourse.
References


