INVESTIGATING ACADEMIC LANGUAGE PROFICIENCY AND CHEMISTRY CONTENT KNOWLEDGE OF NEWCOMER ENGLISH LANGUAGE LEARNERS IN A PUBLIC HIGH SCHOOL

by

Jingjing Ma

Bachelor of Science, 2008
Ocean University of China
Qingdao, Shandong, China

Master of Science, 2010
University of the Incarnate Word
San Antonio, TX

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS ......................................................................................... iii
TABLE OF CONTENTS ............................................................................................ iv
LIST OF FIGURES ....................................................................................................... vi
LIST OF TABLES ......................................................................................................... vii
LIST OF APPENDICES .............................................................................................. viii

CHAPTER I. GENERAL STATEMENT ....................................................................... 1
  Problem Statement .................................................................................................. 1
  Research Questions ............................................................................................... 3
  Definitions of Terms ............................................................................................. 3

CHAPTER II. LITERATURE REVIEW ..................................................................... 7
  Chemistry Content Knowledge (CCK) .................................................................. 7
  Acquisition of CCK ............................................................................................... 9
  Language Acquisition and Proficiency ............................................................... 14

CHAPTER III. METHODS ...................................................................................... 22
  Overview of the Research Design ......................................................................... 22
  Context ................................................................................................................ 24
  Setting .................................................................................................................. 26
  Participants ......................................................................................................... 27
  Procedure ............................................................................................................ 30

CHAPTER IV. QUALITATIVE RESULTS ................................................................ 50
  Overview ............................................................................................................ 50
  ALP Levels .......................................................................................................... 51
  CCK Levels .......................................................................................................... 72

CHAPTER V. QUANTITATIVE RESULTS .............................................................. 97
  Overview ............................................................................................................ 97
  Descriptive Analysis .......................................................................................... 98
  Effects of Gender, Age, and Prior Schooling ..................................................... 109
  Relationship between ALP and CCK levels and their Changes Over Time .......... 110
  Summary ........................................................................................................... 111

CHAPTER VI. DISCUSSION .................................................................................. 112
  Overview ........................................................................................................... 112
  Academic Language Proficiency for Newcomer ELLs ....................................... 112
  Chemistry Content Knowledge for Newcomer ELLs ......................................... 118
  Relationships between ALP, CCK, and Extraneous Factors ............................ 123
  Conclusion .......................................................................................................... 126
  Implication for Teaching .................................................................................... 127
  Limitations and Future Research ....................................................................... 129
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDICES</td>
<td>132</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>135</td>
</tr>
<tr>
<td>VITA</td>
<td>149</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>150</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 3.1. Research Procedure ........................................................................................................... 30
Figure 3.2. Timeline of Data Collection (2014-2015) ................................................................. 32
Figure 3.3. The Interview Setting in the Preparation Room ..................................................... 33
Figure 3.4. Relationships between IPT II test levels and newcomer beginning ELL levels ................................................................. 36
Figure 5.1. Distributions of Participants’ Demographic Characteristics ......................... 102
Figure 5.2. Distributions of ALP, CCK, FAW, and TAW at the Pre-interviews .......... 104
Figure 5.3. Distributions of ALP levels at the Mid-interviews ............................................. 105
Figure 5.4. Distributions of ALP, CCK, FAW, and TAW at the Post-interviews........... 107
## List of Tables

Table 3.1 ......................................................................................................................... 25  
Table 3.2 ......................................................................................................................... 27  
Table 3.3 ......................................................................................................................... 27  
Table 3.4 ......................................................................................................................... 28  
Table 3.5 ......................................................................................................................... 29  
Table 3.6 ......................................................................................................................... 29  
Table 3.7 ......................................................................................................................... 38  
Table 3.8 ......................................................................................................................... 39  
Table 3.9 ......................................................................................................................... 42  
Table 3.10 ....................................................................................................................... 44  
Table 3.11 ....................................................................................................................... 47  
Table 3.12 ....................................................................................................................... 48  
Table 3.13 ....................................................................................................................... 48  
Table 3.14 ....................................................................................................................... 49  
Table 4.1 ......................................................................................................................... 51  
Table 4.2 ......................................................................................................................... 51  
Table 4.3 ......................................................................................................................... 51  
Table 5.1 ......................................................................................................................... 98  
Table 5.2 ....................................................................................................................... 108  
Table 5.3 ....................................................................................................................... 109  
Table 5.4 ....................................................................................................................... 110  
Table 5.5 ....................................................................................................................... 111
LIST OF APPENDICES

APPENDIX A ..................................................................................................................... 132
APPENDIX B ..................................................................................................................... 133
APPENDIX C ..................................................................................................................... 134
CHAPTER I. GENERAL STATEMENT

Problem Statement

In the most recent two decades, the structure of student population has changed dramatically in the United States (Bautista & Castaneda, 2011; Lee, 2005; United States Department of Education, 2013). Between 1990 and 2011, the number of Hispanic 8th graders increased nationally from seven percent to 23 percent; at the same time, the number of white 8th graders dropped from 73 to 54 percent (US Department of Education, 2013). Since 45 percent of Hispanic public school students are English language learners (ELLs), positive academic outcomes of Hispanic students greatly rely on Hispanic ELLs’ achievement (Lazarín, 2006). In addition to Hispanic ELLs, the total number of English language learners increased nationally from seven to 11 percent of the population from 1998 to 2011 (US Department of Education, 2013). By 2030, this number is estimated to reach 25 percent of the total student population (Goldenberg, 2008). Given the rapid growth of Hispanic students and ELLs, the overall academic achievement of the United States school students are gradually more dependent on the performance of ELLs (Lazarín, 2006).

However, currently, ELLs do not meet the academic outcomes. For example, the results of the 2011 National Assessment of Educational Progress, an assessment that measures students’ reading comprehension by using age-appropriate materials and corresponding questions, shows that fourth-grade ELLs scored 28 percent less than their non-ELL peers in reading (US Department of Education, 2013). In science education, multiple studies consistently indicate a gap of academic outcomes between native English speakers and ELLs (Campbell, Hombo, & Mazzeo, 2000; Schmidt, McKnight, & Raizen,
1997). Although this gap has reduced recently, the science achievement gains of ELLs are still small (Santau, Maerten-Rivera & Huggins, 2011).

Multiple factors contribute to ELLs’ academic underperformance, including English proficiency, individual differences, such as age and gender, and non-individual factors, such as home and school environment (Ardasheva & Tretter, 2013; Cho & McDonough, 2009; Dixon et al., 2012; Halle, Hair, Wandner, McNamara, & Chien, 2012; Settlage, Madsen & Rustad, 2005). English proficiency, including oral and written English, has tremendous impact on ELLs’ achievement in content areas since academic outcomes are commonly assessed in English (Santau, Maerten-Rivera & Huggins, 2011). Therefore, improving English proficiency is crucial to promote ELLs’ academic achievement. Lee (2005) summarizes a wide range of components of science outcomes, such as standardized tests scores, degrees received, and attitude and motivation in learning science. Specifically, “desired science outcomes” include ELLs “becoming bicultural, bilingual, and biliterate” in both the United States culture and language and their home culture and language (Lee, 2005, p. 493). Although English proficiency is not a concrete science outcome, it is crucial for learning content knowledge, including science.

Research about the relationship between academic language and science has resulted numerous studies. Many researchers also investigated the interactions between students’ academic language proficiency and content knowledge acquisition. However, little is known about the characteristics of this relationship among ELLs, especially newcomer ELLs who recently entered schools in the United States. In addition, understanding influential factors of ELLs’ English proficiency and content knowledge
acquisition can help classroom teachers, educational researchers, and policy makers provide more effective support for ELLs’ content learning. The goal of the present study is to examine the characteristics of, relationships between, and the extraneous variables’ effects on newcomer ELLs’ academic language proficiency (ALP) and chemistry content knowledge (CCK) about a few specific topics. The present study will investigate the relationship between newcomer ELLs’ academic language proficiency (ALP) and their chemistry content knowledge (CCK) about a few specific topics. In addition, this study will examine some common predictors of ALP and CCK, including ELLs’ age, gender, and prior schooling experiences.

**Research Questions**

**Qualitative research question:** *What are the levels and characteristics of newcomer ELLs’ academic language proficiency and chemistry content knowledge?*

**Quantitative research questions:**

**Primary:** *What is the relationship between academic language proficiency and chemistry content knowledge levels of newcomer ELLs? How does this relationship change over a four-month period of time?*

**Secondary:** *What are the effects of age, gender, and/or prior schooling experience on newcomer ELLs’ academic language proficiency and/or chemistry content knowledge?*

**Definitions of Terms**

**ELLs.** ELLs is often used at the K-12 level (Shore & Sabatini, 2009) and is the most common term to refer to students with limited English proficiency. Besides ELLs, researchers have used other terms, such as English learners or ELs (e.g., Hakuta, Butler
& Witt, 2000), second language learners or L2 learners (e. g, Dixon et al., 2012), English as a foreign language learners or EFL learners (e.g., Ardasheva, & Tretter, 2013), emergent bilinguals (Garcia, 2009; Garcia, Kleifgen, & Falchi, 2008), language minority students (Duran et al. 1998), and linguistic minority students (Stoddart, Bravo, Solis, Mosqueda, & Rodriguez, 2011). The present study employed English language learners, or ELLs, to refer to students who enroll in school settings (public or private) and do not speak English as a native language, including students who are learning English as a second, third, or fourth language, excluding bilingual students who can speak English fluently as native speakers.

**Newcomer ELLs.** In the present study, newcomer ELLs refer to English language learners who recently immigrated to the United States (normally within a year, in rare occasions within two years) and enrolled in school programs that primarily use English.

**Scientific literacy.** Although the definition of this term is “notoriously elusive” (Dawson & Venville, 2009, p. 1422), Norris and Phillips (2003) summarize 11 ways of using it, including traditional views such as “knowledge of the substantive content of science and the ability to distinguish science from nonscience,” practical views such as “ability to use scientific knowledge in problem solving,” civic views such as “knowledge needed for intelligent participation in science-based social issues,” philosophical views such as “understanding the nature of science,” and personalized views such as “appreciation of and comfort with science, including its wonder and curiosity” (p. 225). Lemke (2004) points out that “scientific literacy is not just the knowledge of scientific concepts and facts; it is the ability to make meaning conjointly with verbal concepts,
mathematical relationships, visual representations, and manual-technical operations” (p. 38). In the present study, scientific literacy is used in a more traditional way, referring to the ability to understand scientific concepts, conduct scientific investigations, and communicate with the teacher or peers in science.

**Academic language/English.** Scarcella (2003) defines academic English as “a variety or a register of English used in professional books and characterized by the specific linguistic features associated with academic disciplines” (p. 19). While the registers of schooling generally involve more written-like discourse, academic English also includes oral language (Gibbons, 2006). In the present study, academic language refers to oral English primarily used in academic contexts. The words used in academic language are tier-two (non-specialized academic words) and tier-three (specialized academic words) words (Snow, 2008).

**Language Proficiency.** Peregoy, Boyle and Cadiero-Kaplan (2013) define language proficiency as “the ability to use a language effectively and appropriately throughout the range of social, personal, school, and work situations that comprise daily living” and point out that it consists of both oral and written language (p. 41). In the present study, the researcher only considered oral language proficiency of participants.

**Academic language proficiency (ALP).** Cummins (1981) introduces the concept of cognitive academic language proficiency (CALP), meaning the proficiency of language use that relates to literacy in academic contexts. CALP has been cited numerously for decades (e.g., Snow & Uccelli, 2009). However, some researchers reject this concept and propose opposing perspectives (e.g., Scarcella, 2003). In the present study, the researcher chose ALP to represent the competencies of newcomer ELLs’ using
oral academic language to express scientific ideas.

**Chemistry content knowledge (CCK).** Content knowledge (CK) typically refers to a domain of teacher knowledge, which is “the amount and organization of knowledge per se in the mind of the teacher” (e.g., Shulman, 1986, p. 9). In the present study, CCK refers to the amount and organization of chemistry knowledge, including matter, chemical reactions, and the periodic table. This knowledge is a common content knowledge, not specifically for teachers.

**Misconception.** In the present study, misconception refers to any idea that is different from currently accepted scientific knowledge, including ideas that are intuitive, naive, informal, incomplete, and/or incorrect. Other researchers used similar terms to express this meaning, such as *alternative conceptions* (Boo, 1998; Garnett et al., 1995).
CHAPTER II. LITERATURE REVIEW

Chemistry Content Knowledge (CCK)

The National Research Council (2012) issued a national document, *A Framework for K-12 Science Education* (referred to as “the framework” below), as the first step of developing new national science standards and improving existing documents for science education. Besides scientific practices and crosscutting concepts, the framework also provides descriptions of core ideas in multiple disciplines of science and engineering. Following the development of the framework, *Next Generation Science Standards* (NGSS) was developed under the endeavor of Achieve, the states, multiple stakeholders, and the National Research Council (NGSS Lead States, 2013). NGSS integrates practices, crosscutting concepts and big ideas of the framework, providing science standards across all disciplines and grade levels (K-12). Both the framework and NGSS provide science educators with information about the development of students’ conceptual understanding of matter, chemical reactions and the periodic table. Specifically, the framework describes big ideas of structures and properties of matter and chemical reactions under the dimension of physical sciences (i.e., physics and chemistry).

Both documents suggest that matter can be illustrated by describing the types of atoms and their interactions. For example, the state of matter is a phenomenon on the macroscopic scale, but it can be explained from the atomic level, such as motions of atoms. Similarly, as a property of matter on macroscopic scale, conductivity can be understood by describing the patterns of subatomic structures.

*Structures of matter* and its interactions on the macroscopic scale are caused by
interactions of electrical forces around and inside of the atoms. The substructure of atoms includes a small area in the center, a nucleus, and a large surrounding area spread with electrons (negative charge). The nucleus consists of protons (positive charge) and neutrons (no charge). The number of protons is also the atomic number, which determines the properties of matter. Properties of matter vary among elements, depending on their atomic and subatomic structures and forces between atoms and molecules. Some properties, such as density and viscosity, do not change when the quantity of matter changes; other properties, such as mass and volume, are directly correlated with the amount of matter, thus can be measures of its quantity. NGSS (NGSS Lead States, 2013) requires high school students to be able to compare structures and properties of matter on macroscopic scale (e.g., melting point) to infer the electrical forces among particles (e.g., atoms, molecules, and ions).

As described in the framework (2012), chemical reactions produce new substances and thus lead to different properties of matter. During this process, atoms rearrange to form new substances, but the types of elements and numbers of atoms are conserved. Properties of reactants can be used to describe and predict the products of chemical reactions. The periodic table systematically organizes all the known elements based on their structures and properties. The horizontal rows represent the order of elements’ atomic number (increasing from left to right and from top to bottom) and vertical columns show the similarities of elements based on their chemical properties. The patterns of the periodic table (e.g., the number of outer layer electrons) not only contribute to the discovery of new elements, but also provide explanations for the occurrence of chemical reactions. NGSS (NGSS Lead States, 2013) explicitly stated that
understanding matter and its interaction at high school level includes being able to use the periodic table to predict and explain chemical properties and reactions, such as the reactivity of matter, types and numbers of bonds formed, and oxidation.

**Acquisition of CCK**

Chemistry is an important yet complicated subject in science. In the United States, chemistry is not officially taught as a separate discipline until high school, but basic chemical concepts are embedded in science curricula for early grades as well (NGSS Lead States, 2013; National Research Council, 2012). *Structure and properties of matter* and *chemical reactions* are commonly taught in introductory chemistry courses. Conceptual understanding of these ideas contributes to one’s ability to distinguish physical and chemical changes, and is essential for students’ future learning in higher level chemistry courses (Boo, 1998; Boo & Watson, 2001; Stavridou & Solomonidou, 1998; Van Driel, Vos, Verloop, & Dekkers, 1998). However, numerous studies report students’ difficulties and misconceptions of learning matter and chemical concepts (e.g., Barker & Miller, 1999; Cavollo, McNeely, & Marek, 2003; Garnett, Garnett, & Hackling, 1995; Liu & Lesniak, 2006).

**Empirical studies of student understanding in CCK.** Science education researchers suggest that a sound understanding of chemical reactions requires comprehension of and clear distinctions among basic concepts, such as atoms, molecules, elements, compounds, (pure/single) substances, mixtures, materials, matter/stuff, objects, mass and density (Ahtee & Varjola, 1998; Barker & Miller, 1999; Driver, Squires, Rushworth, & Wood-Robinson, 1994). Liu and Lesniak (2006) interviewed 54 students (Grade 1-10) for their understandings about substances. Findings suggest that students’
conceptions of matter are influenced by multiple factors, which leads to a complicated and overlapped progression of development from elementary to high school grades. This progression moves from macroscopic to microscopic, and from intuitive understanding of common materials to utilizing the particulate model of matter. Krnel, Glazar, and Watson (2003) conducted a more systematic study in the UK by interviewing 84 children aged 3-13 about their understandings of classifications of matter. Results indicate that younger children often categorized matter with both extensive properties (e.g., volume, weight) and intensive properties (e.g., density, melting point), while children above age nine mostly used intensive properties. This difference between younger and older children’s classification suggests that children gradually distinguish between the concepts of matter and objects by developing a deeper understanding of the properties of matter.

On the other hand, research also indicates various misconceptions of these basic concepts. In a study conducted in Finland, Ahtee and Varjola (1998) found that although half of 7th and 8th graders knew that atoms are the smallest units to form substances, during interviews they still used other words (e.g., piece of structure, element, substance) to refer to the concept of atoms. Chandrasegaran, Treagust, and Mocerino (2008, 2011) report multiple misconceptions about particles (e.g., atoms, molecules, ions) among 9th graders in Singapore. For example, 14% of 65 students in their study incorrectly view the magnesium ribbon as having a +2 charge, because individual magnesium ions contain that charge; 15% of the students think individual chlorine and iron ions are also green, just as the color of iron chloride aqueous solution; similarly, 31% of the students think that copper ions are blue and copper atoms are reddish brown. In another study of students’ reasoning about chemical reactions, Barker and Miller (1999) report that post-
16 UK students confused mass with density. Thus, they hold the misconception that liquids are lighter than solids but heavier than gases.

Stavridou and Solomonidou (1998) identified three stages through which students build their understanding of chemical reactions based on interviews with 40 Greek students aged from 12 to 18 years. At the first stage, students noticed the phenomenological events, such as a color change or an explosion, but they do not view chemical reactions as changes from reactants to products, and they cannot make a distinction between types of changes. Students at the second stage understand that chemical reactions involve production of new substances and thus are able to distinguish some chemical reactions from physical changes; however, they hold misconceptions about the process. For example, some students think that only changes with two visible reactants are chemical reactions; therefore, salt dissolving in water is a chemical reaction while wood burning is not; some students consider any visible change between the initial and final substances as chemical reactions. Therefore, state changes of matter, such as water boiling or wax melting are chemical reactions. At the third stage, students are able to define chemical reaction at the microscopic scale (e.g., the change of molecular structure), but most of them fail to explain the production of a new substance in the same way. Descriptions of stages two and three are consistent with interview results of German 7th graders (age 12 to 13) in another study (Eilks, Moellering, & Valances, 2007). The results of that study shows that all eight pairs of participants understood that chemical reactions involve producing new substances. However, only the high achievers were able to make connections between macroscopic phenomena and microscopic changes.

**Difficulties of students’ CCK acquisition.** Misconceptions are held by students
across age, grade and achievement levels. Several factors contribute to this situation. Two of the major categories are: multiple representations of chemical concepts and influence from prior experience.

**Multiple representations of chemical concepts.** Chandrasegaran, Treagust, and Mocerino (2008) describe three types of representations for understanding chemistry: macroscopic (e.g., color, pH value), submicroscopic/molecular (e.g., atoms, ions), and symbolic (e.g., formulas, equations). Conceptual understanding of chemical phenomena involves using microscopic presentations to interpret macroscopic phenomena, and the former are often expressed with symbolic representations (Chandrasegaran et al., 2008; Gabel, 1999). For example, the macroscopic representation of sodium reacting with water are observations such as a sodium pellet burning in a flame and rapidly moving around the surface of the water with a fizzing noise; at the same time, the water turns pink (at the presence of phenolphthalein indicator) and becomes warm. At the microscopic level, sodium atoms intensely react with water molecules, producing sodium ions, hydroxide base (water turning pink) and hydrogen molecules (fizzing noise). At the same time, the heat released is enough to cause hydrogen gas to burn (flame), which is also an exothermic reaction (water becoming warm). This process is often represented with the symbolic equation: $2\text{Na} (s) + \text{H}_2\text{O} (l) \rightarrow 2\text{NaOH} (aq) + 2\text{H}_2 (g)$.

Knowing and being able to use all three representations simultaneously may cause great difficulties for students learning chemistry (Chandrasegaran & Treagust, 2009). Gabel (1999) points out that incoherent instruction can exacerbate these difficulties. Some high school teachers navigate between multiple representations without making explicit connections. For instance, directly using the symbolic equation of sodium
reacting with water to represent observable phenomena can be a challenge for students to make sense of the scientific idea. Instead, students may memorize both representations without developing any connections.

**Influence from prior experience.** Students primarily make sense of scientific phenomena based on their everyday life experience rather than unfamiliar scientific ideas (Ahtee & Varjola, 1998; Chandrasegaran el al., 2008; Stavridou & Solomonidou, 1998). In a study of Lebanese students’ understanding of chemical reactions, Jaber and BouJaoude (2012) report that most 10th graders can interpret chemical reactions at the macroscopic level. Although this intuitive process can help students make connections with chemistry concepts and everyday life, it can also cause misconceptions (Eilks et al., 2007; Lee, 2004). For example, if students always experience solids as rigid substances, they may have difficulties imagining “soft, malleable, and granular solids”; if students assume all liquids are supposed to flow like water, they may have trouble with the concept of viscosity (Lee, 2004, p. 21). Another example is understanding oxidation and combustion/burning, which are common phenomena in everyday life. However, knowing that oxidation and combustion are chemical reactions might lead to a student’s misconception that all chemical reactions are spontaneous, irreversible, and/or produce gases and water (BouJaoude, 1991; Nakhleh, 1992; Yalcinkaya, Tastan, & Boz 2009). Similar misconceptions can be formed in chemistry courses where chemical reactions are commonly introduced with observable examples (e.g., changing color, releasing heat, producing gas or precipitation) and occur towards one direction (Van Driel et al., 1998). Therefore, students may consider that all chemical reactions are visible, produce gas or precipitation, and are single-directed.
In addition, students often confuse microscopic interactions and macroscopic change. For example, some students use additive reasoning and suggest that if the visible substance is expanding or reducing in size, individual atoms or molecules must be expanding or shrinking, as well (Ebenezer & Erickson, 1996; Jaber & BouJaoude, 2012; Johnson, 2000; Meheut, Saltiel, & Tiberghien, 1985; Talanquer, 2013). Students may also get confused with abstract modeling and concrete entities. For example, some students consider the man-made model of chemical bonds as a miniature version of reality (Boo & Watson, 2011; Eilk et al., 2007; Grosslight, Jay, Unger, & Smith, 1991; Jaber & BouJaoude, 2012).

**Language Acquisition and Proficiency**

Christie, Enz, Vukelich, and Roskos (2014) provide a broad definition of language as “any system of symbols that is used to transmit meaning,” which can include “sound, finger movements, print, and so on” (p. 5). Peregoy, Boyle and Cadiero-Kaplan (2013) describe language as “a dynamic and complex symbol system that functions for communication and group identity” (p. 40).

Traditionally, language consists of four linguistic areas: listening (input), speaking (output), reading (input), and writing (output). These areas share structural rules of language, such as phonology, morphology, syntax, semantics, pragmatics, and discourse (Peregoy, Boyle & Cadiero-Kaplan; 2013; Gee; 2002). Specifically, phonology refers to the study of the sound system; morphology is the study of morphemes, which are the smallest unit of the meaning in a certain language; syntax, also called grammar, refers to the rules of combing and organizing words to construct sentences; semantics is the study of meaning that language possesses; pragmatics studies the context and
functions of the language (Christie, Enz, Vukelich, and Roskos, 2014). Gee (2002, 2004) compares two types of discourse: a “Discourse” is a distinguishing way of being and doing that reflects an individual’s or a group of peoples’ characteristics of their social identities, culture, or community of practice; a “discourse”, on the other hand, refers to the use of language. Effective communication requires knowledge and abilities to apply these rules.

Cummins (1981) categorizes language in two types: basic interpersonal communication skills (BICS) and cognitive academic language proficiency (CALP). The former is defined as “cognitively undemanding manifestations of language proficiency in interpersonal situations” and the latter refers to “those dimensions of language proficiency that are strongly related to literacy skills” (Cummins, 1981, p. 23). Researchers posit that developing BICS normally requires one to three years, and the development of CALP often requires five to seven years, depending on the amount and quality of exposure to academic English (Allen & Park, 2011; Carrier, 2005; Cho & McDonnough, 2009; Dong, 2004, Scarcella, 2003). Empirical studies show similar results in which ELLs take three to five years to develop oral English proficiency, and four to seven years to develop academic language proficiency (Hakuta et al., 2000).

Scarcella (2003) points out that one of the causes of this acquisition gap is that students can use paralinguistic and contextual cues to assist developing BICS, but often only rely on linguistics cues when attaining CALP. On the other hand, she rejects the binary system of BICS/CALP and claims that it is because students’ academic language development is not a “fixed choice”: “some aspect of BICS are acquired late and some aspects of CALP are acquired early,” also, “many variables encourage the development
of both CALP and BICS” (Scarcella, 2003, p. 18). Furthermore, Scarcella compares the
differences of five language components in academic language and in ordinary language,
including the phonological, lexical, grammatical, sociolinguistic, and discourse
components. For example, from a lexical perspective, using the word “investigate” is
more appropriate in academic language than using “find out.”

Gee (2004) defines academic language as a form of social language, which refers
to “a way of using language to enact a particular socially situated identity and carry out a
particular socially situated activity” (Gee, 2004, p. 14). However, other researchers (e.g.,
Watts-Taffe & Truscott, 2000) disagree that academic language is a type of social
language and argue that it is “context-reduced” so that “gestures, body language, and
facial expressions that could facilitate the communication process are absent or
diminished” (p. 259). Because academic language performs certain functions in
communication, it requires organization, logic, and cohesion (Peregoy, Boyle & Cadiero-
Kaplan; 2013) and is “not just pretentious ways of using language” (Schleppegrell, 2004,
p. 137).

The three domains of academic language are the qualities (e.g., whether the
language is precise, logical, or formal), functions (e.g., to describe, explain, or compare),
and linguistic features (Peregoy, Boyle & Cadiero-Kaplan, 2013). The domain of
linguistic features contains three subdomains: vocabulary (e.g., general academic, content
specific and nominalization), syntax (e.g., passive voice, if-then constructions and
dependent clauses) and discourse strategies (e.g., narrative, enumeration and persuasion).

Snow (2008) describes three tiers of word use: tier-one, also called high-
frequency words, can be used in almost all contexts, especially in daily life. Examples of
Tier-one words are *air, yellow*, and *drink*. Tier-two words are non-specialized academic words that are often used in general academic contexts. Examples of tier-two words are *articulation, paradoxical* and *justify*. Tier-three words, also called specialized academic words, are highly discipline-specific and rarely used in everyday conversation. Examples of tier-three words are *centriol, diploid,* and *electrophoresis*.

The complexity of language can be represented by two ratios of word use. The lexical density refers to the ratio of content words to non-embedded clauses; the lexical diversity refers to the ratio of different words to total word use (Malvern & Richards, 2013; Schleppegrell, 2004; Snow & Uccelli, 2009). For example, “The four *states of matter* are *solid, liquid, gas* and *plasma*” contains one clause, six content words (italicized), 11 unique words and 11 total words, so the lexical density of this clause is 6.0 and the lexical diversity is 100%; on the other hand, the clauses of “*Matter is everything. Matter is atoms*” contains two clauses, three content words, four unique words and six total words, so the lexical density is 1.5 and the lexical diversity is 67%. The differences in these two examples show that the greater the lexical density and lexical diversity, the more complex the language is. In other words, greater lexical density and diversity contribute to the complexity and efficiency of academic language (Schleppegrell, 2004).

**Influential Factors for ELLs’ Language Acquisition.** Multifold factors influence ELLs’ second language development and academic achievement. These factors include individual differences, such as age, gender, prior schooling experience, first language proficiency, cognitive ability, culture, personality, motivation, etc., and non-individual factors, such as quality of the home environment and education programs.
(Ardasheva & Tretter, 2013; Cho & McDonough, 2009; Dixon et al., 2012; Echevarria & Graves, 2007; Halle, Hair, Wandner, McNamara, & Chien, 2012; Settlage, Madsen & Rustad, 2005). In order to teach science to ELLs effectively, science teachers and teacher educators should identify and be aware of these factors to provide students with appropriate instructional support and accommodate their different needs (Duran, Dugan, & Weffer, 1998). In addition, these factors are interactive and sometimes overlap. Therefore, one cannot attribute ELLs’ achievement or unsuccessful learning experience to a single factor.

**Age.** Age has significant impact on ELLs’ language learning. Most age-related factors, such as current age (Ardasheva, Tretter & Kinny, 2012; Torras & Celaya, 2001; Wrigley, Chen, White & Soroui, 2009), age-of-arrival (Dixon et al., 2012; Roessingh, 2008; Shore & Sabatini, 2009), length of residence (Roessingh, 2008; Roessingh & Douglas, 2012), and start age [of learning English]/age of initial instruction (Dixon et al., 2012), stem from the critical period hypothesis (Harley, Howard, & Hart, 1995). This hypothesis describes an important time frame when children develop their linguistic skills (Lenneberg, 1967). The critical period ends at puberty, after which language acquisition becomes more challenging. Generally speaking, the older the students are, the more difficult it is for them to achieve native-like second language proficiency, especially after age 12 (Dixon et al., 2012). Second language learning is particularly difficult for high school students due to the limited time remaining in K-12 school settings (Bautista & Castaneda, 2011).

However, other hypothesis posits that although younger ELLs have advantages of learning the phonology of English, older ELLs can often make quicker progresses in
second language acquisition, especially in morphology and syntax (Dixon et al., 2012; Ervin-Tripp, 1974; Snow & Hoefnagel-Höhle, 1978). Harley and colleagues (1995) received a different result from their study, in which 2nd, 7/8th, and 12th graders worked on a task of completing sentence cues. Findings suggest no significant differences of performance between different-aged groups.

Recent studies have investigated age-related factors in one of the specific language areas, such as reading or writing. For example, Ardasheva and colleagues (2012, 2013) identify a negative correlation between students’ age and their reading scores (for both ELLs and non-ELLs). A possible explanation of this result is that reading materials for older students are more challenging and require higher level language skills. On the other hand, researchers have not found similar patterns in ELLs’ writing skills. Torres and Celava (2001) conclude that although ELLs unevenly develop their areas of writing proficiency, including fluency, complexity and accuracy, earlier starters (of English learning) did not significantly outperform late starters.

**Gender.** Research shows that female students in general demonstrate more interest and motivation than male students when learning a second language (Csizér & Dörnyei, 2005). Lee and Schallert (1997) report that female students scored significantly higher than male students in an English (L2) proficiency test in Korea. However, female and male students in this study came from different secondary schools. Therefore, the difference of English proficiencies may attribute to educational factors, such as the quality of school programs or instruction, rather than differences between genders. On the other hand, the review of literature in the present study found little research about gender differences among ELLs in science content learning. Although it has viewed males and
females differently since the last century, general public still has different expectations for different genders with respect to academic achievement and careers. This social perspective also influences teachers’, parents’, and sometimes even students’ expectations for second language acquisition and academic achievement. In schools, female students are more likely to be ignored by teachers, and easily underperform male peers, especially in mathematics and science (Hafernik, Messerschmitt, & Vandrick, 2002). This situation is more severe in countries outside of the United States. Many ELLs are immigrants from those countries and their attitudes, motivation, and self-confidence in academic learning could be greatly different from native English speaking students and long-term ELLs in the United States.

Prior schooling experience. Prior schooling is one of the most influential factors to ELLs’ academic achievement (Cho & McDonnough, 2009). Within the growing population of ELLs, many have incomplete or even no prior schooling experience. Researchers (e.g., Freeman, Freeman & Mercuri, 2003; DeCapua, Smathers & Tang, 2009) refer to these ELLs as students with interrupted formal education (SIFE) or students with limited or interrupted formal education (SLIFE). Because they lack basic disciplinary training and proper academic language development in their native language, SIFE/SLIFE often face serious challenges of understanding content knowledge (DeCapua, Smathers & Tang, 2007). However, research studies have shown different results about the predictive value of prior schooling. For example, more educated immigrants reported their English proficiency much higher than non-educated counterparts after living in the United States for 10 years, regardless of their age of arrival (Hakuta, Bialystok & Wiley, 2003). On the other hand, Ardasheva and Tretter
(2013) found a different result that shows ELLs’ prior schooling had no significant impact on their reading test scores.
CHAPTER III. METHODS

Overview of the Research Design

The goal of the present study was to investigate the characteristics of, the relationship between, and the effects of extraneous factors (e.g., age) on newcomer ELLs’ academic language proficiency (ALP) and chemistry content knowledge (CCK) levels. To answer these research questions, the mixed method approach was adopted. During data collection, 51 participating newcomer ELLs were interviewed individually at the beginning, middle, and end of the fall semester of 2014-2015 academic year. All interviews were video-recorded, transcribed, coded for common themes, and graded using two rubrics: one for ELLs’ ALP levels and another for ELLs’ CCK levels. In addition, participants’ demographics, including age, gender and prior schooling experience, were collected and analyzed along with their ALP and CCK levels.

Mixed method research. The traditional qualitative and quantitative approaches derive from different ontological and epistemological stances, and hold different expectations for the research outcomes. Mixed method research offers an alternative means to these traditional methods. Teddlie and Tashakkori (2011) illustrate the differences between the context/logic of justification (e.g., testing a prediction or a theory) and the context/logic of discovery (e.g., understanding a phenomenon in-depth or developing a theory). They point out that although the former is frequently the emphasis of the mixed method research, the latter, which often stems from the qualitative data analysis, is also valuable and can contribute to generating new knowledge. More importantly, the mixed methods are not merely a combination of qualitative and quantitative research, but an “eclectic” process that can potentially “cancel out respective
weaknesses” of both traditional approaches (Teddlie and Tashakkori, 2011, p. 286). One premise of this eclecticism is the compatibility of qualitative and quantitative methods. However, there has been a prolonged debate about whether the compatibility exists (e.g., Howe, 1988; Smith & Heshusius, 1986). For the present study, the researcher argues that the mixed methods are the optimal approach to answer the research questions.

**Naturalistic inquiry (qualitative).** The qualitative phase of the present study employed the approach of naturalistic inquiry. Lincoln and Guba (1985) discuss the distinctions between positivist paradigm and naturalist paradigm, describing the latter as a knower-known interactive, time-bound, context-bound, and value-bound. The present study was conducted with a specific population (newcomer ELLs) in a specific context (a science classroom in a newcomer academy) at a specific time (before the ELLs exit to typical schools) using a specific communication tool (face-to-face individual interviews). All these features carved the boundaries of the present research and therefore made it closely align with the naturalistic paradigm. The technical approach of the qualitative data analysis incorporated the method of constant comparison as described by Lincoln and Guba (1985) with adaptations to the present study. This phase answered the research questions about newcomer ELLs’ ALP and CCK levels and the characteristics of those levels.

**Non-experimental design (quantitative).** Since the present study was conducted in a pre-set educational setting, all relevant variables (e.g., prior schooling years) were not controllable. Therefore, a non-experimental design was adopted. The technical approach of the quantitative data analysis incorporated the methods of descriptive analysis, Kruskal-Wallis test, Pearson’s correlation test, Spearman’s rank-over
correlation test, and Friedman’s test (Gay, Mills, & Airasian; Urdan, 2010). This phase answered the research questions about the relationship between newcomer ELLs’ ALP and CCK levels and the effects of extraneous factors on these levels.

**Context**

The present study was conducted at an urban public high school in North Texas. This school offered short academic programs specifically for middle school and high school students who were recent immigrants to the United States. The school’s mission was to foster newcomer ELLs’ rigorous, on-level content learning, and promote their proper social and cultural development (cited from the school website, reference omission for confidentiality purposes).

In the early 1980s, the district established the Language Center program, which was designed to serve middle and high school immigrant students. This program was located in and integrated with typical middle or high schools, and provides intense ESL instruction, content-area courses, and electives. The idea of initiating a stand-alone program specifically for newcomer ELLs was suggested but quickly abandoned due to the concerns about isolation and inequality. Ten years later, the planning committee reconsidered this idea and reached a consensus that the crucial factor is the quality of education, not the location (the school website). With great efforts from the planning committee, a newcomer secondary school, called Newcomer Middle and High School (NMH, pseudonym) was established in the early 1990s. The goal of the school was to promote students’ language acquisition, integrate language and content knowledge learning, introduce students to the local culture, and assist them in making a smooth transition to study in the Language Centers after they exit the NMH (the school website).
By promoting learning outcomes for newcomer ELLs, the NMH contributed to improve the whole program, as the newcomers move to other levels at the Language Center. The process of student placement at the NMH involved the following steps: a student would be placed at the NMH if he/she (1) enrolled in the student placement center within six months of entering the United States; (2) was identified as Limited English Proficiency (LEP) or ELL based on self-reported home language surveys; (3) was designated as beginners after taking IPT II test. The enrollment in the NMH typically lasted for one-academic year, after which students exited and enrolled in a Language Center at a regular school campus (T. Wilson, personal communication, May 13, 2014, June 17, 2015; Texas Education Agency, 2014).

During Fall 2014, the NMH served approximately 400 newcomer ELLs (the exact number changes during the semester due to students moving in or out of the program). Students came from six continents/areas (Table 3.1) and spoke at least 23 different languages, including Arabic, Burmese, Khmer, Chin, Chinese, Dari, Farsi, Persian, Dinka, French, Hakka Chin, Kachin, Karen, Karenni, Kenyarwanda, Lingala, Nepali, Pashto, Portuguese, Somali, Spanish, Swahili, and Tigrinya (the school website).

Table 3.1

<table>
<thead>
<tr>
<th>Students’ Regions of Origin at the NMH (as in Fall 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continents/Areas</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Central America</td>
</tr>
<tr>
<td>North America</td>
</tr>
<tr>
<td>Africa</td>
</tr>
<tr>
<td>Middle East</td>
</tr>
<tr>
<td>Asia</td>
</tr>
<tr>
<td>South America</td>
</tr>
</tbody>
</table>

\(^a\) The IPT II test is part of the IDEA Oral Language Proficiency Test series, which are individually-conducted assessments of oral English proficiency for secondary ELLs (Stansfield, 1990).
In the past three years (2011-2014), the NMH adopted the model of Quality Teaching for English Learners (QTEL). All teachers participated in professional development offered by WestEd about how to integrate this model into daily instruction.

Setting

The setting of this study was a high school science classroom at the NMH. Ms. Wilson (pseudonym), who had been collaboratively working with the researcher for three years since Fall 2012, was the teacher of this classroom. The high school department at the NMH had three science teachers for the academic year of 2014-2015, and Ms. Wilson was the peer coach and former department chair. She had been working at the NMH for 16 years (since 1999) and this school was the only place she had ever taught. The teaching path of Ms. Wilson started with teaching reading, and one year later she taught ESL for about three years. After that, she taught a course called ESL for science, which provided students with scientific vocabulary and concepts, aiming to prepare them for future science learning in high school. However, students could not receive science credits for taking this course. At that time, Ms. Wilson was the only teacher at the NMH who was certified in science and had enough college science credit hours to be considered “highly qualified” for teaching this course. In 2011, the NMH began offering students an on-grade-level course called Integrated Physics and Chemistry (IPC) for four science credits. Ms. Wilson had been teaching that course since the beginning (T. Wilson, personal communication, November 04, 2013).

In Fall 2014, Ms. Wilson taught four periods per day (Table 3.2). She started with 70 students (16, 19, 17, and 18 students in periods 2, 3, 4, and 6, respectively) at the beginning of the semester (as in September, 2014).
Table 3.2

*Teaching Schedule for Ms. Wilson (1st and 5th periods are preparation periods)*

<table>
<thead>
<tr>
<th>Periods</th>
<th>Monday—Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>09:05 am-10:07 am</td>
<td>08:55 am-09:47 am</td>
</tr>
<tr>
<td>3rd</td>
<td>10:10 am-11:12 am</td>
<td>09:50 am-10:42 am</td>
</tr>
<tr>
<td>4th</td>
<td>11:48 am-12:50 pm</td>
<td>10:45 am-11:37 am</td>
</tr>
<tr>
<td>6th</td>
<td>01:58 pm-03:00 pm</td>
<td>01:10 pm-02:02 pm</td>
</tr>
</tbody>
</table>

Participants

The participants of the present study were 51 newcomer ELLs from Ms. Wilson’s classroom during the 2014-2015 academic year (Table 3.3). In a four-month period (late September to late January), the researcher interviewed a total of 75 ELLs, among which, six students enrolled after the first interview session; 11 students left the program before the final interview session; four students were enrolled during the whole investigation period but absent during at least one of the interview sessions; and three students have unusable or incomplete data due to lacking consent forms or lost recordings. Therefore, a total of 51 ELLs had complete, usable data sets and become the final participants of the present study. The following sections used participants, ELLs and students interchangeably, all referring to the 51 final participants.

Table 3.3

*Student Participation Categories (N = 75)*

<table>
<thead>
<tr>
<th>Categories</th>
<th># of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Participants of the Study</td>
<td>51</td>
</tr>
<tr>
<td>Enrolled the Program After the Study Started</td>
<td>6</td>
</tr>
<tr>
<td>Exitd the Program Before the Study Ended</td>
<td>11</td>
</tr>
<tr>
<td>Absent During At Least One of the Interview Sessions</td>
<td>4</td>
</tr>
<tr>
<td>Unusable or Lost Data</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
</tr>
</tbody>
</table>

At the time of the data collection (Fall 2014), all participants were 9th graders, including 10 of whom had studied at the NMH since Spring 2014 as 8th graders,
therefore, they were in their second semester in this school. Three participants were identified as Students with Interrupted Formal Education (SIFE), and they had been studying at the NMH for one academic year (2013-2014), therefore, they were in the third semester in this school. All participants were from 13 countries (including the United States) and one territory (i.e., Puerto Rico) and represented at least 10 languages (Table 3.4).

Table 3.4  

*Country of Origin and First Language of Participants (N = 51)*

<table>
<thead>
<tr>
<th>Country or Territory</th>
<th># of Students</th>
<th>Language</th>
<th># of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan</td>
<td>3</td>
<td>Arabic</td>
<td>1</td>
</tr>
<tr>
<td>Bhutan</td>
<td>2</td>
<td>Burmese</td>
<td>4</td>
</tr>
<tr>
<td>Congo (Democratic Republic)</td>
<td>1</td>
<td>Dari</td>
<td>2</td>
</tr>
<tr>
<td>Cuba</td>
<td>2</td>
<td>Karen</td>
<td>1</td>
</tr>
<tr>
<td>El Salvador</td>
<td>3</td>
<td>Kinyarwanda</td>
<td>1</td>
</tr>
<tr>
<td>Guatemala</td>
<td>2</td>
<td>Nepali</td>
<td>2</td>
</tr>
<tr>
<td>Honduras</td>
<td>7</td>
<td>Pashto</td>
<td>1</td>
</tr>
<tr>
<td>Iraq</td>
<td>1</td>
<td>Spanish</td>
<td>38</td>
</tr>
<tr>
<td>Mexico</td>
<td>16</td>
<td>Swahili</td>
<td>1</td>
</tr>
<tr>
<td>Myanmar</td>
<td>5</td>
<td>Total</td>
<td>51</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rwanda</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States(^b)</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

About half of the participants were males (N = 26) and half were females (N = 25). Their ages ranged from 14 to 19 (Table 3.5).

\(^b\) These students were born in the United States but grew up and received prior education in other countries, such as Mexico.
Table 3.5

*Gender and Age of Participants (N = 51; age: M = 15.65, SD = 1.197)*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>2</td>
<td>7</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9</td>
<td>15</td>
<td>17</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>51</td>
</tr>
</tbody>
</table>

The self-reported prior schooling experiences ranged from six to 13 years (Table 3.6). All participants scored level A or B (a scale of A-F with F being the highest) in the IPT II test operated by the district/school at the beginning of the semester.

Table 3.6

*Participants’ Prior Schooling Experience (N = 51, M = 9.8, SD = 1.6)*

<table>
<thead>
<tr>
<th>Prior Schooling (years)</th>
<th># of Students</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>11</td>
<td>19</td>
<td>37</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**Recruitment.** To recruit participants for this study, the researcher and Ms. Wilson spoke with her students and explained the purpose of the study. The principal of the NMH and the Institutional Research Board at the researcher’s institution both approved this study [DRB-1408-05]. Because the NMH obtained parental permissions for school functions, such as field trips, using both English and Spanish versions, the researcher provided participants with a student assent form and a parental consent form in both languages as well. The Spanish versions helped Spanish-speaking students (75% of the class) and their parents understand the consenting process. The final participants only included students who agreed to participate and signed both assent forms by themselves.
and consent forms by their parents.

**Procedure**

The procedure of the present study involved four separated processes. Figure 3.1 shows each step of all processes with each process in a different color. The pink rectangles represent the process of interview data collection; the blue ellipses represent the process of creating and using grading rubrics; the thin blue lines between rectangles and ellipses represent that the latter utilized the former; the green parallelogram represents the process of collecting extraneous factors, including participants’ age, gender, and prior schooling years; the purple rounded rectangles represent the process of data analysis, both qualitatively and quantitatively. The following sections describe the details of each stage.

*Figure 3.1. Research Procedure*

**Collecting Interview Data.** This process consisted of five steps: one step of creating the interview protocol and four steps of conducting interviews. Each of the interview steps followed by data transcription.
Creating the interview protocol. The initial interview protocol was created by Ms. Wilson based on her instructional plans. This protocol included eight sets of questions. After discussions with the dissertation committee, the researcher reduced the protocol to four open-ended questions: (1) *Tell me everything you know about matter.* (2) *Tell me everything you know about chemical reactions.* (3) *Tell me everything you know about the periodic table.* (4) *Can someone use the periodic table to predict the combination of substances? Tell me about it.* The dissertation committee and Ms. Wilson approved this final protocol before any interviews were conducted.

Pilot interviews. In order to increase internal validity of the present study, the researcher interviewed three university students (convenient sample) with the initial protocol. Two of the interviewees were native English speakers and the third one was an ELL. All interviewees provided feedback to the researcher, such as providing prompt/follow-up questions during the interview. After discussing with the dissertation committee, the researcher decided to not accept this suggestion in order to make sure that all participants were asked the exact same questions.

Pre-, mid-, and post-interviews. The researcher conducted three rounds of interviews between late September and January (Figure 3.2). The pre- and post-interviews contained all four questions from the protocol for assessing students’ ALP and CCK levels. The mid-interviews only contained the first question (i.e., *Tell me everything you know about matter*) for assessing students’ ALP levels.
Prior to the pre-interviews, the researcher met all of the students in Ms. Wilson’s classroom and spent six periods with them (e.g., sat at the table with students and helped them with class activities/discussions). All pre-, mid- and post-interviews occur during class time in the presence of Ms. Wilson or a substitute teacher. For each interview, Ms. Wilson (or the researcher if Ms. Wilson was not in the classroom) called a student’s name and asked him/her to talk with the researcher in the preparation room (Figure 3.3), which was attached to the classroom. The door of the preparation room remained open, so the student felt less isolated and Ms. Wilson could observe what happened in there. In addition, the researcher used a camcorder during the interviews to capture students’ gestures (without faces) and how they manipulate materials on the table.

Figure 3.2. Timeline of Data Collection (2014-2015)
Before each interview started, the researcher always informed the student that they could use verbal, written, and/or body languages to answer questions, and the camcorder only focused on their hands (Appendix A). During interviews, the researcher strictly followed the protocol and asked each student exactly the same questions. If a student did not respond to a question or if he/she asked for clarification, the researcher repeated the question, but did not provide further information. In other words, the researcher did not explain questions with different words other than the protocol nor provide positive/negative feedback, such as “good” or “that is incorrect.” After a student finished answering a question, the researcher asked if he/she had anything else to say about the question (e.g., “Can you tell me more?” “Anything else?” or “Can you show me?”), but did not provide prompt questions or follow-up questions. As stated previously,
the reason for not providing prompt or follow-up questions was to maintain a completely structured, generic protocol to make sure that participants answer the same questions under the same situations. If a student did not respond to a question, the researcher moved to the next one until all four questions were asked. The researcher also provided pictures and real items that related to the topics (e.g., rock, water, balloon, the periodic table) and sentence starters (e.g., “I can describe matter by______”, see Appendix B) to help students answer questions. Students could choose to respond with gestures, oral language, written language (a pencil and paper were available), and/or drawings. If a student only responded with gestures, drawings or written responses, the researcher encouraged him/her to provide oral response as well (e.g., “Could you please talk to me about it?”).

Creating and grading with the rubrics. This process consisted of four steps: creating rubrics, validating rubrics, grading practice and official grading. Two researchers, including a colleague of the author’s, contributed to all steps in this process. In this section, “researchers” referred to the author and her colleague.

Creating rubrics. The initiation and modification of grading rubrics was an ongoing process, which occurred simultaneously with the interview data collection. First, the researchers read and discussed related literature about using rubrics to assess ELLs’ language proficiency and/or content knowledge (e.g., Bergman, 2013; Dong, 2013; Martinez, 1999; Murphy, 2009; Pappamihiel & Mihai, 2006; Winsor, 2008). Second, the researchers viewed and discussed Ms. Wilson’s lesson plans as well as samplers of the interview transcriptions. The goal of this discussion was to help the researchers develop a general understanding about the range of participants’ ALP and CCK levels. Third, each
researcher independently wrote two grading rubrics based on the readings and his/her current understanding about participants’ levels. Then the researchers met again and combined two ALP rubrics as well as two CCK rubrics. These three sub-steps were cyclical and repeated for two rounds.

The importance and necessity of creating new rubrics. Many researchers and institutions have developed well-structured rubrics for assessing ELLs’ English proficiency levels, such as TELPAS (Texas Education Agency, 2011) and WIDA’s Standards-based System (WIDA Consortium, 2012). However, these rubrics cannot be directly used in assessing ELLs in the present study for the following reasons: (1) Rubrics like TELPAS and WIDA were comprehensive rubrics designed for identifying all language proficiency levels. Therefore, they were not sensitive enough to detect differences within the participants of the present study, especially when these participants were already designated as beginners using IPT II test (Figure 3.4). (2) Participants of the present study were all 9th graders, but rubrics like TELPAS or WIDA were normally designed for assessing ELLs at all grade levels (some sub-rubrics are designed for certain grade bands, such as 9-12). (3) Most importantly, rubrics like TELPAS or WIDA primarily assess ELLs’ general/everyday English language proficiency, but the present study aimed to examine both academic language and content knowledge. Given the three reasons above, creating new rubrics that specifically address newcomer beginning ELLs’ ALP and CCK levels was important and necessary.
Figure 3.4. Relationships between IPT II test levels\(^c\) and newcomer beginning ELL levels (Texas Education Agency, 2014)

**Modifying rubrics.** At this stage, researchers used two strategies to modify the initial rubrics: (1) Grading the pilot interviews’ transcriptions with the initial rubrics to test their feasibility; (2) Sending the rubrics to Ms. Wilson, dissertation committee, and laypersons and asking for feedback. After these, researchers modified the initial rubrics based on the experience of grading pilot interviews and the feedback. Each validated rubric contained five levels, and each level included a name, descriptions with three indicators, and characteristics of students’ performance (Table 3.7 & 3.8). Moreover, the modification of rubrics was an on-going process because more and more characteristics

\(^c\) NES = non-English speaking; LES = limited English speaking; FES = fluent English speaking (Stansfield, 1990).
of students are identified during the grading. In addition, although vocabulary is an important component of beginning ELLs’ language development (Texas Education Agency, 2011), the amount of academic word use was not considered as an indicator for students’ ALP levels. Instead, the academic words (both unique and total) were counted and considered as separate dependent variables.
Table 3.7

Rubric of Academic Language Proficiency Levels for newcomer beginning ELLs

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Characteristics (The student may)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Entering)</td>
<td><strong>Comprehension of Questions:</strong> No understanding of the verbal and/or written questions</td>
<td>• Maintain silence</td>
</tr>
<tr>
<td></td>
<td><strong>Language Complexity:</strong> No use of words</td>
<td>• Provide no response or meaningless response</td>
</tr>
<tr>
<td></td>
<td><strong>Expression:</strong> No scientific ideas are explained through the verbal or written language</td>
<td>• Repeat the question or part of the question multiple times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Need significantly long processing time (e.g., 2 minutes)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Communicate scientific ideas with manipulatives and/or hand gestures</td>
</tr>
<tr>
<td>2 (Emerging)</td>
<td><strong>Comprehension of Questions:</strong> Minimal understanding of the verbal and/or written questions</td>
<td>• Understand only one word or one phrase of the question</td>
</tr>
<tr>
<td></td>
<td><strong>Language Complexity:</strong> Minimal amount and quality of academic language</td>
<td>• Hold obvious misunderstanding about the questions</td>
</tr>
<tr>
<td></td>
<td><strong>Expression:</strong> The scientific ideas are minimally explained through the language</td>
<td>• Need long processing time (e.g., 30 seconds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exclusively uses tier 1 words or words that are both in tier 1 and tier 2 (e.g., gas)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Communicate scientific ideas with isolated words, manipulatives, and/or hand gestures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Point and call names of the manipulatives on the table without further elaboration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use sentences such as “I don’t know” or “I don’t understand”</td>
</tr>
<tr>
<td>3 (Developing)</td>
<td><strong>Comprehension of Questions:</strong> Incomplete understanding of the verbal and/or written questions</td>
<td>• Provide responses that are on topic or closely related to the topic</td>
</tr>
<tr>
<td></td>
<td><strong>Language Complexity:</strong> Rudimentary amount and quality of academic language</td>
<td>• Hold minor misunderstanding about the questions</td>
</tr>
<tr>
<td></td>
<td><strong>Expression:</strong> The scientific ideas are superficially explained through the language</td>
<td>• Need a short processing time (e.g., 10 seconds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimal academic word use (tier 2 or 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Communicate scientific ideas with words, phrases and/or fragmented sentences</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use manipulative and/or hand gestures to help</td>
</tr>
<tr>
<td>4 (Maturing)</td>
<td><strong>Comprehension of Questions:</strong> Basic understanding of the verbal and/or the written questions</td>
<td>• Provide responses that are on the topic</td>
</tr>
<tr>
<td></td>
<td><strong>Language Complexity:</strong> Adequate amount and quality of academic language</td>
<td>• Hold no obvious misunderstanding about the questions</td>
</tr>
<tr>
<td></td>
<td><strong>Expression:</strong> The scientific ideas are adequately explained through the language</td>
<td>• Respond quickly after the question was presented (e.g., 5 seconds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Adequate academic word use (tier 2 or 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Communicate scientific ideas mostly in sentences</td>
</tr>
<tr>
<td>5 (Advanced)</td>
<td><strong>Comprehension of Questions:</strong> A full understanding of the verbal and/or the written questions</td>
<td>• Provide responses that are specific and appropriate</td>
</tr>
<tr>
<td></td>
<td><strong>Language Complexity:</strong> Extensive amount and quality of academic language</td>
<td>• Respond immediately after the question was presented (e.g., no processing time or less than 2 seconds)</td>
</tr>
<tr>
<td></td>
<td><strong>Expression:</strong> The scientific ideas are clearly explained and elaborated through the language</td>
<td>• Extensive academic word use (tier 2 or 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Communicate scientific ideas in complete sentences</td>
</tr>
</tbody>
</table>
### Rubric of Chemistry Content Knowledge Levels for newcomer beginning ELLs

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Characteristics (The student may)</th>
</tr>
</thead>
</table>
| 1 (Entering)| (1) **Knowledge**: Evidence of no understanding of the concepts of chemical reactions or the periodic table  
(2) **Coherence**: N/A  
(3) **The Use of Academic Vocabulary**: No use of academic vocabulary; showing no conception | • Maintain silence  
• Incorrectly select manipulatives without explanations  
• Incorrectly read off the periodic table without further elaboration |
| 2 (Emerging)| (1) **Knowledge**: Evidence of minimal understanding of the concepts of chemical reactions or the periodic table  
(2) **Coherence**: Explanations are difficult to follow; the concepts/ideas are isolated and/or inconsistent  
(3) **The Use of Academic Vocabulary**: Major errors in academic vocabulary use showing serious misconceptions | • Understand that chemical reactions involve certain changes (e.g., combination), but is unable to specify the type of changes  
• Provide no, minimal, and/or incorrect examples  
• Correctly read some of the elements’ names without describing the patterns of the periodic table |
| 3 (Developing)| (1) **Knowledge**: Evidence of incomplete understanding of the concepts of chemical reactions or the periodic table with obvious gaps in knowledge and insufficient examples and notations  
(2) **Coherence**: Explanation of concept has some lapses and mistakes in organization that affect understanding of concept; the concepts/ideas are weekly related with occasional inconsistency  
(3) **The Use of Academic Vocabulary**: Several errors in academic vocabulary use, with evidence of misconceptions | • Understand that chemical reactions involve producing new substances, but is unable to explicitly distinguish between chemical and physical changes  
• Know the existence of electrons, but is unable to recognize that chemical reactions and bonding are related to valence electrons  
• Describe the components of the periodic table (groups, periods, symbol, atomic mass, etc.), but is unable to relate the physical and chemical behavior of an element to its placement on the periodic table |
| 4 (Maturing)| (1) **Knowledge**: Evidence of basic understanding of the concepts of chemical reactions or the periodic table with minor gaps in knowledge, examples, and notations  
(2) **Coherence**: Explanation of concept is easy to follow and understand; the concepts are weakly connected  
(3) **The Use of Academic Vocabulary**: Appropriate use of academic vocabulary with minor errors/misuse | • Understand the difference between physical and chemical reactions  
• Recognize that chemical reactions and bonding are related to valence electrons, but is unable to tell that they are based on the number of these electrons  
• Recognize that the physical and chemical behavior of an element (metals, non-metals, metalloids), including bonding and classification, is related to its placement on the periodic table, but is unable to describe the connection  
• Recognize that chemical properties of substances are related to the arrangement of their atoms or molecules, but is unable to describe the connection |
5 (Advanced)  

(1) **Knowledge:** Evidence of full understanding of the concepts of chemical reactions or the periodic table and sufficient examples and notations  
(2) **Coherence:** Explanation of concept is well organized and concept links are correct, easy to follow, and coherent  
(3) **The Use of Academic Vocabulary:** Appropriate and accurate use of academic vocabulary  

- Understand the difference between chemical and physical changes on microscopic level with sufficient and appropriate examples  
- Recognize that chemical reactions and bonding are based on the number of valence electrons  
- Demonstrate that mass is conserved during a chemical change, and that the number and kinds of atoms are the same in both the reactants and products  
- Analyze energy changes that accompany chemical reactions, and classify them as endothermic or exothermic  
- Relate the physical and chemical behavior of an element, including bonding and classification, to its placement on the periodic table  
- Relate chemical properties of substances to the arrangement of their atoms or molecules
**Grading practice.** In order to increase grading consistency, researchers engaged in grading practice with an incomplete data set collected from non-participant students (e.g., enrolled the program late or exited early). During the practice, researchers coded 13 transcriptions with an interrater reliability of 77% for ALP levels, and 85% for CCK levels. After that, researchers discussed the disagreements until a consensus was reached.

**Official grading.** At this stage, both researchers coded all of the participants’ interview transcriptions ($N = 153$, 51 transcripts from each interview session). Each pre- and post-interview received an ALP score based on the answers of questions 1-4, a CCK score based on the answers of questions 2-4, a count of unique academic words use, and a count of total academic word use. Each mid-interview only received a score for the ALP level based on the answer of the only question asked. The reason of not using responses of question 1 to code CCK levels was that by the time of pre-interviews, the properties and structures of matter were already introduced to students. Therefore, this question (i.e., tell me everything you know about matter) was only coded for participants ALP levels.

Particularly, researchers independently coded 10 or 20 transcriptions per week and met weekly to discuss the grading results. The average interrater reliability was 85% for ALP levels of both pre- and post-interviews and 89% for CCK levels; the interrater reliability of ALP levels for mid-interviews was 80%. After discussions at the weekly meetings, the final interrater reliabilities reached 99% for both ALP and CCK pre- and post-interviews, and 100% for ALP mid-interviews. In addition, researchers discussed the inclusive and exclusive rules for the academic word count (Table 3.9) and created a list of academic vocabulary (Appendix C) based on participants’ word use during the interviews.
Table 3.9

*Rules for Counting Academic Words Used by Newcomer ELLs*

<table>
<thead>
<tr>
<th>Description of the Rules</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading off the periodic table counts as academic vocabulary</td>
<td>N/A</td>
</tr>
<tr>
<td>Plural and singular forms of the same word count as the same word</td>
<td>“element” vs. “elements”</td>
</tr>
<tr>
<td>The same word with different forms counts as different words</td>
<td>“chemical” in “chemical reaction” vs. “chemicals”</td>
</tr>
<tr>
<td>The same word with different meanings counts as different words</td>
<td>a “key” to a lock vs. a “key” to the periodic table</td>
</tr>
<tr>
<td>Words that are both in tier 1 and tier 2 count as academic words if they were used in academic contexts</td>
<td>“color” of the table—does not count; “color” change in a chemical reaction—does count</td>
</tr>
<tr>
<td>Using the same words appearing in the asked questions does not count as academic vocabulary</td>
<td>“The periodic table” does not count as a student’s academic vocabulary unless he/she used it before the interviewer did.</td>
</tr>
<tr>
<td>Some phrases count as one word if they represent a cohesive meaning</td>
<td>“atomic mass”, “pure substance”</td>
</tr>
</tbody>
</table>
**Collecting extraneous factors.** Ms. Wilson provided information about participants’ age, gender and prior schooling years in a master chart. The researcher recorded these data in a separate worksheet only with students’ pseudonyms to protect their confidentiality.

**Data analysis.** Before introducing the details of data analysis, the endeavor of increasing the trustworthiness of the present study is worth presented. Many researchers have debated whether the concept of validity is compatible with qualitative research (Maxwell, 2012). Table 3.10 shows alternative terms and their definitions of four aspects of trustworthiness (including internal and external validities) for both qualitative and quantitative studies (Guba, 1981; Lincoln & Guba, 1985), followed by descriptions of the strategies that were adopted in the present study to improve each aspect.
Table 3.10

*Interpretations of Four Aspects of Trustworthiness* (Guba, 1981; Lincoln & Guba, 1985) *in the Present Study*

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Type&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Term</th>
<th>Definition</th>
<th>Strategy to Increase the Trustworthiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truth value</td>
<td>QUAL</td>
<td>Credibility</td>
<td>The extent to which the results deal with the patterns in the entirety and take into account the complexities.</td>
<td>The researcher conducted pilot interviews. The researcher persistently engaged in the classroom activities before, during and after the study for five months.</td>
</tr>
<tr>
<td></td>
<td>QUAN</td>
<td>Internal validity</td>
<td>The extent to which the variations of dependent variables are directly resulted from the control of variation in independent variables.</td>
<td>The researcher frequently debriefed with the classroom teacher (member checking) and a colleague (peer debriefing).</td>
</tr>
<tr>
<td>Applicability</td>
<td>QUAL</td>
<td>Transferability</td>
<td>The extent to which the results are derived from and relevant to a given context</td>
<td>The researcher provided detailed descriptions of the context, setting, participants, data analysis, and results.</td>
</tr>
<tr>
<td></td>
<td>QUAN</td>
<td>External validity or Generalizability</td>
<td>The extent to which the results are generalizable or applicable to other participants, contexts, and times.</td>
<td>The researcher randomly assigned participants’ interview sequences.</td>
</tr>
<tr>
<td>Consistency</td>
<td>QUAL</td>
<td>Dependability</td>
<td>The extent to which the results are both stable (reliable) and tractable (taking into account the phenomenal or design induced changes).</td>
<td>Using digital recording devices to capture the exact conversations. The researcher strictly followed the interview protocol without any clarification or explanation during the interviews</td>
</tr>
<tr>
<td></td>
<td>QUAN</td>
<td>Reliability</td>
<td>The extent to which the results are consistent over time or duplicable in another context.</td>
<td>Two researchers graded all interview data with interrater reliabilities over 80%.</td>
</tr>
<tr>
<td>Neutrality</td>
<td>QUAL</td>
<td>Conformability</td>
<td>The extent to which the results are verifiable (emphasize the data)</td>
<td>The researcher safely kept all the raw data, data analysis products, process notes, communication records, and instrument development information, which were presented several times to the dissertation committee and available for audit.</td>
</tr>
<tr>
<td></td>
<td>QUAN</td>
<td>Objectivity</td>
<td>The extent to which the results are value-free and drawn by a non-disturbing and non-disturbed researcher (emphasize the researcher).</td>
<td></td>
</tr>
</tbody>
</table>

<sup>d</sup> QUAL=the qualitative phase of the study; QUAN=the quantitative phase of the study
**Qualitative Data Analysis.** The process of qualitative data analysis was overlapped with the initiation and modification of rubrics. Constant comparison approach (Lincoln & Guba, 1985) was used to code literature and interview data and resulted three indicators for each rubric: comprehension of questions, language complexity, and expression for the ALP rubric; knowledge, coherence, and the use of academic vocabulary for the CCK rubric.

**Statistical Data Analysis.** As previously stated, the primary quantitative question investigated the relationship between newcomer ELLs’ ALP and CCK levels; the secondary quantitative question examined the effects of age, gender, and prior schooling experience on newcomer ELLs’ ALP and CCK levels. To answer these questions, the qualitative interview data were graded and transformed into numerical data for statistical analysis. This data transformation is one of the analytical strategies of mixed method research as described by Caracelli and Greene (1993). The variables for statistical analysis are as following:

*Independent variables (IV).* Independent variables of the present study included participants’ demographics (i.e., age, gender and prior schooling years) and time: (1) Age: all participants’ ages were recorded as of August 25, 2014 and rounded to integers (interval data). For example, if a student was born in January 2000, he/she was 14 years and 7 months old on August 25, 2014, therefore, his/her age was recorded as 15. (2) Gender: as categorical data, participants’ genders were recorded as 1 (male) or 2 (female). (3) Prior schooling experience: participants’ prior schooling experience was self-reported as of August 2014, and represented by integers (interval data). (4) Time: three time points (pre-, mid- and post-interviews) were used and represented by 1 (pre-interview), 2 (mid-
Dependent variables (DV). Dependent variables of the present study included participants’ ALP levels, CCK levels, frequency of unique academic word use (FAW), and total academic word use (TAW). The measure of these dependent variables was individual interviews with all participants. (1) ALP levels: ALP referred to participants’ academic language proficiency. It was represented by integers 1-5 (ordinal data) coded with the ALP rubric (Table 3.7). Each participant received three ALP scores for pre-, mid-, and post-interviews, respectively. (2) CCK levels: CCK referred to participants’ chemistry knowledge about matter, chemical reactions, and the periodic table. It was represented by integers 1-5 (ordinal data) coded with the CCK rubric (Table 3.8). Each participant received two scores for CCK levels for pre and post interviews, respectively. (3) FAW: FAW showed the amount of unique, unrepeated academic words that each participant used during interviews. As interval data, FAW was represented by integers (0—∞) using the word counting rules (Table 3.9). (4) TAW: TAW showed the total amount of academic words that each participant used during interviews. Similar as FAW, this variable was represented by integers (0—∞) using Table 3.9. The reason of having separate word counts in addition to ALPs was because the word use was a main indicator of the beginning level ELLs according to the TELPAS rubric (Texas Education Agency, 2011).

Because the answer to the secondary question could potentially affect the answer to the primary question, these two questions were answered in a reverse order. Specifically, quantitative analysis was conducted through the following three steps:

*Step one: using the Kruskal-Wallis test to examine the effects of age, gender, and
prior schooling experience on participants’ ALP and CCK levels (secondary question).

The Kruskal-Wallis test is a non-parametric test equivalent to one-way Analysis of Variance (ANOVA). This test was used to analyze the differences among independent variables (age, gender, and prior schooling experience) and dependent variables (ALP and CCK levels) at pre-interviews. In other words, this step aimed to determine whether gender, age, and/or prior schooling experience could affect students’ ALP and/or CCK levels before any instructional intervention occurred. Specifically, six tests were conducted to answer six sub-questions (Table 3.11).

Table 3.11

Tests to Examine the Effects of IVs on DVs

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tests</th>
<th>Sub-Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender—ALP pre</td>
<td>Kruskal-Wallis</td>
<td>Do ALP levels differ between male and female students at the pre-interviews?</td>
</tr>
<tr>
<td>Gender—CCK pre</td>
<td>Kruskal-Wallis</td>
<td>Do CCK levels differ between male and female students at the pre-interviews?</td>
</tr>
<tr>
<td>Age—ALP pre</td>
<td>Kruskal-Wallis</td>
<td>Do ALP levels differ for students at different ages at the pre-interviews?</td>
</tr>
<tr>
<td>Age—CCK pre</td>
<td>Kruskal-Wallis</td>
<td>Do CCK levels differ for students at different ages at the pre-interviews?</td>
</tr>
<tr>
<td>Prior schooling—ALP pre</td>
<td>Kruskal-Wallis</td>
<td>Do ALP levels differ for students who have different prior schooling experiences at the pre-interviews?</td>
</tr>
<tr>
<td>Prior schooling—CCK pre</td>
<td>Kruskal-Wallis</td>
<td>Do CCK levels differ for students who have different prior schooling experiences at the pre-interviews?</td>
</tr>
</tbody>
</table>

Step two: using the Kruskal-Wallis test and the Pearson’s correlation test to analyze the differences between participants’ ALP levels, frequency of unique academic word use (FAW), and total academic word use (TAW). Although it was not one of the
research questions, examining the differences and correlations between these dependent variables indicate the relationship among the language variables. Specifically, three tests were conducted to answer three sub-questions (Table 3.12).

Table 3.12

*Tests to Examine relationships between the Language Variables*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tests</th>
<th>Sub-Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALP—FAW</td>
<td>Kruskal-Wallis test</td>
<td>What is the difference between FAWs for students at different ALP levels?</td>
</tr>
<tr>
<td>ALP—TAW</td>
<td>Kruskal-Wallis test</td>
<td>What is the difference between TAWs for students at different ALP levels?</td>
</tr>
<tr>
<td>FAW—TAW</td>
<td>Pearson’s correlation</td>
<td>How are FAW and TAW related for the same student?</td>
</tr>
</tbody>
</table>

*Step three: Using Spearman’s rank-order correlation test to analyze the strength of relationship between participants’ ALP and CCK levels (primary question).* The Spearman’s rank-order correlation test is a non-parametric test equivalent to Pearson’s correlation test. Specifically, two tests were conducted to answer two sub-questions (Table 3.13).

Table 3.13

*Tests to Examine Correlations Between DVs*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tests</th>
<th>Sub-Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALP (pre)—CCK (pre)</td>
<td>Spearman’s rank-order correlation</td>
<td>What is the relationship between students’ ALP and CCK at the beginning of the semester?</td>
</tr>
<tr>
<td>ALP (post)—CCK (post)</td>
<td>Spearman’s rank-order correlation</td>
<td>What is the relationship between students’ ALP and CCK at the end of the semester?</td>
</tr>
</tbody>
</table>

*Step four: using Friedman’s test to analyze the change of relationship between participants’ ALP and CCK over a four-month period of time (primary question).* The Friedman’s test is a non-parametric test equivalent to Repeated Measures ANOVA.
Specifically, two tests were conducted to answer two sub-questions (Table 3.13)

Table 3.14

*Tests to Examine the Change of Relationships Between DVs Over Time*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tests</th>
<th>Sub-Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time—ALP</td>
<td>Friedman’s test</td>
<td>Do students’ ALP levels differ between the pre-, mid- and post-interviews?</td>
</tr>
<tr>
<td>Time—CCK</td>
<td>Friedman’s test</td>
<td>Do students’ CCK levels differ between the pre- and post-interviews?</td>
</tr>
</tbody>
</table>
CHAPTER IV. QUALITATIVE RESULTS

Overview

The purpose of the present study was to investigate the characteristics of, the relationship between, and the effects of extraneous factors (e.g., age) on newcomer ELLs’ academic language proficiency (ALP) and chemistry content knowledge (CCK) levels. A mixed method approach was employed to answer the research questions. Chapter IV and V report the qualitative results and quantitative results, respectively.

This chapter answered the qualitative research question: *What are the levels and characteristics of newcomer ELLs’ ALP and CCK?* Two rubrics, one for ALP and another for CCK (Tables 3.8 and 3.9), were developed to summarize the definitions and characteristics of each level. The following sections presented details of each level with empirical examples. Particularly, the grading of ALP levels considered all four questions. The grading of CCK only considered questions 2-4, because at the time of the pre-interviews, matter, the topic of the first question had already been introduced in class. In order to identify the biggest differences of students’ CCK levels between pre- and post-interviews, the first question was not included when grading CCK levels. In addition, all levels were graded based on the entire performance during the interviews. Partial responses might not reflect the overall level. For example, ALP level 5 student might answer a certain question or used a certain sentence of level 2. In this sense, having two researchers independently grade all interviews was crucial to increase the overall reliability of the present study. Table 4.1, 4.2, and 4.3 show the distributions of ALP and CCK levels at pre-interviews, post-interviews, and combined interviews, respectively.
### Table 4.1

The Distributions of ALP and CCK Levels at the Pre-interviews

<table>
<thead>
<tr>
<th></th>
<th>ALP1</th>
<th>ALP2</th>
<th>ALP3</th>
<th>ALP4</th>
<th>ALP5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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### Table 4.2

The Distributions of ALP and CCK Levels at the Post-interviews

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<th>ALP3</th>
<th>ALP4</th>
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### Table 4.3

The Distributions of ALP and CCK Levels in both Pre- and Post-interviews

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### ALP Levels

The grading of overall ALP levels considered indicators in responses to all four questions.

**Level 1 (entering).** At the entering level, students’ comprehension, language
complexity, and expression were none to minimum. A typical level 1 student might show no understanding to the interview questions, both verbally and/or in written forms, by remaining silence, providing meaningless response, repeating questions, or communicating only through gestures, (e.g., waving hands, pointing at objects on the table). Approximately one-eighth of the pre-/post-interviews ($N = 13$) were graded as level 1 for ALP.

_No response_. A typical characteristic of the entering level ELLs was not providing any valid responses to the interview questions. Here the non-valid responses included remaining silence without any communication or clearly stating that they do not know the answer. Commonly, these students had severe difficulties fully understanding the questions.

_Example ALP1-1. Post #36_

Q1: Tell me everything you know about matter.
D13: [Silence]
Researcher: Anything you can remember about matter.
D13: [Silence]
Researcher: You can use anything on the table to help you.
D13: [Point at the prompt semi-sentences]
Researcher: Yes, you can use them if you want.
D13: [Silence]
Researcher: Do you want to tell me something about matter or you want to move on to the next question?
D13: I don’t know.
Researcher: Do you want to move on to the next question?
D13: [Nod]

Q2: Tell me everything you know about chemical reactions.
D13: [Silence]
Researcher: That’s ok. Anything you can think of.
D13: [Select a picture of logs]
Researcher: Can you tell me about it?
D13: [Silence]
Researcher: Could you please explain this one?
D13: Explain?
Researcher: Yes.
D13: [Silence]

Tell me everything you know about the periodic table. [Show a periodic table to the student]
D13: [Silence]
Researcher: Ok.

Can someone use the periodic table to predict the combination of substances? Tell me about it.
D13: [Silence]
Researcher: That’s ok. That’s all the questions I want to ask.

In this example, D13 did not provide any information for answering questions except for pointing at a picture of logs at Q2. However, no more evidence showed the connection of this picture and the question. More importantly, D13 remained silent almost the entire time.

*Example ALP1-2. Pre1* #24

Q1: Tell me everything you know about matter.
D17: [Shrug] I don’t know.

Q2: Tell me everything you know about chemical reactions.
D17: [Shake head]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D17: Boo.
Researcher: What? Boo?
D17: Yes.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D17: [Shrug]
Researcher: That’s ok.

In this example, student D17 clearly showed that he did not know the answers, verbally (Q1) and via gestures (Q2 & Q3).

* Pre1 and Pre2 merely indicate whether the interview was conducted before or after an data export, which resulted an renumbering of recordings.
**Unrecognizable response.** Unrecognizable response refers to the answers (verbally or non-verbally, in English or non-English) that were not meaningful in the context of the question due to unrecognizable languages or gestures. These students often hold misconceptions of the questions as well. Some students might repeat the questions several times or ask for clarification in their native languages.

*Example ALP1-3. Pre1 #19*

Q1: Tell me everything you know about matter.
D01: [Speak in Spanish]
Interviewer: English please.
D01: [Silence]
Interviewer: Matter? Everything you know about matter?
D01: [Silence]
Interviewer: That’s ok.

Q2: Tell me everything you know about chemical reactions.
D01: [Unidentified words]
Interviewer: That’s fine.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D01: [Silence]
Interviewer: Ok. That’s fine.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D01: [Silence]
Interviewer: That’s ok.

In this example, student D1 used verbal language twice: once in speaking Spanish, and the second time using words that were hard to recognize. This minimum information did not convey any ideas.

**Response with body language.** This type of entering level students provided answers primarily with body language, such as waving hands or pointing at pictures on the table. The students might or might not fully understand the questions.
Example ALP1-4. Pre1 #22

Q1: Tell me everything you know about matter.
D18: [Play around with pictures and in the end select a picture of battery, pictures of solid, liquid and gas models and a picture of coke]

Q2: Tell me everything you know about chemical reactions.
D18: [Select a picture of dancing]
Researcher: Can you tell me more about it?
D18: [Select a picture of bacteria]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D18: [Look at the periodic table for a long time, then select a picture of logs from the table]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D18: [Silence]
Interviewer: That’s ok.

Despite the correctness of answers, student D18 did not provide any verbal responses. All the information was given in body language.

Response with non-academic words. The primary description of entering level students was that they are not able to use academic language to express scientific ideas. Therefore, one of the characteristics of their responses was the absence of academic words. However, these students might use non-academic words to express their ideas. These students often understood the questions at least partially.

Example ALP1-5. Post #57

Q1: Tell me everything you know about matter.
D07: Tree [point at a picture of trees].
Researcher: Can you tell me more?
D07: Dancing [point at a picture of people dancing].
Researcher: Can you explain them? Can you tell me more about matter?
D07: Clouds [point at a picture of clouds].

Q2: Tell me everything you know about chemical reactions.
D07: I don’t know.
Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D07: [Unidentified words]
Researcher: Can you show me?
D07: [Point at H]
Researcher: Can you tell me more?
D07: [Silence]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D07: [Silence]

In the answer to Q1, student D07 named each picture to which he pointed. However, no more explanation was provided to further explain the connections between those items and matter. The answers to the last three questions showed other characteristics of the entering level students as previously described.

**Summary.** In general, the entering level students (level 1) did not show any ability of communicating in academic language during the interview. Instead, they often remained silence, provided meaningless answers, and/or responded with body language or non-academic words. Most students at this level used multiple types of responses (e.g., pointing at pictures for answer questions 1 and 2, and remaining silence for questions 3 and 4).

**Level 2 (emerging).** At the emerging level, students’ comprehension, language complexity, and expression were minimal. A typical level 2 student might show evidence of understanding only one word/phrase of the questions or hold obvious miscomprehension of the questions; started to express scientific ideas with isolated words and/or phrases, but did not use sentence structures; the words used were often tier 1 (Snow, 2008) or both in tier 1 and tier 2 (e.g., gas); extensively needed assist of body language to communicate in science. Twenty-eight percent of the pre-/post-interviews (N = 29) were graded as level 2 for ALP.
**Reading off the materials.** A typical characteristic of the emerging level ELLs was to read off the provided materials, including the pictures and the periodic table (for Q3). A corresponding characteristic was that the responses are all isolated words. Most importantly, this kind of “reading off” involved verbally using academic words in order to reach the second level, emerging.

*Example ALP2-I. Post #35* (the academic words were underlined in all examples of this chapter)

Q1: Tell me everything you know about matter.
D08: I think matter is…this [select pictures of the gas, solid, and liquid models].
Gas, solid, liquid.
Researcher: Can you tell me more about it?
D08: [Select a picture of trees and a picture of a soccer ball].

Q2: Tell me everything you know about chemical reactions.
D08: Chemical reaction is this [select a picture of logs and a picture of a moldy orange]
Researcher: Can you tell me about them?
D08: [unidentified words]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D08: Hydrogen [point at H]. Explain?
Researcher: You can say everything you want.
D08: Hydrogen, sodium, calcium, potassium, boron [point at H, Na, Ca, K, and B]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D08: [Unidentified words]
Researcher: [Repeat the question]
D08: Hydrogen with oxygen [point at H and O].
Researcher: Can you tell me more?
D08: No.

In this example, student D08 showed a basic understanding of the questions, and ability to read off the pictures about scientific concepts (e.g., solid) and the periodic table. Although the academic words used are highly related to the questions, the expression of
scientific ideas was limited due to the lack of sentence structure. Again, the primary goal of grading ALP levels was to evaluate ELLs’ ability to communicate in science with academic language. Therefore, the everyday English language was crucial but not the primary concern. In other words, speaking fluent everyday language did not guarantee a high ALP level.

*Example ALP2-2. Pre #26*

Q1: Tell me everything you know about matter.
A09: Matter? Matters is [point at a picture of lightening] this one. Matters is fire [point at a picture of fire]. This one, and this one; this one [point at pictures of the solid, liquid and gas models]. Coca cola? …That’s it.

Q2: Tell me everything you know about chemical reactions.
A09: Chemical reaction?
Researcher: Yes.
A09: What is chemical reaction?
Researcher: I cannot tell you that. I just ask you questions.
A09: Chemical reaction…chemical reaction chemical reaction…[murmur]
Researcher: That’s ok. Do you want to move on to the next question?
A09: Yes.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A09: Oxygen, carbon, aluminum…sodium [read from the table]
Researcher: Ok.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A09: [Shake head]
Researcher: That’s ok.

As previously stated, using everyday English was not equivalent to having high academic language proficiency. Similar to D08, student A09 showed the ability to communicate in simple sentences (e.g., what is chemical reaction?). However, academic language (words) was only used in answering Q3.

*Example ALP2-3. Post #7*

Q1: Tell me everything you know about matter.
C05: [Point at a picture of solid model]
Researcher: Can you tell me about it?
C05: [Point at the models again] solid, liquid, gas.
Researcher: Ok. Can you tell me more?
C05: [Point at tadpoles] Fish.

Q2: Tell me everything you know about chemical reactions.
C05: [Point at a picture of a moldy orange]
Researcher: Can you tell me about it?
C05: Orange.
Researcher: What about it?
C05: [Point at fossils]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C05: [Point at an element, murmur]
Researcher: What about it?
C05: Oxygen.
Researcher: Can you tell me more?
C05: [Silence]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C05: [Silence]
Researcher: [Repeat the question]
C05: [Point at He] this one.
Researcher: Ok.

In this example, student C05 clearly did not have the same everyday language proficiency as the D08 and A09. However, being able to use academic words, including reading off the provided materials, was the crucial difference from level 1. This example represented the lower end of the emerging level.

**Response with abstract or generic academic words.** During the interviews, some students at ALP level 2 could use abstract and generic academic words that did not directly relate to the provided materials. In other words, these academic words were completely from their own vocabulary.

*Example ALP2-4. Post #53*

Q1: Tell me everything you know about matter.
C09: Matter…I know matter is the…matter is the everything the substance…buoyancy and [unidentified words]  
Researcher: Sorry, can you say it again?  
C09: [Unidentified words] I know matter…I know…[unidentified words]  
Researcher: Do you want to move on to the next question?  
C09: Yes.

Q2: Tell me everything you know about chemical reactions.  
C09: Chemical reaction? [Long pause] chemical reaction…  
Researcher: Can you tell me everything you remember now? You can use anything on the table to help you.  
C09: [Unidentified words] definition of chemical reaction…Chemical reaction definition?  
Researcher: You can tell me the definition if you know it.  
C09: I don’t know.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]  
C09: [Unidentified words] hydrogen, carbon…  
Researcher: Can you show me?  
C09: [Long pause] Hydrogen [point at H]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.  
C09: I don’t understand this question.  
Researcher: That’s ok.

In this example, student Q4 did not point and name pictures as the previous student did. Instead, he used more abstract academic words such as substance (before the researcher brought it up) and buoyancy.

Example ALP2-5. Post #51

Q1: Tell me everything you know about matter.  
B09: [Repeat the question]  
Researcher: Yes, can you tell me that?  
B09: [Select a picture of battery] Metallic? Because it is metallic…the matter? Because energy…the elements…  
Researcher: Is the battery for energy or for matter?  
B09: Matter.  
Researcher: Can you tell me more?  
B09: [Select a picture of coke] Water…element…matter because the substance…the liquid.
Q2: Tell me everything you know about chemical reactions.
B09: [Select a picture of lightning, unidentified words]
Researcher: Ok. Is that chemical reaction?... I’m just trying to confirm it.
B09: No… chemical reaction…
Researcher: Can you tell me more about it?
B09: [Select a picture of the gas model] chemical reaction…gas? Solid liquid and gas? [Murmur]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
B09: Hydrogen [point at H]?
Researcher: Can you tell me more?
B09: Baron [point at B], [start reading off the periodic table but hard to identify the words]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
B09: Nitrogen and hydrogen [point at N and H]…
Researcher: Can you tell me more about them?
B09: [Unidentified words] substances.

In this example, student B09 used significantly more academic words than the previous level 2 students. The main reason to grade him at the emerging level was because his language barely conveyed any scientific ideas, regardless of the correctness of the content.

**Summary.** Overall, the entering level students started to use academic words to express their scientific ideas. However, the usage of academic words was very limited with low language complexity and weak expression. In addition, although two types of language use were separately described, many level 2 students’ responses contained both reading off materials and using abstract words. For example, a student might point and name pictures for answering Q1 and Q2, and used more abstract academic words for answering Q3 and Q4.

**Level 3 (developing).** At the developing level, students’ comprehension, language complexity, and expression were improved but still significantly limited. A typical level 3
student might show incomplete understanding of the questions, which lead to on topic but indirect answers; use a combination of words, phrases, and simple sentences to express scientific ideas (the academic words used were primarily tier 2 or tier 3 words); and occasionally need assistance of body language to communicate. One-third of the pre-/post-interviews (N = 34) were graded as level 3 for ALP.

**Response in both verbal and body languages.** A typical characteristic of the developing level ELLs was pointing at pictures and/or elements on the periodic tables and explaining with academic words. Compare to the emerging level, this explanation had higher language complexity than merely naming the objects or elements. However, the verbal explanation was highly dependent on the action of pointing. In other words, without the body language, these students might not be able to smoothly and explicitly express scientific ideas.

*Example ALP3-1. Post #56*

Q1: Tell me everything you know about matter.
D14: These three [point at pictures of the solid, liquid and gas models, respectively]. This is solid, this is liquid, and this is gas [unidentified words] Researcher: Can you tell me more please?
D14: This [point at a picture of coke], this too [point at a picture of a moldy orange]; this is gas [point at a picture of clouds].

Q2: Tell me everything you know about chemical reactions.
D14: [Point at the a picture of coke] This [unidentified words] substance. Researcher: What substance?
D14: Gas. Ice too. [Point at a picture of fire] fire. [Point at the picture of a moldy orange].

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D14: This is [unidentified words]. These are gases [point at the noble gasses] and this [point at H]. This is [unidentified words, point at the orange area]. Researcher: Can you tell me more?
D14: The periods are vertical… [point at the columns], the groups are … [point at the rows]…No [nervous voice]…
Researcher: Do you want to try it again?
D14: The periods are these [point at the rows] and the groups are ... [point at the columns].
Researcher: Anything else?
D14: [Silence]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D14: Yes.
Researcher: Can you tell me about it?
D14: Because...elements are...can together...other no...[unidentified words]. Like the water, oxygen...

In this example, student D14 extensively utilized the pictures and the periodic table to express her scientific ideas. In her answers, pointing at pictures and elements frequently replaced the subject or objects of her sentences (e.g., these [point] are...; ... are these [point]). Without the body language, many of the sentences would not make any sense. It is worth noticing that the essential function of this type of examples is very similar to the level 2 students’ point-and-name-objects responses. The difference was that level 3 students’ overall comprehension, language complexity, and expression outperform level two students.

Example ALP3-2. Post #28

Q1: Tell me everything you know about matter.
C04: The matter is all the...the matter no is energy. I remember the three state of matter, that is the gas, solid and liquid. [Point at a picture of the gas model] This picture represent the matter, gas, the particle move fast. [Point at a picture of the liquid model] This is liquid because the particles...move less. [Point at a picture of the solid model] And the solid particles [unidentified words].
Researcher: Can you tell me more about matter?
C04: No.

Q2: Tell me everything you know about chemical reactions.
C04: The chemical reaction is you create a new substance and is no reverse.
Researcher: Can you tell me more?
C04: When the...this is [point at a picture of logs]...when chemical reaction is...new substance is no...you can...cannot [unidentified words].

Q3: Tell me everything you know about the periodic table. [Show a periodic table
to the student]
C04: I don’t know…
Researcher: Anything you remember?
C04: The three… is separate… the metallic nonmetallic and metalloids?
Researcher: Anything else?
C04: The elements is [unidentified words] the elements has balance. The elements need… no.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C04: The oxygen, hydrogen…
Researcher: Can you tell me more?
C04: No.

Similar to the previous example, student C04 utilized words, phrases, sentences and body language (pointing) to express his ideas. However, besides pointing, C04 also provided further explanation of the items she pointed. For example, when pointing at a picture of the gas model, C04 verbally stated “this picture represent the matter, gas, the particle move fast”; in the contrast, when D14 pointed at the same pictures, she stated “this is gas.”

**Verbal response with support of body language.** This type of response also used body language, but only as support to the verbal language. Differently from the first type, these verbal responses still made sense without the action of pointing at items.

*Example ALP3-3. Post #41*

Q1: Tell me everything you know about matter.
C08: I think matter is everything that we can touch we can see and we can feel. Matter have four… solid, liquid, gas and… the other is… I don’t remember.
Researcher: That’s ok. Go on.
C08: The matter is… The tree is the matter [point at a picture of logs]. Fire is not matter [point at a picture of fire] because fire give energy.
Researcher: Anything else?
C08: No.

Q2: Tell me everything you know about chemical reactions.
C08: Chemical reaction is… new substances… made new substances… chemical reaction cannot go back.
Researcher: Can you tell me more?
C08: Like…would be cut the tree [point at a picture of a tree] and it’s gonna be [unidentified words] this tree.
Researcher: Are you saying that’s a chemical reaction?
C08: Yes.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C08: Periodic table is organized everything and is…number…team by team number. By periodic table we can find everything in science.
Researcher: Can you tell me more about it?
C08: No.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C08: Yes.
Researcher: Can you tell me about it?
C08: I don’t understand…

In this example, student C08 used body language too. However, pointing at pictures only served to supplement her verbal statements. For example, when she said “Fire is not matter because fire give energy,” she also pointed a picture of fire at the same time. Her statement was understandable without the body language.

*Verbal response only.* The third type of responses at the developing level often exclusively contained verbal statements without or with limited body languages. Generally, the verbal expression of these students was adequate to superficially express scientific ideas.

*Example ALP3-4. Post #10*

Q1: Tell me everything you know about matter.
D04: I know that all…matter takes space…[unidentified words] the people have matter too, the animals too. All [unidentified words]. And the matter is like the molecule, all the states have molecules.
Researcher: Anything else you can think of?
D04: No.

Q2: Tell me everything you know about chemical reactions.
D04: Chemical reactions…The chemical reaction is when you combine two chemicals [unidentified words] substance.
Researcher: Anything else about chemical reactions?
Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D04: I know the periodic table is they have all the elements [unidentified words]. And the periods table has all the matter, the molecules, pure substance. The substance like carbon, [unidentified words]
Researcher: Anything else about the periodic table?
D04: No.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D04: Yes.
Researcher: Can you tell me about it?
D04: Yes, I practiced it in class to predict something…I use the key [point at the demonstration key]…the protons and electrons to predict substance.
Researcher: Can you give me an example for that?
D04: Like carbon…I don’t remember, I think so is multiple to 12 [unidentified words], and other [unidentified words].

In this example, student D04 primarily answered questions with verbal language and only used body language once to supplement the response. Despite of the miscomprehension, misconceptions and unidentified words, this student had a basic ability to convey simple scientific ideas.

Summary: At the developing level, students’ academic language showed evidence of development. The academic language use could involve words, phrases, sentences, and most commonly, a combination of all three. In addition, most students adopted two or three types of responses as described above. For example, some students used pointing as both partial explanation and to supplement the explanation; some students responded to one question using pointing as partial explanation and respond to another question with exclusively verbal language. In the present study, these three types of responses were considered equal with respect to the level of academic language proficiency. In other word, one type was not superior than the other—they were all different means to express scientific idea at a developing level.
**Level 4 (maturing).** At the maturing level, students’ comprehension, language complexity, and expression are significantly improved and have shown evidence of functional communication in science. A typical level 4 student could accurately understand the basic meanings of questions, primarily use sentences to respond, and show a variety of tier 2 and tier 3 academic vocabulary in their answers. The most distinguishing characteristic of this level was that the students can extensively use sentence structures to communicate in science. The sentences used could be simple, compound, and/or complex. Also, level 4 students might, but very rarely use body language to assist their idea expression. Almost a quarter of the pre-/post-interviews ($N = 24$) were graded as level 4 for ALP.

**Response with simple/compound sentences and rich academic vocabulary.**

Compare to the previous level, students at the maturing level used more sentences in their answers, and their use of academic words was more extensive and proficient. Although these sentences often contained grammatical errors, they were adequate to express scientific ideas that students had. The most common type of responses at this level was using simple (e.g., table is solid) and/or compound sentences (e.g., table is solid and water is liquid). These responses also contained more tier 2 and tier 3 academic words than the developing level.

*Example ALP4-1. Pre1 #11*

Q1: Tell me everything you know about matter.
D11: The matter is …mass and space, and everything…and nitrogen made of matter. Matter…the type of matter is pure substance and mixture. Mixture…[unidentified words]…and pure substance…[unidentified words].
Researcher: Ok. Can you tell me more?
D11: Matter is not energy?
Researcher: Ok.
Q2: Tell me everything you know about chemical reactions.
D11: Chemical reactions is like when the trees grow. The…chemical reactions is like…liquid because…[unidentified words]
Researcher: Anything else?
D11: Anything…chemical reaction can be…[smile]
Researcher: Ok.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D11: …Mendeleev is make the periodic table…is make this Mendeleev and this is to be chemicals and things like nitrogen, lithium…and three two chemicals together and give me water and together like H₂ hydrogen and O is H₂O is made water.
Researcher: Can you tell me more?
D11: This right here is the atomic number [point at the demonstration element box] and… [unidentified words]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D11: Like together? Yeah?
Researcher: Tell me about it.
D11: Someone can…sodium and…like sodium chloride when we do sodium plus chloride is going to be sodium chloride and [unidentified words]
Researcher: Can you tell me more?
D11: [point at the columns] This is period and [point at the rows] this is…
Researcher: Ok.

In this example, student D11 primarily used sentences in her responses. The majority of the sentences were simple or compound structures except for the first sentence in response to Q2 and the third sentence in response to Q4. The word use in these responses showed an expanded academic vocabulary. However, the syntax of the sentences contained obvious errors, which impacted the fluency and the expression of her scientific ideas.

**Response with extensive complex sentences.** Another type of response at the maturing level contained evidently more complex sentences using signal words (e.g., if…then…; …when…; …because…). These students might also have a rich academic vocabulary, but their most distinctive characteristic is being able to extensively use
complex sentences. The similarity between the two types of responses at this level was that students could use different sentence structure and academic words to express scientific ideas, but they still experienced obvious frustration doing so. For instance, students may not be able to use complete sentences all the time, or their language is clearly inadequate for their idea expression.

*Example ALP4-2. Pre1 #27*

Q1: Tell me everything you know about matter.
A15: Matter is everything that has mass in the universe. It’s three…states of matter…and it’s four…it’s liquid, solid, gas, and plasma. The state of solid is the…when the thing are like…the atom inside the state of solid are like together. The gas…the atom are separated and moving around. The state of liquid…they have a little bit more space than solid and a little bit less than gas. The atom in plasma…they are so crazy…they are…[wave hands].
Researcher: Can you tell me more about matter?
A15: Ok. [point at a picture of logs] This is matter. This is the state of solid; [point at a picture of lightening] this is too. So matter is solid, and it makes plasma. And this is…I think that [point at a picture of gas model] this is like liquid. The atoms are like space up…not too much as gas. This one [point at a picture of clouds] I think is gas because they are clouds and the atoms got too much space to move.

Q2: Tell me everything you know about chemical reactions.
A15: Chemical reactions…like when you put together two substance, then the chemical reaction will react. They can be together when I get that…about reaction. They get together and they will be stay like…woo…
Researcher: Can you tell me more about it?
A15: Chemical reaction…I don’t know any more.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A15: This one I know…I know this because Ms. Wilson got one of those things on the wall. I know those are the elements, the substance, elements…here are everything.
Researcher: Can you tell me more?
A15: The elements…they are here and they got like here’s how they…some…where they are, and then they got one number to be a group by 1, 2, 3…

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A15: Yes, because if they see the substances, maybe they can put that together to
have a good combination of substances.
Researcher: Can you tell me more?
A15: Ok…you may look this [point at the table], and they got these things [circle the words in each element box with a finger], everyone here…got these. They got a name, and also they got these numbers. They maybe tell you…if you put them together, they will make a good combination of substance.

Clearly, student A15 used more complex sentences than the student in the previous examples and also showed evidence of a rich academic vocabulary. However, A15 frequently demonstrated frustration when verbally expressing his ideas: he used body language twice as part of his response (e.g., when describing particles in plasma, he waved his hands to represent the intense movement); his responses contained many sentence fragments (e.g., the last sentence in the response to Q3), which were difficult to make sense of given the contexts.

**Summary.** At the maturing level, students were able to express their scientific ideas with primarily using sentences (may contain syntactical errors) and rich academic vocabulary. This ability significantly improved their language complexity and efficiency of idea expression. Compare to students at the previous level, these students generally provided more volume and more specific descriptions of chemistry concepts and ideas. The expressed ideas were not limited to concepts represented by available items on the table, but also abstract content knowledge. However, these students still had difficulties expressing all ideas they have. This frustration was infrequent but obvious when it existed.

**Level 5 (advanced).** At this last level, students’ comprehension, language complexity, and expression showed competency of expressing scientific ideas with academic language. Given that these students were still newcomers and were designated as beginners right before the semester started, this “competency” was still limited.
However, a typical advanced level student could quickly and accurately understand the questions, almost exclusively use sentences to respond with an extensive academic vocabulary, and provide accurate description and/or explanation of scientific concepts/ideas. In this study, only two students (2%) received a score of level 5, both at the post interviews.

*Example ALP5-I. Post #1*

Q1: Tell me everything you know about matter.
A12: Matter is almost everything in the universe, except electricity and energy because…matter is everything that has no movement. But like matter can be together with energy, like we are matter, we energy. That’s why we can…we can have movements or run or walk or talk… Matter can change, but cannot…we cannot destroy matter, but we cannot create matter, so matter is almost always…
Researcher: Can you tell me more?
A12: Yeah, matter can be solid, liquid or gas. Solid it’s something like this [knock the table]. Liquid is like the water. Gas like oxygen and air. I think that’s it.

Q2: Tell me everything you know about chemical reactions.
A12: Chemical reaction is…I don’t know so much about chemical reactions.
Researcher: That’s ok. Tell me everything you remember.
A12: Chemical reaction is produced with when two atoms or more atoms change…like protons or things [unidentified words]. We can [unidentified words] see chemical reaction.
Researcher: We can or we cannot?
A12: It’s different, sometimes we can, sometimes we cannot. Sometimes we need [unidentified words] we need to use some tool to see chemical reactions, but sometimes we cannot see chemical reactions.
Researcher: Can you tell me more?
A12: No.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A12: The periodic table is divided by groups and periods. We have seven periods and 18 groups. We can see like all of these [point at the transition elements] are [unidentified words]. And another five of metals [point at group 2 elements] and here another types of metal [point at the metal area on the right side]. Almost all the period table are metals. We have noble gasses [point at noble gasses]. We have non-metals [point at non-metals]. We can use these to make new substances, like chemical reactions.
Researcher: Anything else?
A12: No.
Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A12: Yes, we can. Because if we have like two elements, we can see they can make mass and the name and the atomic number. So we can know how many atoms have one substance and another. We can combine without see the substance.
Researcher: Can you tell me more about it?
A12: We can models of the…every element. We can do a Bohr model, like the equation, or…yes? That’s why we can…or we can put together…I don’t know…to make new substances.

In this example, student A12 provided explicit answers to all four questions. Her comprehension of questions was accurate and her ideas were clearly explained with verbal academic language. Actually, she used less complicated sentence structures than some of the level 4 students. However, her academic vocabulary was rich, and more importantly, the verbal expression of scientific ideas was smooth and well elaborated. She used some body language to support her statements, and sometimes she demonstrated subtle frustration while explaining (e.g., at the end of answering Q4), but these factors did not significantly impact the understandability of her responses.

**Summary.** At the advanced level, students showed the ability to efficiently and accurately communicate in science. One of the possible confusions between level 4 and level 5 students was that sometimes level 4 students showed a larger academic vocabulary and the use of more complicated sentence structures. However, the researcher argued that these characteristics may be crucial in the development of everyday language, but for the proficiency of academic language, the effectiveness and accuracy of communication in science were more important than merely knowing academic words and using complex sentence structures.

**CCK Levels**

The grading of overall CCK levels considered indicators in responses to questions
Level 1 (entering). At the entering level, students’ responses did not show any evidence of knowing and/or understanding the target topic of chemistry knowledge. A typical level 1 student might remain silent after being asked the questions, select/point at available items without explanation or with incorrect/insufficient explanation, or directly state that they did not know and answer. In the following sections, Q1 and its answers were italicized, meaning that they were not considered for grading CCK levels but for grading ALP levels. Over one-sixth of the pre-/post-interviews (N = 18) were graded as level 1 for CCK.

Example CCK1-1. Post #48 (ALP level 1)

Q1: Tell me everything you know about matter.
D01: [Point at the pictures on the table] These?
Researcher: Sure, you can use them.
D01: [Long pause] this [point at a picture of a battery]
Researcher: Can you tell me about it?
D01: [Silence]

Q2: Tell me everything you know about chemical reactions.
D01: [Point at a picture of the solid model]
Researcher: Can you tell me about it?
D01: [Silence]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D01: [Silence]
Researcher: Ok.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D01: [Silence]
Researcher: Ok.

In this example, student D01 remained silent for most of the time. She also pointed at one picture when answering Q2, but did not provide any explanation.
Therefore, she did not demonstrate any evidence of her content knowledge.

Example CCK1-2. Pre2 #13 (ALP level 2)

Q1: Tell me everything you know about matter.
C05: [point at a picture of liquid model] ...Solid.
Researcher: Can you tell me more?
C05: Gas...liquid. [Look at a picture of eggs] Eggs...[point at a picture of shells] This.

Q2. Tell me everything you know about chemical reactions.
C05: [point at a picture of bacteria] This.
Researcher: Ok. Can you tell me about it?
C05: [point at a picture of an molding orange]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C05: …[Long pause]
Researcher: Try your best.
C05: [point at one of the elements, unrecognizable from the recording]
Researcher: Can you tell me about it?
C05: [Silence]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C05: [Silence]

The response to Q1 showed the student’s basic knowledge about states of matter, a limited vocabulary, and the ability to connect the pictures of abstract models with the corresponding academic words. However, his responses to Q2-4 contained no evidence of knowing and/or understanding any content knowledge.

Example CCK1-3. Pre2 #15 (ALP 3)

Q1: Tell me everything you know about matter.
C08: Matter is everything something is matter. Matter have three...I don’t know what it is...like liquid, solid and gas. And... [point at the pictures] this?
Interviewer: Yes, you can use them if you want.
C08: [Point at a picture of lightening] this is not matter because it is energy. And [point at a picture of logs] this is matter...The tree is matter. Egg is matter.
Interviewer: Can you tell me more?
C08: Yes... and [point at a picture of clouds and picture of bacteria] this and this is not matter because this is energy is not give matter energy.
Q2: Tell me everything you know about chemical reactions.
C08: Chemical reactions…like [murmur]
Interviewer: Can you tell me more?
C08: Chemical reaction…I don’t know.
Interviewer: That’s totally ok.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C08: About …
Interviewer: The periodic table.
C08: [shake head]
Interviewer: Do you want to try it?
C08: I don’t know.

Q4: Can someone use the periodic table to predict the combination of substances?
Tell me about it.
C08: Use it as…
Interviewer: Use it to predict the combination of substance.
C08: I don’t know.
Interviewer: That’s ok.

Similar to the previous example, student C08 showed basic knowledge about matter in answering Q1. However, she could not provide any more information when answering Q2-4 except for repeating part of the questions. Therefore, the evidence that C08 did not possess knowledge of the target content was obvious.

Summary. Overall, the entering level students did not show any evidence of possessing the target content knowledge. The verbal responses might contain more information when they discussing familiar topics (e.g., Q1), depending on the individual’s language proficiency. However, students who were at CCK entering level generally did not have any knowledge or skills about the target content knowledge.

Level 2 (emerging). At the emerging level, students showed evidence of isolated content knowledge about the target topics. This kind of knowledge often appeared in the form of names of single concepts or vague descriptions of a scientific idea, depending on the language proficiencies of the students. Almost half of the pre-/post-interviews ($N =$
48) were graded as level 2 for CCK.

**Response in ALP level 2.** Since the main characteristic of ALP level 2 was the use of isolated academic words/phrases without sentence structures, the content knowledge expressed by this type of language was extremely limited. Some students used body language to assist communication; others tried to spout out as many words as possible to convey some meanings.

*Example CCK2-1. Pre1 #37*

Q1: *Tell me everything you know about matter.*
C04: *The matter is...I don’t know...is...*
Researcher: *Try your best. Tell me as much as you can.*
C04: *[Silence]*

Q2: Tell me everything you know about chemical reactions.
C04: *[Point at a picture of a moldy orange] Two elements [put hands together] some chemical...for example...the...this...*
Researcher: *Can you tell me more?*
C04: *[Silence]*

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C04: *[Long pause] No, I don’t understand.*

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C04: *I don’t know...[Point at some elements on the table, murmur]*

In this example, the only meaningful information in response to Q2 was the phrase “two elements” with a gesture of putting hands together, which implied “combines”. Although the verbal language was minimum, the combination of verbal and body language expressed a clear example of chemical reactions.

*Example CCK2-2. Pre2 #05*

Q1: *Tell me everything you know about matter.*
A06: *This is something?*
Researcher: *[Repeat the question]*
A06: *[unidentified words]*
Researcher: Can you tell me more?
A06: I don’t know.

Q2: Tell me everything you know about chemical reactions.
A06: [Silence]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A06: I don’t understand the question.
Researcher: [Repeat the question]
A06: I don’t understand.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A06: [point at the periodic table] carbon?
Researcher: Ok. Anything else?
A06: Oxygen? … Hydrogen?
Researcher: That’s everything I want to ask you.

In this example, student A06 clearly had significant difficulties in understanding the interview questions. Also, no evidence showed that her response to Q4 was based on accurate comprehension of the question. However, being able to name three elements from the periodic table (even if she was reading them off) indicated some minimum level of content knowledge. An opposite example would be reading off the symbols of elements (e.g., C, O, H, etc.), which showed lack of basic knowledge about the periodic table.

Response in ALP level 3. Student at ALP level 3 could use a combination of academic words, phrases and sentences to communicate in science. Therefore, these students were able to superficially describe a concept or idea instead of just naming it.

Example CCK2-3. Post #4

Q1: Tell me everything you know about matter.
B18: Matter?
Researcher: Yes.
B18: Matter is everything, includes everything.
Researcher: Can you tell me more?
B18: No. I don’t know.
Q2: Tell me everything you know about chemical reactions.
B18: Chemical reactions? Chemical reaction is what we are talking right now. For example, I don’t know.
Researcher: Just everything you can remember now.
B18: Chemical reaction is…I don’t know.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
B18: I know?
Researcher: [Repeat the question]
B18: Carbon…I know hydrogen, magnesium. Hydrogen has only one atoms…yeah, one…it has one atom. And magnesium has two. And…carbon has 6?
Researcher: You mean 6 what?
B18: Atoms. That’s all.

A4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
B18: Yes.
Researcher: Can you tell me about it?
B18: When you add…I don’t know.
Researcher: Try your best. You said yes, why?
B18: Because [unidentified words] use [unidentified words] …to product something?
Researcher: Can you tell me a little more please?
B18: No, that’s all.

Similar to A06, student B18 named a few elements from the periodic table. The difference was that B18 could also convey the idea that hydrogen has one atom [electron] and magnesium has two atoms [outermost electrons]. The misusage of academic words (i.e., atoms vs. electrons) and the vague description (i.e., total electrons vs. outermost electrons) indicated inadequate content knowledge. In addition, no more evidence of knowing and understanding content knowledge was shown in this response.

Example CCK2-4. Pre1 #32

Q1: Tell me everything you know about matter.
B03: Everything. Everything is matter. The table is matter. Is everything that take up space in the universe.
Researcher: Can you tell me more?
B03: More? [Point at a picture out of the camera sight] It’s no matter, its energy.
It's matter. It's energy. And the matter is...they are three types of matter solid, liquid and gas. These are the molecules...this is solid [point at a picture of the solid model]; this is liquid [point at a picture of the liquid model], and gas [point at a picture of the gas model].

Q2: Tell me everything you know about chemical reactions.
B03: [Unidentified words] Maybe it's a reaction [point at a picture of fire]
Researcher: Can you tell me more?
B03: I don’t know.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
B03: The periodic table has elements...are all elements.
Researcher: Can you tell me more about it?
B03: With these elements, you can make compounds.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
B03: Combination.
Researcher: Can you tell me more?
B03: Oxygen [unidentified words]...hydrogen? Hydrogen is water. [Point at O and then H on the periodic table] is water. I don’t know more.

Apparently, student B03 had a more extended academic vocabulary than his previous CCK level 2 peers. However, B03’s content knowledge shown in responses 2-4 was not evidently superior to others. The scientific ideas expressed in this example included that the periodic table is a collection of all elements, which can be used to make compounds, and that water is a combination of hydrogen and oxygen. However, his expression contained some inconsistency. For example, when he stated: “hydrogen is water,” he pointed at both hydrogen and oxygen on the periodic table. This inaccuracy impacted his expression in science.

*Response in ALP level 4.* Student at ALP level 4 could primarily use sentences to communicate in science. Interestingly, the more proficient a student’s academic language was, the more obvious the insufficiency of the content knowledge was at this level. The proficiency of language was like a microscope that can exaggerate problems of students’
content knowledge.

Example CCK2-5. Pre1 #25

Q1: Tell me everything you know about matter.
A12: Matter is everything in the universe take like space, because if we say the matter is everything it's a mistake because energy is not matter. Matter is like...we are matter...everything [point at the pictures on the table]...almost everything here are matter except for the things that have energy or is like...
Researcher: Can you tell me more?
A12: Matter can be divided two groups...pure substance and mixtures. Pure substance are...matter cannot be divided by physical means, because pure substance can be divided by chemical means...almost pure substance because pure substance are divided into types of pure substance—elements and compounds. Element is...pure substance cannot divided by physical or chemical means, because it's an element and elements cannot be broken. So...The other type of pure substance is compounds. A compound is like...[draw]...here we have this element, we can put this and here we have water. This is a compound, and this is only an element. The mixture can be divided into homogenous and heterogeneous mixtures. Homogenous mixture is like checkup or like something that we cannot see the elements and compound in the mixture...but like salad or something that could be...we can see the compounds of these, like food or...something like this is heterogeneous mixture.

Q2: Tell me everything you know about chemical reactions.
A12: Chemical...I think we can do a chemical reaction when we do a mixture. I don't know too much about this.
Researcher: That's ok. Just tell me everything you know right now.
A12: I think...I can't explain...
Researcher: That’s totally ok.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A12: The periodic table is something in the past. We only have 5 elements: water, fire...I don’t know in English...
Researcher: That’s ok.
A12: Well...In the past we only have a few elements. When the time is...when the technology is advanced, and all of these things we could be a...of this table, like...An element could be the name that who invited...who found it. Some elements are not in the Earth, like natural. But in the laboratory, we not, but the scientists could be do the elements.
Researcher: Ok. Can you tell me more?
A12: No.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A12: Yes.
Researcher: Tell me about it.
A12: Because…here we have…it’s…like [draw] we could do this elements, like this…with orbit. If we have two hydrogen, we could have this…So when we put two together, are like this…and we have two together.
Researcher: Can you tell me more about this question?
A12: No.

In this example, student A12 showed a significantly more extensive academic vocabulary than students in the previous examples, especially in answering Q1. However, her responses to Q2-4 were somewhat off the topic and merely conveyed a scientific idea: the periodic table contains elements. The other possible idea was that two hydrogen [atoms] can be put together. But A12 did not explain whether the two hydrogen particles were “together without any connections” or “together as a molecule.”

**Summary.** Students at the emerging level of CCK had various levels of academic language proficiency. Therefore, these students’ responses to the same question might seem significantly different, considering the volume and academic vocabulary. However, CCK levels only concerned students’ content knowledge, so any responses that conveyed minimum content knowledge (e.g., name a scientific concept or superficially and vaguely describe an idea) were designated as level 2, regardless of the proficiency levels of their academic language.

**Level 3 (developing).** At the developing level, students showed evidence of possessing more content knowledge. Although these students might recognize some patterns of scientific concepts/phenomenon, they might not be able to explicitly describe them. Some of them could provide examples as explanations, but those examples may contain errors (e.g., related but not directly related to the concepts). In addition, the responses at this level often appeared to be chaotic and sometimes inconsistent (e.g., the answer to Q3 is contradictory to the answer to Q4). Almost a quarter of the pre-/post-
interviews \((N = 24)\) were graded as level 3 for CCK.

**Response in ALP level 3.** Students at ALP level 3 started to use sentences to express their scientific ideas. At level 3 of CCK, these students could use the sentence structures to describe connections between concepts and/or ideas. Isolated academic words and/or phrases were still used when students were not able to elaborate the knowledge with sentences.

*Example CCK3-1. Post #14*

**Q1:** Tell me everything you know about matter.  
A14: [Long pause] I don’t understand this question.  
Researcher: [Repeat the question]  
A14: [Silence]

Q2: Tell me everything you know about chemical reactions.  
A14: Chemical reaction…one *substance* change like new *substance*…the new *substance* is [unidentified words]  
Researcher: Ok. Can you tell me more about it?  
A14: This [point at a picture of fire] is chemical reaction [unidentified words].  
This [point at a picture of coke] is water cold [unidentified words]  
Researcher: Ok. Anything else?  
A14: This [point at a picture of a moldy orange] change the color and *odor*.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]  
A14: This…label…[unidentified words] one *atom* [point at the first column/group], two, three, four, five, six, seven, eight is like [unidentified words]…this is a…seven, six, five, four, three, two… nine *elements* [unidentified words].  
Researcher: Number nine is different from others or everyone is different?  
A14: For the seventeen [unidentified words] The nine, ten, eleven the other…  
Researcher: Anything else?  
A14: [Silence]

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.  
A14: The combination of substances, one, seven…because one and eight don’t…one and seven, two and six, three and five, number twelve…  
Researcher: Can you tell me more about it?  
A14: Because number 8 [unidentified words].  
Researcher: Anything else?
A14: No.

In this example, A14 showed signs of extensive knowledge about the chemical reactions and the periodic table, but he was often frustrated from explicitly expressing it. For example, in the response to Q3, A14 implied that each element in group 1 contains one outermost electron, each element in group 2 contains two outermost electrons, …each element in group 18 contains 8 outermost electrons, respectively (he used “atom” to represent “electrons” or “outermost electrons”). However, this interpretation heavily relies on the listeners’ inferences. Similarly, in his response to Q4, A14 listed different ways of making eight. It was likely that he meant that the outermost layer of elements only contains a maximum of eight electrons, so knowing the amount of outermost electrons of each element/group of elements can predict the combination of substances. Although this interpretation was compatible given the context of the question, it required much inference. The only obvious evidence of his content knowledge was his descriptions about chemical reactions producing new substance (Q2) and the periodic table containing elements (Q3).

Example CCK3-2. Pre2 #07

Q1: Tell me everything you know about matter.
A10: I think matter is take a space…matter is three states, liquid, solid and gas.
Researcher: Can you tell me more about it?
A10: [Shake head]

Q2: Tell me everything you know about chemical reactions.
A10: Chemical reaction? I think chemical reaction is changing to new substance.
Researcher: Can you tell me more about it?
A10: I’m not sure…[unidentified words]

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A10: [Unidentified words] This…they have like group, matter…
Researcher: That’s ok. Just tell me everything you know right now.
A10: I know carbon, oxygen…sodium, hydrogen……[start reading off the table}
Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A10: Yes.
Researcher: Can you tell me about it?
A10: Because the answer is here [point at the periodic table]. When we…something…we can look here, sodium…something about [unidentified words]. The periodic table…
Researcher: Anything else you want to tell me about it?
A10: Table has different groups, so we can look from different color to see what’s this and what’s this. That’s all.

Similar to the previous student, A10 also described the products of chemical reactions as “new substance” and described the classifications of the periodic table as “different groups” (e.g., metals, non-metals etc.). However, A10’s responses were simpler and more straightforward than A14’s. At the end of her response to Q3, she listed some elements that she knew from the periodic table, which was a typical CCK level 2 response. However, her overall performance matched the criteria of CCK level 3.

**Response in ALP level 4.** Because ALP level 4 students could primarily use sentences to express their scientific ideas, their responses were often more explicit than their ALP level 3 peers. However, this language proficiency did not guarantee a higher content knowledge level. In contrast, it more easily exposed students’ misconceptions and/or lack of knowledge.

*Example CCK3-3. Post #09*

Q1: Tell me everything you know about matter.
D10: Ok. Matter is like material, for example, wood, wool, something for make one tape? For example, the wood [select a picture of logs]… The fire [select a picture of fire] can use like matter. I don’t know how…I don’t know.
Researcher: Try your best. Can you tell me more?
D10: Ok. I’m not sure but I think matter is no energy. But the energy can…are…can… [unidentified words]. That’s it.

Q2: Tell me everything you know about chemical reactions.
D10: I think a chemical reaction is a reaction. I know how it [unidentified words].
Ok…you can use one experiment but in the experiment it’s important you can [unidentified words] or… For example…use one boat. This boat…for example coke, [unidentified words all the water and combine]. You can go back and combine, separate. You can make a chemical reaction…here… Here you could [unidentified words] substance and put other material. The material separate. You can put different color and [unidentified words]

Researcher: Can you tell me more about chemical reactions?
D10: That’s it.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D10: I know the period table have materials, like here, metals, metalloids, and non-metals [point at the legend on the periodic table]. The metals can…in the left side, the metalloids in the right side…no…metals in the right side, metalloids in the middle. Metalloids in [unidentified words] don’t have non-metals and have metals…and…I’m not sure, but is one two three [point at H, He, and Li]. The periodic table, like one, two, three like this.
Researcher: Can you tell me more?
D10: No.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D10: Yes, in…sometimes, somethings substance can combine, others no…one substance impossible combine.
Researcher: Can you tell me more about that?
D10: For example, you can combine… The chemical and liquid can combine.

The volume of this example was larger than many of the examples shown previously. However, the evidence of D10’s concrete content knowledge was difficult to capture from these answers. The response to Q2 mainly stated that chemical reactions involve “material” combination and separation, without providing further explanations. The response to Q3 showed that D10 recognized a pattern of the periodic table (i.e., matter can be metals, metalloids, or non-metals). But he quickly confused himself when trying to indicate the location of each type of matter on the periodic table. The response to Q4 was difficult to make sense in the context of the question.

Summary. In the present study, students at the developing level of CCK were either at ALP level 3 or ALP level 4. This variety of language proficiency might
negatively or positively influence their expression of content knowledge. For example, since the level 3 ALP students generally used a combination of words, phrases and sentences in verbal communication, they were not able to thoroughly describe some of the complicated scientific ideas. Generally speaking, the content knowledge at the developing level was no longer in the form of isolated concepts, but of groups of concepts and/or scientific ideas with a basic coherence. However, this kind of knowledge was still significantly limited. Also, misconceptions and inconsistencies commonly existed.

**Level 4 (maturing).** At the maturing level, students’ content knowledge was significantly more extensive and accurate. These students started to understand the connections between content knowledge, such as recognizing a group of concepts/ideas instead of isolated ones. However, this connection was often weak and contains misconceptions. Lapses and gaps of knowledge were also occasionally found in level 4 responses. One-tenth of the pre-/post-interviews ($N = 10$) were graded as level 4 for CCK.

**Response in ALP level 3.** There was only one student (C03) at ALP level 3 who was graded as CCK level 4. Although he was not a typical example, his responses might shed light on the understanding of relationships between academic language and content knowledge. Therefore, instead of a general description about all students at these levels, this section discussed the specific case of student C03.

C03 was one of the most enthusiastic boys in the class. He was very interested in learning science, engaged in all activities, and even asked Ms. Wilson if he could talk to the researcher again the next day after his interview. Since his responses, especially the
one for Q1, were extremely long, the example below only shows a part of the transcription. In the part that is not shown here, C03 talked about quantum physics, biology, geology, astronomy and etc., which were irrelevant topics to the questions.

Example CCK4-1. Pre1 #09

Q1: Tell me everything you know about matter.
C03: The matter is [select a picture of lightening and picture of bacteria] together, space...space and one space and matter is the energy...energy is different because the atoms also the energy can separate...and the separate is the...atoms is the gas or one [unidentified words] because the atoms separate [unidentified words] the one atoms separate [unidentified words] because...and the matter is [select a picture of battery] the two poles, pole positive and pole negative, in the positive pass the energy and...positive together and negative...positive and negative is one...negative and negative reaches and positive and positive [unidentified words]. And...Matter can be changed by physical means and...chemical means... Two changes because it's the two types of the matter, and the mixture and pure substance. The pure substance is the two types, elements and compounds. The elements is the aluminum, gold, silver...the mixture is the water; the salt... The elements...because the [unidentified words] of...carbon is the [unidentified words] and together not is the solid [point at the solid model]. Mixture is the heterogeneous and homogeneous. Heterogeneous is the [unidentified words] of the [unidentified words], is the water the [unidentified words] is the homogeneous is equal and together parts. In heterogeneous is the...is one salt and the...is...
[Keep talking for 30 minutes]

Q2: Tell me everything you know about chemical reactions.
C03: The chemical reaction is the physical...physical reaction is the...separate homogeneous and heterogeneous mixture. The chemical reaction is the separate of the metal...separate the trash or the fruit loop...and difference, this is one display...in the world...separate the matter and plastic. The matter is the...one sample is the food [select a fork]...and two the plastic is ruler [select a plastic ruler] it's different because the form of the particle in the elements...and physical...the chemical means is the separate the water these...H2O...H2O is the different...is the...H is hydrogen...and two...is make this compound [start writing/drawing]...is hydrogen and oxygen. It's separate by chemical means.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C03: This is the element...the family that helium [point at group 18], the family of fluorine [point at group 17], the family of oxygen [point at group 16], the family of nitrogen [point at group 15], carbon [group 14], boron [group 13], ...the family. This is metal...
Interviewer: Think about it and tell me more tomorrow [class dismissed].

[The next day]
C03: Groups… the elements… no, this is the group… yes, the different groups of elements. The example is… metals, this is here [point at group 1], [start reading off the table]… this is the groups of metals [point at the left side of the table] groups of metal… different metals and the… is different than this… this [point at the orange area] is the metal… maybe… maybe metals, maybe non-metals… metalloids! And the non-metals is the carbon… [start reading the green area on the table]. This is the groups [point at group 18] is no… no… no [unidentified words] the elements too [unidentified words] parts of the… when… [unidentified words] is the electron [unidentified words] the [lots of unidentified words]… is the compound.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C03: The combination is the fluorine and… this part and this part [point at group 17] the part [point at group 1] is the [unidentified words]… the part is the family [point at the bottom two rows on the table] this family is different and this and… the here and here… [unidentified words] and because is [unidentified words] for the science and is difficult in search and the work. And the [unidentified words] is the no combine, because this is the no [unidentified words] and the different elements. Hydrogen [point at H] is this part… because hydrogen is the [unidentified words].

Since C03 was a unique example, both his ALP and CCK levels are discussed here. Apparently, C03’s responses showed a significantly extended academic vocabulary compared to his peers, and his comprehension of questions was quick and accurate.

However, he barely used any complete sentence structures and his expression was difficult to understand. For example, when answering Q4, he stated “The combination is the fluorine and… this part and this part [point at group 17] the part [point at group 1] is the [unidentified words]…” C03 might intend to say that using the periodic table, someone can predict the combination of substances by looking at the elements’ families/groups, such as elements from group 17 can combine with elements from group 1. However, this interpretation was based on the researchers’ assumption. The only direct evidence of knowledge in this response was that C03 knew the element of Fluorine. After balancing the indicators, the researchers decided to grade his ALP as level 3.
As an ALP level 3 student, C03 did a good job of describing scientific concepts. He used multiple ways to convey meanings, including words, phrases, simple sentences, and body language. In the answer to Q2 (the last sentence), C03 described separating the compound water (molecules) into hydrogen and oxygen (atoms). This made him the only student using decomposition as an example of chemical reactions, while others all used composition as examples. In the answer to Q3, he described elements’ families/groups, as well as classification of elements, such as metal, non-metal, and metalloids. He mentioned electrons when describing noble gasses (group 18), but the specific meaning of that “sentence” is difficult to capture. In the answer to Q4, as previously discussed, he might have suggested predicting substance’s combination by looking at elements’ groups, but this interpretation was only weakly supported by the transcription. Overall, C03’s responses showed evidence of possessing extensive amount of content knowledge and recognizing connections among different concepts. Therefore, he received level 4 as his CCK grade.

**Response in ALP level 4.** Students at ALP level 4 generally had more access to academic language, and were often more capable in describing scientific concepts and ideas than the lower ALP level students. They started to use complex sentences (e.g., …because…) to convey ideas, so relationships between concepts were easier to be explicitly expressed.

*Example CCK4-2. Post #33*

*Q1: Tell me everything you know about matter.*  
*A16: Matter is everything that takes up space, like this is matter [point at a picture of logs], because it takes space and it has weight. And like the ball [point at a picture of a soccer ball] is matter because [unidentified words] it takes space. That’s it.*  
*Researcher: Can you tell me more?*
A16: Like this picture [point at a picture of a flower and a bee] has different type of matter because this is a flower and a animal, is different type of matter, but both matter.

Q2: Tell me everything you know about chemical reactions.
A16: Chemical reactions are…if you mix solutions and you can get another thing, it would be different, different mix. I don’t know.
Researcher: Can you give me an example?
A16: If you mix like a water with gas, you can get soda…something like that.
Researcher: So that’s a chemical reaction?
A16: Yes.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
A16: The periodic table has elements and they are different. They are divided in groups.
Researcher: Can you show me?
A16: This is group one, group two, group three [point at the first three columns on the left]. these are the periods [point at the rows]. They are divided by metals, non-metal, noble gasses [point the noble gasses]…they have eight…eight something…these are not mixed because they have eight something…I don’t remember the name…atoms? These can be bonded because these only have one, these two, these have three [point at the first three columns] because the group tells you how many have, that is why these cannot be bond [point at the noble gases], so this one [group 1] can be bond with this one [group 17] because this one has seven [group 17] and this one has one [group 1].
Researcher: Can you tell me more about it?
A16: No.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
A16: Yes.
Researcher: Can you tell me about it?
A16: Here the metals [point at the red area]. If this one is 21, you can put the 22, if you don’t have it. Because if you have 21 and 23, you can put the balance.

In this example, student A16 showed evidence of knowing the arrangement of the periodic table (groups), classification of elements (metals, non-metals, noble gasses).

Similar to the previous student, A16 also mentioned combining elements from group 17 and elements from group 1, but she provided a much clearer description. For example, she said that the noble gasses have “eight something” so they cannot be “mixed.” Although she incorrectly used the academic words—the “eight something” should be
eight outermost electrons instead of atoms, and “mixed” should be “combined”—she still presented the basic relationship between having the electrons and the ability of combing with other elements. However, the response to Q3 still showed gaps in her understanding of the elements’ classification (i.e., “metal, non-metal and metalloids” would be more comprehensive than “metal, non-metal, and noble gasses). Also, her response to Q2 was not completely accurate: gas (e.g., CO₂) mixed (dissolve) with liquid (e.g., coke) is theoretically not a chemical reaction. A more accurate explanation could be that CO₂ dissolves in the coke due to the increase of solubility under high pressure, which is also why the bubbles and gasses quickly release when a coke can or bottle is opened.

*Example CCK4-3. Post #11*

**Q1:** Tell me everything you know about matter.

A15: Matter is almost everything in the world but no energy, just light and something there...matter is just liquid, solid and gas, also plasma [unidentified words]. Almost everything is... matter...matter...is three states, liquid, solid, gas and plasma. The particles, when that, they are like separate they are not together, and solid, they are together and no space to move, and liquid...a lot of...I mean some space but not too [put hands together and then spread them]

*Interviewer: Can you tell me more?*

A15: No, I forget it.

**Q2:** Tell me everything you know about chemical reactions.

A15: We have started chemical reactions. Chemical reaction are...like when the substance change to a new substance, make a new substance. It’s not chemical reaction is not physical. Because physical could be color and shape...chemical create a new substance.

*Interviewer: Can you tell me more?*

A15: No.

**Q3:** Tell me everything you know about the periodic table. [Show a periodic table to the student]

A15: Periodic table...I don’t know a lot about this. I know about metals, non-metals.

*Interviewer: Can you show me?*

A15: Metals is from here [point at group 2] to here [point at group 12]. Non-metals [point at metalloids/the orange area]...noble gases [point at noble gases/group 18], right? I forgot what was these, non-metals? [point at metalloids
Interviewer: Sorry I cannot tell you. I’ll tell you after the interview.
A15: Ok. I thought this is metals [point at the left of the periodic table], non-
metals [point at metalloids], and noble gases [point at noble gases/group 18]. And
this is called period [point at the columns] and this is a group [point at the rows].
And there are seven groups. Every element has an atomic number, the symbol, the
name, the average atomic mass, I don’t know about this [point at the last line of
the key element]
Interviewer: Can you tell me more?
A15: No.

Q4: Can someone use the periodic table to predict the combination of substances?
Tell me about it.
A15: The combination?
Interviewer: [Repeat the question]
A15: Yes, I think you can see how atomic mass and you can see the other atomic
mass and kinda of put them together and predict for new substances is that the
atomic mass is like not the same, like there not something between those.
Interviewer: Can you tell me more?
A15: That’s it.

Similar to the previous example, A15 described the classification of elements as
metals, non-metals, and noble gases, as well as the periods and groups (incorrectly
showed them on the periodic table though). He also described the components of each
element (atomic number, symbol, name, and average atomic mass). His response to Q2
was simple but contained the most distinctive characteristics of chemical reactions. His
last response possibly contained miscomprehension of the question: instead of predicting
“the combination of substances,” A15 focused on predicting “substances.”

**Response in ALP level 5.** Students at ALP level 5 were generally competent with
using academic language to convey scientific ideas. Compare to students at ALP level 4,
the level 5 students’ academic word use, descriptions of concepts, and explanations of
ideas were more precise and accurate. Only two interviews were graded as ALP level 5.
One of them was discussed in the ALP section. In order to avoid repetition, following is
the second example.
Example CCK4-4. Post #20

Q1: Tell me everything you know about matter.
D16: Matter is all is made up substance in the world, well... in the universe, that means that about the state of matter, physical properties, chemical changes, or physical changes. I think that’s it.

Interviewer: Can you explain more about each of the things you just told me.
D16: The states of matter are liquids, solids or gases. It’s a change that it provoke molecules and atoms... particles. And the chemical change provoke new substance, and the liquid is this one [select a picture of liquid model] this one is gas [select a picture of the gas model], and this is solid [select a picture of the solid model].

Interviewer: Anything else about matter?
D16: No.

Q2: Tell me everything you know about chemical reactions.
D16: Chemical reactions we can see how the color change, or the [unidentified words], maybe... the color. This may... that means it [unidentified words] chemical reactions, that it means when one substance and another substance come together and form a new substance.

Interviewer: Can you tell me more about it?
D16: No.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
D16: The periodic table has groups and the... groups and the... I don’t remember. But... I’m not sure there is a particle [unidentified words]. The elements are all elements we can see in the world. They have a symbol, each element has a symbol, that means they are... they have the atom... the atomic mass, atomic number, and... in the periodic table we can see the protons, the neutrons, and electrons.

Interviewer: Can you tell me more about it?
D16: In the periodic table, we can see the non-metals, metals, metalloids, and the metals. We can see if it’s a gas or no gas. In the periodic table, if for example, the gas is oxygen, that means all this section [point at the non-metals/the green are] is about the gases. It’s about the section for the colors.

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
D16: Yes. We can use the periodic table to combine the substance and put them together to provoke a chemical change or physical change. For example, when we do... for example, H₂O has the oxygen and hydrogen [point at O and H]. When we put them together, we provoke a new substance, that means a water.

Interviewer: Can you tell me more?
D16: No, that’s all.

In this example, student D16 indicated that chemical reactions involve producing
new substance; the periodic table is arranged in groups; for each element, the periodic
table shows the symbol, atomic mass, atomic number, and the amounts of protons,
neutrons, and electrons; the classification of the periodic table include metals, non-
metals, and metalloids. In the end, D16 used oxygen and hydrogen as an example to
explain the combination of substances. Although most of these scientific concepts/ideas
were explicitly and accurately presented, some of her responses were vague and
contained errors. For example, in the response to Q2, D16 mentioned “the elements are
all elements we can see in the world,” which was unclear about the meaning of “see”—
whether it meant being visible by humans’ naked eyes, or being discovered already.

**Summary.** Overall, students at CCK level 4 showed significantly more extensive
content knowledge. Their description and/or explanation were often more detailed, to the
point, and coherent. Miscomprehension, misconceptions, and inaccurate use of academic
words still exited, but these errors were subtle and did not impact the big scientific ideas.

**Level 5 (advanced).** At the advanced level, students’ content knowledge was
beyond simply describing concepts/ideas. They could explicitly provide rationales to
support their statements. The responses were often coherent and accurate without obvious
misconceptions. Two percent of the pre-/post-interviews (N = 2) were graded as level 5
for CCK, and both of them were at level 4 of ALP. Since the characteristics of CCK in
these two interviews were similar, only one of them is presented in this section.

*Example CCK5-1. Post #31*

*Q1: Tell me everything you know about matter.*

*C10: Matter is everything. Matter made of atoms and matter is three states, solid, liquid and gas. Matter has two part, pure substance and mixture. When…we cannot see the atoms matter and energy is not matter. We are [unidentified words]*

*Researcher: Can you tell me more about it?*

*C10: I don’t remember…*
Q2: Tell me everything you know about chemical reactions.
C10: Chemical reaction is equation reaction. Chemical reaction is a part of change. Chemical reaction can’t reverse like before….And chemical reaction when making new substance.
Researcher: Anything else about chemical reactions?
C10: No.

Q3: Tell me everything you know about the periodic table. [Show a periodic table to the student]
C10: The periodic table is…element…and [unidentified words]. Mendeleev made the periodic table. The periodic table was element of matters. [Unidentified words] And the periodic table… This side [point at the left side] of the periodic table is metals. And this side [point the right side] is non-metals. And between metal and non-metals are…the periodic table has atomic number that’s the same the protons and has eight groups. The groups are like this [point at the columns] and periods are like this [point at rows]. Each number of groups has the same number of electrons. Like hydrogen has one [unidentified words]. Hydrogen is [unidentified words].
Researcher: Can you tell me more?
C10: The periodic table has also symbol of elements and number of electrons. The metals are shiny and non-metals…

Q4: Can someone use the periodic table to predict the combination of substances? Tell me about it.
C10: Yes, because when we take this together [point at the table] we can make the new substance and we can complete and balance of electrons of the elements.
Researcher: Can you tell me more?

Student C10’s responses were similar to those of level 4 students with respect to the amount of content presented and coherence. The major difference was that student C10 more extensively explained concepts/ideas from a microscopic perspective. For example, in addition to describing groups of the periodic table, she also said “each number of groups has the same number of [outermost] electrons.” This piece of knowledge bridged the idea of being in a certain group/having a certain amount of outermost electrons and the ability to combine with other elements. Moreover, C10’s responses were clear and did not contain any obvious errors.
Summary. Overall, students at CCK level 5 showed more in-depth, coherent, and accurate content knowledge. Besides simply describing and/or explaining scientific concepts/ideas, these students could also provide rationales behind them. Very subtle misconceptions and/or misusage of the academic words might occur sometimes, but were very rare and insignificant.
CHAPTER V. QUANTITATIVE RESULTS

Overview

The previous chapter presented details of participants’ academic language proficiency (ALP) and chemistry content knowledge (CCK) levels. This chapter answered the quantitative research questions:

Primary: What is the relationship between ALP and CCK levels of newcomer ELLs? How does this relationship change over a four-month period of time?

Secondary: What are the effects of age, gender, and/or prior schooling experience on newcomer ELLs’ academic language proficiency and/or chemistry content knowledge?

In order to answer these questions, this chapter presented the quantitative results in three sections. The first section provided results from descriptive analyses of participants’ age, gender, prior schooling experience, as well as their ALP levels, CCK levels and academic word counts. As previously stated, word usage is a crucial component for beginner ELLs language development, so academic words used during interviews (unique and total) were also counted during grading. This section also presented the additional tests that indicate the magnitude of relationships between ALP levels and academic word counts.

The second section showed results from the Kruskal-Wallis tests to answer the secondary research question. Because the answer to the secondary question could potentially affect the answer to the primary question, these two research questions were answered reversely. For example, if the Kruskal-Wallis tests indicated a significant difference of ALP levels between male and female students, gender would be considered
as a covariate

The third section presented results from Spearman’s rank-order correlation tests that indicated strength of relationships between students’ ALP and CCK levels, and results from Friedman’s tests that indicated the change of this relationship over a four-month period of time. This last section answered the primary research question.

Descriptive Analysis

Chapter III described demographic information of participants, such as countries of origin and first language. Since gender, age and prior schooling were independent variables of the present study, this chapter provided their descriptive analysis again. Table 5.1 shows the mean, median, and standard deviation of each variable, as well as the frequency and percentage of each sub-scale within the variables. Particularly, the frequencies of academic word counts (FAW) and total academic word (TAW) are presented in ranges (e.g., 0 words, 0-5 words…>40 words).

Table 5.1

Results from Descriptive Analysis of Participants’ Gender, Age, Prior Schooling Experiences, ALP and CCK Levels at Pre-, Mid-, and Post-interviews, and FAW and TAW.

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The pie charts in Figure 5.1 show participants’ demographic characteristics with respect to gender, age and prior schooling experience. Among 51 participants, the gender distribution was roughly even with 26 males (51%) and 25 females (49%). The ages ranged from 14 to 19 years, with an average age of 15.65 years (\(SD = 1.20\)). The participants’ prior schooling experience ranged from six to 13, with an average schooling of 9.78 years (\(SD = 1.59\)).
Figure 5.1. Distributions of Participants’ Demographic Characteristics
Data for the dependent variables at the pre-interviews were shown in Figure 5.2. Ten participants (19.6%) were graded as ALP level 1; 14 of them (27.5%) were at ALP level 2; 19 students (37.3%) were at ALP level 3; 8 students (15.7%) were at ALP level 5; none of the participants were graded as ALP level 5 (Figure 5.2, the percentage is rounded up to whole numbers). For CCK levels, the numbers of students who received levels 1-4 are 14 (27.5%), 28 (54.9%), 8 (15.7%), and 1 (2.0%). Similar to ALP, none of the participants received a score of 5 for pre-interview CCK. The academic word counts were interval data ranged from 0 to $\infty$. In order to show the patterns more clearly, the FAW and the TAW were grouped and presented with ranges: 10 participants (19.6%) did not use any academic words; 15 students’ FAWs and 12 students’ TAWs (29.4% and 23.5%, respectively) were between one and five words; 12 students’ FAWs and nine students’ TAWs (23.3% and 17.6%, respectively) were between six and 10 words; 13 students (25.5%) and 10 students (19.6%) used 11-20 words as their FAWs and TAWs, respectively; one student (2.0%) and seven students (13.7%) used 21-40 words as their FAWs and TAWs, respectively; finally, three students (5.9%) used more than 40 academic words in total during the pre-interviews, but none of the students’ FAW reached this range.
Figure 5.2. Distributions of ALP, CCK, FAW, and TAW at the Pre-interviews
At the mid-interviews, only one interview question was used for assessing participants’ ALP. Therefore, the CCK levels and academic word counts were not included in data analysis. The number of students who received ALP levels 1, 2, 3 and 4 at mid-interviews were 10 (19.6%), 12 (23.6%), 19 (37.3%) and 10 (19.6%), respectively. None of the participants received a score of 5 for ALP (Figure 5.3).

Figure 5.3. Distributions of ALP levels at the Mid-interviews

At the post-interviews, more students achieved higher levels for both ALP and CCK. Also, more students had higher FAW and TAW (Figure 5.4). Specifically, the number of students who received ALP levels 1, 2, 3, 4, and 5 at post-interviews were 3 (5.9%), 15 (29.4%), 15 (29.4%), 16 (31.4%), and 2 (3.9%), respectively. The number of students who received CCK levels 1, 2, 3, 4, and 5 were 4 (7.8%), 20 (39.2%), 16, 9 (31.4%), and 2 (3.9%), respectively. For the FAW, three students did not use any academic words during the post-interviews; 12 students (23.5%) had FAWs between one and five words and another 12 students (23.5%)’ FAWs were between six and 10 words; 18 students (35.3%)’s FAWs were between 11 and 20 words; six students (11.8%)’s FAWs were between 21 and 40 words; none of the students used more than 40 unique
academic words. For the TAW, the same three students (5.9%) had a TAW of 0 words; six students (11.8%) had TAWs between one and five words; 14 students (27.5%)’s TAWs were between six and 10 words; eight students (15.7%)’s TAWs ranged from 11 to 20; 15 students’ (29.4%) TAWs were between 21 and 40; finally, five students (9.8%) had TAWs over 40 words.
Figure 5.4. Distributions of ALP, CCK, FAW, and TAW at the Post-interviews
Additional tests were conducted in order to assess the relationships between the language variables, including ALP levels, FAW, and TAW at both pre- and post-interviews. Since ALP levels were ordinal data, and FAW and TAW were interval data, Spearman’s rank-order correlation tests were used to compare ALP levels and FAW/TAW, and Pearson’s correlation tests were used to compare FAW and TAW (Table 5.2). Results showed no significant FAW or TAW differences between ALP levels at pre-interviews. In other words, the FAW and TAW of students at high ALP levels were not significantly different from those at low ALP levels. However, significant positive correlations were found at the post-interviews ($r = .81$ between ALP and FAW, and $r = .84$ between ALP and TAW). This result indicated that students with higher ALP levels at the post-interviews were more likely to have higher FAWs and TAWs. In addition, significant positive correlations ($r = .925$ at pre-interviews and $r = .948$ at post-interviews) were found between students’ FAW and TAW as well, which meant that the more unique academic words students used, the more total academic words they used. These correlations were significant at the .001 level (1-tailed).

Table 5.2

_Correlations between Language Variables (ALP, FAW and TAW) from Spearman’s Tests_ (N = 51)

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Effects of Gender, Age, and Prior Schooling

This section answered the secondary research question: *What are the effects of age, gender, and/or prior schooling experience on newcomer ELLs’ academic language proficiency and/or chemistry content knowledge?* Kruskal-Wallis tests were conducted between independent variables (gender, age and prior schooling) and dependent variables (ALP and CCK levels at both pre- and post-interviews, and ALP levels at the mid-interviews). Results indicated that no significant differences of gender, age, or prior schooling exist between different ALP and CCK levels (Table 5.3). In other words, gender, age, and prior schooling experience did not have significant effects on participants’ ALP and CCK levels.

Table 5.3

*Relationships between Independent Variables (Gender, Age, and Prior Schooling) and Dependent Variables (ALP and CCL levels) from Friedman’s Tests (N = 51)*

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</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td>1.92</td>
<td>.860</td>
</tr>
<tr>
<td>CCK</td>
<td>χ² (H)</td>
<td>df</td>
<td>Asymp. Sig</td>
</tr>
<tr>
<td>Pre-Interview</td>
<td>1.30</td>
<td>1</td>
<td>.254</td>
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<tr>
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<td></td>
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<td></td>
<td></td>
<td>1.69</td>
<td>.890</td>
</tr>
<tr>
<td>ALP</td>
<td>χ² (H)</td>
<td>df</td>
<td>Asymp. Sig</td>
</tr>
<tr>
<td>Mid-Interview</td>
<td>.00</td>
<td>1</td>
<td>.953</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.76</td>
<td>.445</td>
</tr>
<tr>
<td>CCK</td>
<td>χ² (H)</td>
<td>df</td>
<td>Asymp. Sig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>.75</td>
<td>.387</td>
</tr>
<tr>
<td>ALP</td>
<td>χ² (H)</td>
<td>df</td>
<td>Asymp. Sig</td>
</tr>
<tr>
<td>Post-Interview</td>
<td>.75</td>
<td>1</td>
<td>.387</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>3.71</td>
<td>.593</td>
</tr>
<tr>
<td>CCK</td>
<td>χ² (H)</td>
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<td></td>
</tr>
</tbody>
</table>

“*” indicates statistical significance
Relationship between ALP and CCK levels and their Changes Over Time

This section answered the primary research question: *What is the relationship between ALP and CCK levels of newcomer ELLs? How does this relationship change over a four-month period of time?* Since ALP and CCK were both ordinal data, Spearman’s rank-order correlation tests were used to examine the relationships between them (Table 5.4). Results showed no significant correlation between ALP and CCK levels at the pre-interviews, but significant positive correlation ($r = .87, p < .001$) between ALP and CCK at the post-interviews.

Table 5.4

*Correlations between Dependent Variables (ALP and CCK) from Spearman’s Tests (N = 51)*

<table>
<thead>
<tr>
<th></th>
<th>ALP Pre-Interview</th>
<th>CCK Pre-Interview</th>
<th>ALP Post-Interview</th>
<th>CCK Post-Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALP Pre-Interview</td>
<td>$r_s (\rho)$</td>
<td>1.00</td>
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<td>-</td>
</tr>
<tr>
<td>CCK Pre-Interview</td>
<td>$r_s (\rho)$</td>
<td>0.13</td>
<td>1.00</td>
<td>-</td>
</tr>
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<td>ALP Post-Interview</td>
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<td>1.00</td>
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<tr>
<td>CCK Post-Interview</td>
<td>$r_s (\rho)$</td>
<td>-</td>
<td>-</td>
<td>0.87</td>
</tr>
</tbody>
</table>

"*" indicates statistical significance

In order to examine the changes of ALP and CCK over a four-month period of time, Friedman’s tests were used as a nonparametric alternative to repeated-measure ANOVA (Table 5.5). Results showed significant differences of ALP levels between pre-, mid-, and post-interviews ($p = .002$) and significant differences of CCK levels between
pre- and post-interviews ($p < .001$). Post hoc analysis (Wilcoxon signed ranks test) indicates significant differences of ALP levels between pre- and post-interviews ($p = \ldots$ and between mid- and post-interview ($p < .001$). However, no significant differences of ALP levels were found between pre- and mid-interviews.

Table 5.5

*The Change of ALP and CCK Levels Over a Four-Month Period of Time from*

Friedman’s Tests ($N = 51$)

<table>
<thead>
<tr>
<th></th>
<th>Mean Rank</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time 1 (Pre-Interview)</td>
<td>Time 2 (Mid-Interview)</td>
<td>Time 3 (Post-Interview)</td>
<td></td>
</tr>
<tr>
<td>ALP</td>
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<td>1.81</td>
<td>1.84</td>
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<td></td>
<td>df</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Asymp. Sig</td>
<td>.002*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCK</td>
<td>$\chi^2$ (H)</td>
<td>31.11</td>
<td>1.18</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Asymp. Sig</td>
<td>.000*</td>
<td></td>
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</tr>
</tbody>
</table>

“*” indicates statistical significance

Summary

This chapter presented results from a series of statistical analyses to answer two quantitative research questions. The results indicated significant differences between ALP levels and academic word counts (FAW & TAW) at post-interviews, significant differences between ALP levels and CCK levels at post-interviews, significant changes of ALP levels over time from pre- to post-interviews, and significant changes of CCK levels over time from pre- to post-interviews. However, no significant results were found between the effect of gender, age, and prior schooling on students’ ALP and CCK levels.
CHAPTER VI. DISCUSSION

Overview

The objective of the present study was to examine the characteristics of newcomer ELLs’ academic language proficiency and chemistry content knowledge levels, the relationships between these levels, and the effects of extraneous factors on these levels. The previous two chapters presented results from qualitative and quantitative data analyses. Since these results were closely related and both had implications related to all of the research questions, they were discussed together in this chapter. The first section discussed findings of the language variables, including the characteristics of ALP levels from the qualitative analyses and significant differences between ALP, FAW, and TAW from the statistical analyses. The second section discussed findings of the content variables, including the characteristics of CCK levels from qualitative analyses and significant differences between CCK levels from the statistical analyses. The third section discussed the relationships between ALP and CCK levels and effects of extraneous factors (i.e., gender, age, and prior schooling) on ALP and CCK levels.

Academic Language Proficiency for Newcomer ELLs

The academic language proficiency, or ALP, primarily referred to the speaking and listening aspects of participants’ academic language in the present study. Therefore, a more accurate description of the ALP levels of the present study is students’ abilities to engage in oral communication with academic language, including both expressive and receptive skills. Gee (2004, 2015) argues that literacy is not merely reading and writing, but social practices that integrate thinking, learning, and applying content information. This section discussed newcomer ELLs’ comprehension of interview questions, language complexity, expression, body language, and academic word counts, focusing on the oral
aspect of academic literacy.

**Comprehension of interview questions.** All other indicators in this section were about language output, only the comprehension focused on language input. The reason to add this indicator was because many participants answered all four questions as a whole. For example, some students described types of matter when answering Q4 while this topic was asked in Q1; some students explained chemical reactions as an answer to Q3 but this topic was asked in Q2. In order to take into account as much of participants’ knowledge as possible, the researcher decided to consider the answers together when grading for levels. However, the variation of students’ comprehension was significant, which partially yet clearly reflected their academic language proficiency. Therefore, researchers decided to add *comprehension of the questions* as an indicator to the ALP rubric.

Listening and reading comprehension are crucial for second language acquisition. This cognitive process involves information reception, prior knowledge interaction, and meaning reassignment to the text (Jones & Plass, 2002). Since prior knowledge played a role in understanding the interview questions, a clear demarcation between miscomprehension by language and miscomprehension by knowledge was difficult to draw. In the present study, comprehension was only considered when clear evidence of no or partial comprehension exist. For example, many participants clearly stated “I don’t understand” or “I don’t understand the question (e.g., participants A14, B01). Although the reason that they didn’t understand interview questions might be caused by the lack of content knowledge, the statement “I don’t understand” was adequate to show students’ low extent of comprehension (especially that students often used “I don’t know” to indicate their lack of content knowledge). Another type of poor comprehension was
associated with incomplete answers or answers about only one word/phrase in the question. For instance, some students provided descriptions about “chemicals” as an answer for “chemical reactions” (e.g., participant A11); some students described how to predict features of an element based on features of the elements next to it as an answer for “predicting the combination of substances” (e.g., participant C02). This kind of miscomprehension only considered the utterance meaning of some words, but ignored the meaning of the whole question. Taguchi (2007) defines the comprehension that integrates both literate meanings and implied meanings as pragmatic comprehension, which is an important ability for second language acquisition. In the present study, interview questions were straightforward and did not contain much implied meanings. However, participants who only understood some words but miscomprehended the meaning of the whole question clearly had not achieved pragmatic comprehension.

**Language complexity.** Like other forms of social languages, academic language (English) makes sense when used in a situated context to convey specific meanings and reflect certain social identity (Gee, 2004, 2015). The use of academic language is a process of coding and decoding the syntactic patterns and the Discourse (with the big D, see Chapter II), which reflects social identities and activities (Gee, 2002, 2004).

Academic language’s grammatical patterns (e.g., “heavy subjects,” nominalization, and passive voice) enact its unique characteristics and distinguishes it from other styles of languages (Gee, 2004, 2015). Given the limited language proficiency of participants in the present study, those academic features were not included in the grading rubric (most students’ responses do not contain these features). However, the grading results showed that higher ALP level responses were more likely to contain academic language features, as those responses were more likely to contain complex sentence structures and more
academic words. A typical level 5 response contained nominalization such as using “movement” instead of “move” and use passive voice such as “chemical reaction is divided by…” (participant A12). In contrast, lower ALP level responses typically contained less or no academic language features. A typical level 2 response was composed of isolated words and gestures (e.g., participants B09, D08).

Expression. Expression showed the extent to which students could convey their scientific ideas with academic language. For instance, the sentence “chemical reaction is for example the water” (participant A06) did not express any meaningful scientific idea, because the example “water” did not contain enough information to describe/explain “chemical reaction.” A better expression might be “for example, combining hydrogen and oxygen to make water is chemical reaction” (correct) or “for example, the process that water becomes ice is chemical reaction” (incorrect). It is important to notice that the expression of ALP only focused on the language aspect of the texts and did not concern the correctness and accuracy of content knowledge. Therefore, although the second alternative sentence was scientifically inaccurate, it would still be considered as clear expression.

Another type of incomplete expression provided more information than just isolated words, but the information was too ambiguous to convey meaningful ideas. For example, a response to Q1 was “this is solid because it doesn’t have a space, so it’s solid… This have space so it’s the liquid or gas” (participant A10). This participant described a particular relationship between the states of matter and space. However, this relationship was vague, as A10 did not indicate the locations of the space. A better expression might be “this is solid because the atoms/molecules/particles are tightly packed without space; this is liquid or gas because the atoms/molecules/particles have
space between each other.’’

Gee (2004) suggests that the success of learning academic language relates to students’ willingness to accept certain losses and the ability to realize the gains. This perspective views the process of academic language acquisition as a tradeoff: many subjective features of the everyday language, such as attitudes, beliefs, values, and interests, are lost in the use of academic language; at the same time, abstract ideas, objective descriptions are gained from using the academic language. This tradeoff is obvious in the results of the present study. Generally speaking, students at lower ALP levels tended to express ideas with their observations, so the scientific ideas were often subjective and conveyed in everyday language. For example, a response to Q4 was “…I practiced it in class to predict something…I use the key [point at the legend]’’ (participant D04, ALP level 3). This student started sentences with “I” and mainly described his experience in class as the answer to the interview question. In contrast, students at higher ALP levels often used more general and objective expression, such as “the states of matter are…” (participant D16, ALP level 5) and “chemical reaction is produced with…” (participant A12, ALP level 5)

**Body languages.** Technically, body languages are not part of the academic language but part of “the whole of communication,” which “includes gestures and posture, facial expressions, mime, non-verbal vocalizations, drawings, and a great deal more” (Lemke, 2004, p. 34). Cummins (1994) describes facial expressions, gestures, and body language as language cues and associates them with BICS. Watts-Taffe and Truscott (2000) also argue that those language cues are absent in academic language because the latter is context-reduced. However, participants of the present study had not yet possessed native English proficiency, so body languages were frequently adopted as a supplemental
to their oral languages. Given the special linguistic abilities of these participants, scientific ideas expressed by body languages were included in their CCK, but body language per se was not considered as part of the ALP. In the present study, body language was typically used to support a statement (e.g., pointing at a picture or an element on the periodic table and naming it). Another type of body language use of the participants’ was to replace unknown or unfamiliar words. From the listeners’ perspective, body language could help them capture speakers’ unspoken words or ideas (Goldin-Meadow, 1999). For example, student might make gestures to show certain action: “Two elements [put two hands together] some chemical…” (participant C04); “The particles, when that, they are like separate they are not together, and solid, they are together and no space to move, and liquid…a lot of… I mean some space but not too [put hands together and then spread them]” (participant A15). Both examples used the combination of verbal language and gestures to convey ideas: C04 put the hands together to express “combine” or “react;” A15 spread hands to express “big” or “enlarged.” Roth (2004) points out the importance of gestures to language development: using gestures makes content communication accessible to students before they are able to verbally do it. By serving as a supplemental or replacement of words, gestures could reduce the cognitive requirement for communication, which was extremely helpful for the participants. In short, taking body language into account increased the accuracy of grading participants’ ALP and CCK levels in the present study.

**Academic word counts.** Two word counts were conducted for all pre- and post-interviews: the frequency of academic words used, or FAW, and the total academic word used, or TAW. Mid-interviews were not included in word counts because their numbers of questions were significantly less (only one question) than the pre- and post-interviews.
Results of statistical analyses showed significant correlations between ALP levels and both academic word counts at post-interviews, but no such correlation was found at the pre-interviews. A possible explanation was that at the pre-interviews, most participants only possessed minimum English language skills and limited content knowledge, so their answers to the interview questions were primarily based on prior knowledge and current English proficiency. The academic words they used at this time were often from the instructions at NMH—this was obvious since many pre-interviews contained long responses to Q1 (which had instructed by the pre-interviews) and much less or even no responses to the other three questions (had not instructed by the pre-interviews).

Therefore, a gap emerged between the newly acquired academic vocabulary and the ability to appropriately convey ideas with these academic words. This gap decreased at the post-interviews after a four-month study of both language and content in an integrated environment. FAW and TAW were positively correlated at both pre- and post-interviews, indicating that the more unique academic words a participant used, the more total academic words he/she used.

**Chemistry Content Knowledge for Newcomer ELLs**

The chemistry content knowledge, or CCK, primarily referred to specific topics in chemistry that were taught at NMH during the data collection of the present study. These topics included *structures and properties of matter, chemical reactions, and the periodic table*. It is important to notice that the grading rubric of CCK only considered the second and the third topics since structures and properties of matter had already been introduced in class when the interviews started. So the responses about matter were only used as a baseline to examine participants’ ALP levels.

**Knowledge.** Due to the limited language proficiency and the format of evaluation
(interviews with open-ended questions), the grading of participants’ CCK levels emphasized on the correctness and depth of the responses rather than the comprehensiveness. Chapter IV had presented results of participants’ CCK; this section discussed the common misconceptions that they held during the interviews.

In the present study, misconception referred to any idea that was different from currently accepted scientific knowledge, including ideas that are intuitive, naive, informal, incomplete, and/or incorrect. However, one misconception was excepted: some students stated that chemical reactions were irreversible—although this statement was scientifically incorrect (theoretically all chemical reactions are reversible and reaching an equilibrium status), the grading process did not count it as misconception because the students were taught in class that chemical reactions were irreversible (informal field observation, n.d.). Nonetheless, considering the reversibility as a distinction of chemical reactions might cause students’ confusion about everyday observations. For example, many students stated that folding paper, breaking a glass (participant A09), and cutting a tree (participant C08) were chemical reactions because they were all nonreversible (i.e., they could not go back to the original appearances). For the periodic table, a few participants stated that the periodic table consisted of three groups of elements: metals, metalloids, and gasses/noble gasses (e.g., participant A04). This misconception was possibly caused by confusion about the properties and classifications of matter. In other words, these students might be confused with the states of matter (i.e., solid, liquid, gas, and plasma) and one of the classifications of matters (i.e., metal, non-metal, and metalloids/semi-metal). Some students stated that the sections with different colors on the periodic table (which shows a more classification of the elements, including Alkali metals, transition metals, basic metals and etc.) indicated the states of elements: “in the
periodic table, if for example, the gas is oxygen, that means all the section is about the
gasses” (participant D16).

Overall, students at lower CCK levels tended to provide descriptions about fewer
topics, their explanations of ideas were superficial (e.g., only explained what it was, not
why it was), and the responses often contained obvious misconceptions. These
performances could be either caused by limited languages (i.e., the student had the
knowledge but could not explicitly express it), or caused by limited content knowledge
(i.e., the language skills were adequate to convey students’ ideas, but the content
knowledge was limited). In contrast, responses at higher CCK levels typically contained
descriptions of various concepts, more in-depth explanations (including what the concept
is and the rationale behind it), and minimum to none misconceptions.

Coherence. This indicator described the extent to which the concepts/ideas of the
students’ responses were connected, aligned, and coherent. For responses at lower CCK
levels, this coherence was nearly non-existent because those responses were often
composed of isolated words. For responses at higher CCK levels, the coherence was
shown in the relationship of concepts within a sentence, the connection between
sentences and/or the alignment among ideas, reflecting the consistency of students’
knowledge and their understanding of concept categories. For example, the sentence
“matter has mixture, compounds, elements, molecules, atom…” (participant D06)
reflected lack of coherence because the relationships between some of those concepts
were subordinate or belonged to different categories (e.g., molecules consist of atoms, but
can also make a mixture with atoms). Listing those concepts with a parallel structure was
not necessarily a misconception, but it showed disorganization of this student’s
knowledge about matter. Similarly, the following sentences also reflected this problem:
“Matter is space, everything, air. Matter is atom, molecule, expand. (Researcher: Can you
tell me more?) Gas, molecule, atom” (participant A08). This example contained three
sentences, but none of the sentences showed a cohesive relationship among the concepts
in it. Comparatively, the concepts in following response were well organized, showing
good coherence: “Everything is matter. The matter is liquids, solids, and gas. The matter
is pure substance and mixture, heterogeneous and homogenous. The definition of matter
is everything in the mass to the…not the space” (participant D04). Compare to the
previous two examples, this response provided a clearer structure of ideas: pure substance
and mixture are a pair of concepts, and heterogeneous and homogenous are a pair of
concepts. Besides the coherence within sentences, the coherence between multiple
sentences also showed students’ understanding of CCK. These responses might contain a
correct statement, followed by another correct statement to explain/support the first one.
But these two statements were irrelevant and/or do not align with each other. For
example,

…You can calculate the reaction. (Researcher: Can you tell me more?) If you
don’t know what the next element that you need. For example, if you have
hydrogen, and you need to know what is the next element, you can predict about
all the element…can be there (participant C14).

In this example, the first sentence mentioned “calculate the reaction,” but instead of
explaining how to calculate or what to calculate, the following sentences started to
describe how to find out the next element on the periodic table. In general, the coherence
was more obvious at higher CCK level responses. Being able to coherently convey
scientific ideas required students to not only possess the knowledge of specific concepts,
but also hold big pictures about the relationships between these concepts. Using the
format of open-ended interview questions was critical to capture this cognitive ability, which might be difficult to detect from using multiple-choice questions and/or surveys.

**The use of academic words.** This indicator described the correctness and accuracy of the use of academic words. The reason that it was considered as an indicator for CCK rather than ALP was because the correct usage of academic words heavily depended on the amount of content knowledge possessed by participants. For example, students might read off the periodic table without knowing and/or understanding the meaning of the words. Incorrect use of academic words included using an academic word to represent a different concept other than the word’s intended meaning, or using an academic word in an irrelevant context. The most common misuse of academic words involved using “group” and “period” reversely when describing the periodic table (e.g., participant A06) and calling electrons “atoms” (e.g., participant B18). These errors might be caused by inadequate academic vocabulary (i.e., using a familiar word as the replacement of an unknown/unfamiliar word), which was not directly related to CCK. However, the researcher argues that given the special functions of the academic words, being able to correctly and appropriately use them (not the vocabulary per se) was part of students’ content knowledge. For example, the “periods” in the “periodic table” reflect an important characteristic of elements’ patterns: elements in the same period share the same amount of electronic shell and are organized in the same row in the table. Using “group” to represent “period” implied incomplete or even no understanding of the concept of period. Generally speaking, the accuracy of using academic words was more obvious in higher ALP level response because the words were evaluated within a more specific context.
Relationships between ALP, CCK, and Extraneous Factors

Science is a good context to show the delicacy and sophistication of academic language, and academic language is a good carrier to manifest the precision and complication of science. Gee (2004) explicitly describes this relationship:

No domain represents academic sorts of language better than science. Science makes demands on students to use language—oral and printed—as well as other symbol systems that epitomize the types of representational system and practices that students need to master for higher levels of school success. In addition, these language and representational systems are at the heart of living in the thinking critically about modern societies (p. 13).

In contrast, natural languages do not have continuum of references, so they cannot convey scientifically specific meanings (Lemke, 2004). For example, natural languages can describe temperatures as “hot,” “warm,” “cool,” “cold,” or “freezing,” but they cannot describe specific points of references such as 37.5°C Celsius. Gee (2004) also points out that everyday language “is less careful about difference and underlying systematic relations, although these are crucial to science” (p. 27).

The co-dependent relationship of science and academic language has been described and appreciated by many researchers (e.g., Saul, 2004). While this relationship is obvious in the high end of the scientific world, the present study examined how it looked like at the beginning level—these participants were not only science learners, but they were learning with limited English proficiency. The question is, if science and academic language rely on each other to maximize their functions, how would the learning look like when both sides were short?

The attempt of answering this question started with visualizing the results from
statistical analysis: (1) The results of Spearman’s rank-order correlation tests showed a significant correlation \((r = .87, p < .001)\) between ALP and CCK levels at the post-interviews but not at the pre-interviews. This pattern was similar to the relationship between ALP levels and academic word counts. This meant that during the first four months of study at the NMH, the changes occurred in ELLs’ learning developed connections between their ALP and CCK levels. In other words, during this four-month period, the correlation between academic language and content knowledge had enhanced from insignificant to statistically significant. (2) The results of Friedman’s test showed significant differences between pre- and post-interview ALP levels \((p = .002)\), as well as between pre- and post-interview CCK levels \((p < .001)\). This meant that both post-ALP and post-CCK were significantly changed after the four-month study. (3) Results of post hoc analysis showed a more specific location of the differences between ALP levels, which was between the mid- and post-interviews (no significant differences between pre- and mid-interviews), meaning that the significant development of students’ ALP mainly occurred during the second half of the data collection. It is important to notice that the “development of academic language” is based on students’ performance rather than their competence. The theory of syntax distinguishes competence and performance: the former refers to the knowledge of the language, and the latter reflects the use of the language (Chomsky, 1965). For example, even though some ELLs possess the knowledge of syntactical rules, they may still have difficulties using them in practice (Cairns & Silva, 1969). Therefore, having no significant differences between pre- and mid-ALP levels did not necessarily mean non-existence of language development; it only showed students’ performance as related to academic language.

Academic language not only describes visible objects, phenomenon, and actions,
but also conveys abstract, unfamiliar, non-visible concepts and psychological ideas (Barsalou, 1999), therefore, it might be difficult to make sense even for native English speakers. As a type of social languages, academic language can be understood under two conditions: “being largely verbal” or “being situated” (Gee, 2004, p. 18). Under the first condition, the academic language was difficult for ELLs to understand because this type of comprehension heavily relied on BICS, which was a language skill that ELLs had not been competent with yet. In the present study, this condition matched the situation at pre-interviews, when most participants were newly enrolled in the school and did not possess much content knowledge about the targeted topics yet (e.g., over 80% of participants were at CCK level 1 and 2; none of the participants was at CCK level 5). Under the second condition, academic language could more easily make sense for ELLs because it had been associated with experiential activities (e.g., observing teacher demonstration, conducting hands-on experiments). In the present study, this condition matched the situation at mid-, especially post-interviews, when the participants had received months of science instruction and engaged in experiential activities. At this time, the situated academic language was easier to learn and to be associated with meanings of the content knowledge (less than 50% of participants were at CCK level 1 and 2; over 20% of participants were at CCK level 4 and 5). In addition, the most significant changes of ALP levels occurred during the second half of data collection. A possible explanation was that the improvement of language performance “accelerated” after a “latent” period. In other words, students’ development of academic language was not visible/significant during the first half of data collection, as this development had not been transferred into their language performance yet.

Interestingly, no significant differences of ALP and CCK levels were found in the
present study with respect to students’ gender, age, and prior schooling experience. Similarly, little research was found about gender difference in ELLs’ academic language development and content knowledge acquisition. On the other hand, numerous researchers indicate that age and prior schooling experience can significantly influence those learning processes. One possible cause was the range restriction of participants’ age ($SD = 1.20$) and prior schooling years ($SD = 1.59$). As a common statistical problem, restriction of range often contributes to the underestimation of validity and reduction (or in rare occasions increase) of correlations between values (Raju & Brand, 2003; Zimmerman & Williams, 2000). In the present study, because the participants were explicitly selected from the same high school classroom, the range of age was restricted, and therefore the correlation between participants’ ages and their ALP/CCK levels was difficult to detect even if it existed. Similarly, the correlation between participants’ prior schooling and their ALP/CCK levels was not found, possibly due to the restriction of range as well. Particularly, the data of age and prior schooling were self-reported by students and/or their parents (or other legal guardians). Some parents did not remember the exact birthdays of their children, and they did not have official paperwork of records, so they just documented January 1st of an approximate birth year as the students’ documented birthdays (T. Wilson, personal communication, January 13, 2015). Therefore, the accuracy of these data was questionable.

Conclusion

The present study aimed to investigate the characteristics of, the relationship between, and the effects of gender, age, and prior schooling on newcomer ELLs’ ALP and CCK levels. The grading results with two rubrics showed that the characteristics of ALP range from being completely silent (level 1) to being able to explicitly and adequately
express scientific ideas without assist of non-language cues (level 5); the characteristics of CCK ranged from not having the knowledge of the topics at all (level 1) to understanding the essence of chemical reaction, the patterns of the periodic table, and being able to apply these patterns in solving problems (level 5).

The quantitative research question examined the relationships and the change of relationships between newcomer ELLs’ ALP and CCK. Results indicated that participants’ ALP and CCK levels were significantly correlated at post-interviews but not at pre-interviews. A possible explanation of these results was that the participants had not experienced much of science learning in English at the time of pre-interviews, so their acquisition of academic language largely relied on their everyday language/BICS, which was not proficient. After received instructions in English for four months, the content knowledge started to become situated and experiential to participants, so the academic language acquisition was correlated with content knowledge learning. Particularly, the patterns of ALP levels changed significantly in the second half of data collection (between mid- and post-interviews) but not in the first half (between pre- and mid-interviews). A possible reason of this result was that there was a “latent” period of language learning, during which the language development was not shown in the learners’ performance. This explanation is based on Chomsky’s (1965) theory of syntax, which distinguishes language competence and performance—in the present study, the interviews only tested participants’ performance rather than their competence.

**Implications for Teaching**

The present study shed light on the practice of teaching science content to newcomer ELLs whose English is at the beginning levels. First, the development of academic language and the acquisition of science content knowledge should be integrated
during daily instruction. Although the beginning newcomer ELLs’ basic language (English) skills often seem extremely limited, especially when learning science (which can be difficult for native English speakers), results of the present study suggested that both of their academic language proficiency and science content knowledge could develop during a short period of time when the instruction was integrated.

Second, although the instruction should be integrated, the assessment of academic language and content knowledge should be separated, especially at the beginning of the semester when ELLs first enrolled the program. This separation does not mean using separate measurements, but considering ELLs’ content knowledge separately from their language proficiencies. In this sense, the choice of assessment format matters. For example, open-ended interview questions or essays may detect different levels of academic language and content knowledge from the same student, but surveys or multiple-choice questions may not be as sensitive (the rationale of choosing certain answers is normally unknown with these formats).

Third, instruction of science content should be more hands-on and experiential for newcomer ELLs, especially the ones with lower language proficiencies. Results of the present study showed that students at lower ALP levels tended to communicate scientific ideas by describing their observations from activities or experiments rather than explaining abstract concepts, indicating that the visible and experiential content makes more sense to them.

Finally, instruction and assessment of newcomer ELLs should involve using multiple sources, such as body language (gestures), manipulatives, real objects, etc. Results from the present study showed that participants at all ALP levels utilize other sources other than verbal language to convey ideas. Using different sources can help
ELLs develop the ability to negotiate for meaning (Faltis & Coulter, 2008), and expand their approaches of communication, so that the content becomes more accessible and understandable to them.

**Limitations and Future Research**

Although researchers always try to draw conclusions from the most accurate and most reliable science, “educational research is both messy and imperfect,” therefore, research in education should always be interpreted in context (Saul, 2004, p. 3). The design of the present study attempted to minimize threats to validity and reliability from both qualitative and quantitate aspects, but multiple limitations still exist.

**Limitations of the population.** The present study aimed to investigate newcomer ELLs, however, the concept of “newcomer” was overly broad and referred to ELLs who entered the United States in the recent one or two years. Therefore, participants’ lengths-of-stay in the United States was diverse, ranging from weeks to years at the time when the present study started. Although this diversity did not affect the results, it could have potentially made the interpretation of results difficult and messy (e.g., the explanation about the differences of ALP-CCK correlations between pre- and post-interviews did not apply to former NMH 8th graders and SIFEs). In addition, majority of the participants were native Spanish speakers (74.5%), so the conclusion of the present study might not be generalizable to all newcomer ELLs. Also, the high attrition (32%) might be an uncontrollable threat to validity as well.

**Limitations of the data collection.** First, because all interviews were conducted by the same researcher during class time, the span of each interview session was long (4-18 days). Other factors that contribute to this expanded data collecting duration include holidays, testing days, technical problems, unexpected school power out, and
sickness/absent of participants. This long duration might have affected participants’ answers in the interviews. For example, if the instruction was about chemical reaction right before a participant’s interview, his/her response might include more accurate information about this topic; at the same time, another participant might not perform as well on this topic simply because the instruction was about something else before he/she had the interview. In short, participants’ performance can be largely affected by the instruction of the day. Second, although the researcher never set a time limit for interviews, and informed each participant that the interviews would not affect their grades in any way, at least four times (once in class with Ms. Wilson and once before each interview), the stress of being interviewed during class time might still restrict participants’ answers. Third, the researcher developed a good relationship with some of the participants, who might have provided more information during the interviews than they normally would. In contrast, some participants performed worse during the interviews than in class for multiple possible reasons (e.g., having a bad mood on the day of the interview). Also, some students might have prepared the answers before the interviews since the questions were consistent in all interviews. Finally, the transcription might not catch all the information the students provided during the interviews due to the inarticulateness.

Limitations of the data analysis. Since the researcher was also the interviewer, the grading and interpretation of the results were not completely unbiased. For example, some responses might seem more proficient when read as transcriptions than heard in person. So if the interviewer-researcher recognized some participants from their transcriptions (which was rare but had occurred), the grading result might be subconsciously influenced by participants’ in-class performance, and therefore different
from the other coder’s result (which was graded only based on the transcriptions). In addition, the grading process lasted for two months, involving one week of grading practice and another seven weeks of official coding (the researchers met weekly for debriefing and discussion). These actions increased the interrater reliability of the grading, but the overall criteria might be subtly skewed over eight weekly meetings.

**Future Research.** Future research can be designed to further investigate the findings of the present study. For example, extending the duration of data collection, such as from one semester to one academic year, can examine whether the correlation between ALP and CCK levels found at the post-interviews of the present study would maintain/enhance over time; adding students’ everyday language levels as another dependent variable can examine if a similar correlation exists between BICS and content knowledge; using open-ended essay questions instead of interview questions can investigate the relationship between students’ ALP, with respect to their reading and writing, and scientific content knowledge.

Future research can also be designed to overcome some of the limitations of the present study. For example, an experimental design can be used to test the effects of different interventions on ELLs’ academic language and science content knowledge; participants with more diversity (e.g., first languages, grade levels, length-of-stay in the United States, etc.) can increase the generalizability of the study; conducting this study with different topics in chemistry and/or in other science content areas can examine the general patterns of academic language acquisition and science learning; comparing the results of the present study with those of long-term ELLs and/or ELLs in mainstream classroom; utilizing other forms of measures (e.g., multiple choice questions, essays) other than open-ended questions to compare the outcomes.
APPENDIX A

Interview Protocol

Opener: Hello, ______________ (student’s name). Thank you for agreeing to this interview. I will be asking you some questions about science, and I would like for you to give me the best answer you have. You can talk to me about your answers, write down your answers, draw your answers, or show me your answers with your hands. Also, you are welcome to use any of the materials on the table to help you answer these questions. This camera is only focused on your hands.

1. Tell me everything you know about matter.

   Students may answer the properties, measurement, the structure of matter, and/or the relationship between the properties and structure of matter.

2. Tell me everything you know about the periodic table.

   Students may answer the structure of the periodic table (descriptions of how the periodic table looks like) and/or the rationale of the arrangement of the table (why elements are organized that way; relationships with physical and chemical properties of matter).

3. Tell me everything you know about chemical reactions.

   Students may answer the causes (why chemical reactions occur), processes (how chemical reactions occur), characteristics (what happens when chemical reactions occur), and/or indicators (how to know if chemical reactions have occurred) of chemical reactions.

4. Can someone use the periodic table to predict the combination of substances? Tell me about it.

   Students may answer how to use the periodic table to predict the possibility (whether elements combine) and processes/characteristics (how elements combine) of the combination of substances.

*If students did not respond or students asked for clarification, the interviewer may repeat the question, but cannot provide further information (e.g., explain the questions in different words or provide positive/negative feedback, such as “good”).
APPENDIX B

Sentence Starters (Available at the Interviews)

I think matter is _________________________
I can describe matter as/by _________________________
Matter is composed of _________________________
Matter can be changed by _________________________
Chemical reactions are _________________________
Chemical reactions occur because _________________________
I can describe chemical reactions as/by _________________________
The periodic table is _________________________
The periodic table shows _________________________
Elements are arranged by _________________________
The periodic table can be used to _________________________
### APPENDIX C

Academic Vocabulary Encountered in the Interviews

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<th>Term</th>
<th>Term</th>
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<td>nucleus(es)</td>
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ABSTRACT

INVESTIGATING ACADEMIC LANGUAGE PROFICIENCY AND CHEMISTRY CONTENT KNOWLEDGE OF NEWCOMER ENGLISH LANGUAGE LEARNERS IN A PUBLIC HIGH SCHOOL

by Jingjing Ma, Ph.D., 2015
College of Education
Texas Christian University

Dissertation Chair: Dr. Molly Weinburgh, Professor of Science Education, William L. & Betty F. Adams Chair of Education, & Director of Andrews Institute of Mathematics & Science Education

The present study aimed to investigate the characteristics of, the relationship between, and the effects of gender, age, and prior schooling on newcomer English language learners’ (ELLs) academic language proficiency (ALP) and chemistry content knowledge (CCK) levels. The mixed-method research design involved interviewing 51 participants at an urban public high school for three times over a four-month period using four open-ended questions about certain topics in chemistry. Two rubrics were developed to grade interview transcriptions. Each contained five successive levels: entering (1), emerging (2), developing (3), maturing (4), and advanced (5). Results from the qualitative data analyses showed that the characteristics of ALP range from being completely silent (level 1) to being able to explicitly and adequately express scientific ideas without the assistance of non-language cues (level 5); the characteristics of CCK range from not having the knowledge of targeted topics at all (level 1) to understanding the essence of chemical reactions, the patterns of the periodic table, and being able to apply these patterns in solving problems (level 5). Results from quantitative data analyses indicated that participants’ ALP and CCK levels were significantly correlated at post-interviews but not at pre-interviews. In addition, the ALP levels were significantly
different between mid- and post-interviews but not between pre- and mid-interviews. Interestingly, no significant differences of ALP and CCK levels were found with respect to students’ gender, age, and prior schooling experience. Implications for teaching, limitations, and future research were also discussed in the present study.