

CONJUNCTION IS MORE THAN JUST A GRAMMATICAL RESOURCE:
A COMPARATIVE STUDY OF CONJUNCTIONS IN U.S. AND CHINESE MATHEMATICS
LESSONS

BY

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DISSERTATION

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ABSTRACT

Policy and research suggest that mathematical learning is supported when students speak clearly, coherently and logically. Conjunctions can be instrumental to support this in that they help connect different ideas and allow speakers to elaborate, extend, and enhance their mathematical statements. Borrowing from the systemic functional linguistics (SFL) perspective, conjunction analysis was conducted on 13 U.S. lessons and 17 Chinese lessons to examine differences in the frequency and use of conjunctions between U.S. and Chinese lessons. Findings indicated that students in the Chinese sample had a higher probability of producing conjunctions than their U.S. peers in both internal conjunctions, which connect large chunks of information, and external conjunctions, which connect small chunks of information. Both in the Chinese and U.S. sample, students had a higher likelihood to produce external conjunctions than internal conjunctions. In terms of logical relationships of conjunctions, Chinese students had a higher probability of producing conjunctions of comparison, consequence, and time logical relationships than U.S. students. Within the Chinese sample, consequence logical relationships were more frequently seen than other types of logical relationships, while within the U.S. sample, consequence and addition logical relationships occurred quite often. More importantly, across lessons and cultural samples, a strong negative relationship was found between teachers' using internal conjunctions and students' using internal conjunctions. The significance of these differences lies in their potential impact not only for constructing but also communicating mathematical ideas to others.

Keywords: systemic functional linguistics, classroom discourse, conjunctions, Chinese and U.S. mathematics education, multi-level logistic regression

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CHAPTER 1

INTRODUCTION

Educational policy guidelines and prior research in mathematics education posit that students are expected to communicate with their peers, teachers and others in a *clear, coherent, and logical* manner (e.g. Principles and Standards for School Mathematics, 2000; Orrill & French, 2002). Accordingly, it is of paramount importance to investigate what students say and how they express their ideas in mathematics classrooms because it is through their mathematical talk that they explore ideas, obtain feedback, and come to own those ideas.

Conjunctions provide an intriguing means to understand ways in which speakers can choose to elaborate, extend, and enhance their statements (Halliday & Matthiessen, 2004), and, as framed within systemic functional linguistics (SFL), has relatively recently been appropriated to examine *mathematical* discourse (e.g., González & Herbst, 2013). More particularly, as a form of semantic connectives, conjunctions are helpful in making transitions among different mathematical ideas more clearly and smoothly, and revealing the relationships among those ideas. For example, *because, therefore, and however* are a set of conjunctions that help demonstrate the consequences of certain events, through which people can express the ideas of causes, means, conditions, and purposes; while *since, before, and after* demonstrate the time and sequence of events (Martin & Rose, 2007, p.153). Therefore, analyzing these conjunctions will allow us to examine how students organize their ideas and to understand how these ideas are connected.

Further, conjunctions allow people to make connections within and across idea units, and allow their listeners to anticipate the sort of mathematical content that the speaker will provide. Thus, when teachers use conjunctions, it should be easier for students to follow instructions;

when students use conjunctions explicitly in their answers to their teachers' questions, it should be easier for their peers to follow their thoughts, and for teachers to evaluate the student-level mathematical discourse.

Additionally, classroom discourse is a reflection of culture (Stigler & Hiebert, 2000), and cultural practices will have consequences for students' mathematical communication, thinking, and learning (Sims, 2008). Given the well-known differences in performance between Chinese and U.S. students in mathematics (Kelly et al., 2013; Stevenson, Chen, & Lee, 1993), it should prove useful to investigate differences in discourse practices that could be related to learning outcomes (e.g., Perry, 2000; Schleppenbach, Flevaris, Sims, & Perry, 2007; Schleppenbach, Perry, Miller, Sims, & Fang, 2007). However, how language units play a role in daily instruction, especially from a cultural perspective, has not been well investigated; this will be taken up in the present investigation.

Meanwhile, although English is admittedly different from the Chinese linguistic system, previous studies (e.g., Li, 2007) have shown that conjunctions perform the same function in both languages—connecting ideas—and the general uses of conjunctions in these two cultures show similar patterns. Moreover, conjunctions have fixed forms in both English and Chinese, and English conjunctions have corresponding translations in Chinese, and similarly, Chinese conjunctions have corresponding translations in English. The similarities between conjunctions in English and Chinese made the comparisons in this study possible.

The present study addresses the gap in the extant classroom discourse research by comparing classroom discourse practices—in particular the use of conjunctions in U.S. and Chinese lessons—and takes steps towards further understanding cultural differences in mathematics teaching and learning practices. In addition, while most previous studies chose to

examine conjunctions *qualitatively* within an episode or a lesson (e.g. González & Herbst, 2013; González, 2015), the current study investigates the use of conjunctions *quantitatively* with a much larger cross-cultural sample, which has the potential to provide new insights about classroom discourse. Furthermore, although the analysis of conjunctions is well established within the framework of linguistics, very limited amount of research has been produced regarding the use of conjunctions in the domain of mathematics teaching and learning (e.g., González, 2015), and none, to my knowledge, has examined the use of conjunctions in upper elementary mathematics lessons, especially from a cultural perspective. Thus, the present study is a critical step to understand the way conjunctions are used in upper elementary mathematics lessons.

CHAPTER 2

LITERATURE REVIEW

In this chapter, I review the previous research on how the SFL perspective has treated conjunctions, especially the external and internal conjunctions, and the four logical relations of conjunctions. Next, I turn to the significance of conjunctions produced by teachers versus by students, with a special focus on how teachers use conjunctions and how the use of conjunctions by teachers and students is similar or different. I also present the case for comparing conjunctions in Chinese and in English, which is crucial for a cross-linguistic comparison. The review of these topics leads to four specific research questions, which I outline at the end of this chapter.

Systemic Functional Linguistic Perspectives and Conjunctions

Systemic functional linguistics (SFL) was developed and introduced by M. A. K. Halliday (Halliday & Hasan 1976). He posited that language is social semiotic — explanations of linguistic phenomena should be made in a social context rather than seen as isolated symbols. As a result, language is about the choices that people make in a given context (Halliday & Matthiessen, 2004). A critical theme in SFL is the cohesion system, which comprises linking devices that hold texts together and give them meaning. Many studies have been published on this topic since the introduction of SFL (e.g. Gutwinski, 1976; Bennett-Kastor, 1986), and it continues to be relevant and informs current research (e.g. Mahlberg, 2006). As Morris and Hirst (1991) asserted, discourse is not just a random combination of statements, rather it has a quality of unity, and cohesions function as a binding mechanism that ties statements together.

More specifically, one of the most often-used cohesive devices is the conjunction. Conjunctions, as a part of text or speech, are language units that join words, phrases, and clauses.

From the SFL perspective, conjunctions facilitate textual and ideational metafunctions (Halliday & Matthiessen, 2004). Textual metafunction refers to the organization of texts, while ideational metafunction relates to the representation of our experience to others. As Martin and Rose (2007, pp.116) stated, conjunctions “organize text” on the one hand (i.e., are textual metafunctions), and “organize activity sequences” on the other hand (i.e., are ideational metafunctions).

Consequently, analyzing these items not only allows us to understand the mechanisms that structure and organize texts and discourse (textual metafunctions), but also enables us to see how the flux of human experience (in mathematics classrooms) is construed (ideational metafunctions).

In part, because of the important features and functions of conjunctions, examining the use of conjunctions can lead to an increased understanding of how teaching and learning practices take place in the classroom environment (González, 2015). For instance, González and Herbst (2013) discussed a method to track the development of oral arguments, a promoted practice for student learning in mathematics lessons, using conjunctions. Specifically, they talked about how conjunctions can be used to understand Toulmin’s argumentation scheme, another analytic technique that has been widely studied and used to examine arguments in classroom settings (see, for example, McClain, 2009; Pedemonte, 2007; Pedemonte & Reid, 2011). The conjunction *so*, as an example, connects data (specific information as grounds) and claim (assertion) in Toulmin’s model. For example, in an episode, a teacher stated $2x$ equals 31, *so* x is 15.5. The data, “ $2x$ equals 31,” provided grounds for the teacher’s claim that “ x is 15.5,” connected by the conjunction *so*. *By* preceded the mathematical justification for a statement, and was frequently found in phrases such as “by using the Side-Angle-Side theorem” in a geometry lesson. *Because* preceded mathematical reasons used to justify claims. In a student’s answer, for

example, she stated “I don’t know, but I know that angle *PCO* and angle *MCN* are equal ’cause the triangles are congruent.” In this case, the claim “I don’t know, but I know that angle *PCO* and angle *MCN* are equal” was justified by her statement “the triangles are congruent”, connected by the conjunction *’cause*, a short form of because. By using these conjunctions, researchers found a way to reliably and transparently identify different components of arguments. Conjunctions play a critical role in this case, not only helping researchers analyze argumentation components, but also by informing mathematics teachers who hope to teach and create effective arguments in mathematics lessons.

The potential for analyzing conjunctions to increase our understanding of teaching and learning practices can be further illustrated by another example. Researchers (e.g., González, 2013) have documented the use of analogies by mathematics teachers when they introduce mathematical contents. Through analogies, teachers help students to establish connections between prior knowledge and the targeted mathematics ideas to be taught. González (2013) analyzed conjunctions to demonstrate how these can be helpful to construe and analyze analogies. For example, she found that teachers construed analogies by connecting mathematical and non-mathematical themes using conjunctions such as *like*, which enabled teachers to explain mathematical concepts using non-mathematical examples. Also, she discovered that teachers used *if*, *then*, and *such that* to establish proofs. Thus, by carefully examining conjunctions, researchers have decomposed different parts of analogies used within classroom settings to provide better understanding of mathematical thinking.

Theories beyond SFL have also endorsed the significance of conjunctions. According to Behaghel’s Law (Clark & Clark, 1977, pp. 80-84), when language elements are adjacent within a sentence, the propositions that they bear should also be close conceptually and intellectually.

This can be interpreted as: when students present mathematical ideas or propositions within a sentence, usually connected by conjunctions, these propositions should be considered as being in a close conceptual relation. Accordingly, through conjunctions, teachers and researchers can understand how students relate, group, and organize various mathematics contents and their own propositions.

Furthermore, conjunctions signal and mark shifts in text and discourse (Dooley & Levinsohn, 2001, pp. 20). When listeners hear conjunctions, they may be able to predict the tone and even the content of upcoming statements. For example, *furthermore* would indicate an addition to the previous statement; *although* would imply a statement contrasting with what was previously said; and *therefore* would help establish consequence logic in the speaker's statements. Consequently, when teachers use conjunctions, it should be easier for students to follow instructions; and when students use conjunctions in their answers to teachers' questions, it should be easier for their peers to follow their thoughts, and for teachers to evaluate student-level mathematical discourse.

In addition, the Cognitive Task Complexity Hypothesis, which has been corroborated by a number of studies (e.g. Gilabert, 2007; Kuiken & Vedder, 2007; Robinson, 2007; Robinson & Gilabert, 2007), claims that increased cognitive task complexity promotes linguistic complexity and accuracy, and leads to a greater amount of interactions. In particular, the hypothesis emphasizes the importance of linguistic sophistication and density of linguistic units (Bulté & Housen, 2012). As such, students' use of higher frequency of language units, such as conjunctions, may be a reflection that they are dealing with more complex tasks or that more interactions are happening within the lesson.

It needs to be noted that the concept of density of linguistic units highlighted in Cognitive Task Complexity Hypothesis is in fact consistent with that of lexical density in SFL. **Lexical density** can be calculated as the result of content words (conjunctions in our case) divided by total running words (the total number of words uttered by students or teachers in our case) (Eggins, 1994; Fang, 2005). The major reason that lexical density is preferred over the count of content words is that lexical density is a more precise measure. Take conjunctions as an example. It needs to be noted that the production of more conjunctions can be an outcome of students saying more words. If students in a lesson produce, say 20 conjunctions, one cannot conclude how frequently students use conjunctions because 20 conjunctions in a turn of 100 words is quite different than 20 conjunctions in a turn of 1000 words. Thus the lexical density is a more valid method for measuring the frequency of conjunctions compared to simply counting the number of conjunctions. Accordingly, for the current study, I also used lexical density as a measure to examine the frequency of conjunctions in U.S. and Chinese lessons, to account for the differences in students' utterances across lessons.

Thus, both the SFL framework and other influential theories (e.g. Behaghel's Law) have endorsed the significance of the use of conjunctions in classroom discourse. It is important to examine the frequency and density of conjunctions used in classrooms by students, because conjunction use reflects the degree of clarity and logic in their statements.

External and Internal Conjunctions

According to Halliday and Hasan (1976), conjunctions can be divided into two categories: external conjunctions and internal conjunctions. *External conjunctions* describe what is happening, and can be found anywhere in the text (Martin & Rose, 2007, pp.116). That is to say, external conjunctions tend to be more aligned with ideational metafunctions, helping

speakers describe experiences and activities for a given context. Some examples of external conjunctions include *and*, *because*, *but*, and *if*.

Internal conjunctions, on the contrary, are used to organize the flow of information, and are often used when a new or different chunk of information is introduced. Internal conjunctions tend to fulfill textual metafunctions, facilitating the organization of texts and connecting logical steps (Martin & Rose, 2007). Examples of internal conjunctions include *first of all*, *in addition*, *for example*, and *in conclusion*, which demonstrate the sequences and steps of the text or discourse.

It is critical to differentiate external and internal conjunctions because, during a conversation, internal conjunctions typically are produced by the person(s) controlling the discourse, and in classrooms, are used most frequently by the teacher (González & Herbst, 2013). González and Herbst analyzed an episode from a geometry class, and found that internal conjunctions were only used by the teacher, and no internal conjunctions were found in students' statements. For example, *okay* was a primary internal conjunction used by the teacher (Martin & Rose, 2007). Sometimes *okay* served the purpose of adding a new phase in an argument, framing and staging the following statements; other times *okay* was used to provide evaluations for students' answers. However, for both scenarios, *okay* announced and signaled a change, either a change in the topic the teacher chose in her own explanation or argument, or a change of speaker from students to the teacher, denoting that the teacher had reclaimed the power of speaking back from students. González and Herbst further summarized that "the observation... suggests that the teacher was in control of leading and organizing the argument made through the discussion". These findings echoed previous research and literature, which documented teachers' power over speaking rights (e.g. Cazden, 2001, p. 82). Thus, differentiating external and internal

conjunctions allows us, for example, to examine how teachers affect and organize classroom discourse.

Similarly, Young and Nguyen (2002) examined the use of conjunctions in high school science classes. They showed that the type of conjunctions used by the teacher were predominantly internal conjunctions, which indicated that the teacher maintained the flow of classroom discourse. Furthermore, González (2015) studied how internal and external conjunctions were used in geometry classroom discourse. Consistent with previous findings, she found that the teacher was proficient in using internal conjunctions to construct classroom discourse. For example, the teacher used the internal conjunction *next* as a way to tell the class to build a new triangle, which gave students clear instructions on what a proper action was at that time.

Examining the teacher's differentiated use of external and internal conjunctions in U.S. and Chinese lessons allows us to examine how teachers control their classroom discourse as well as maintaining their authority across cultures. Examining students' differentiated use of external and internal conjunctions serves as a lens to investigate whether or not students are proficient in using internal conjunctions, which is a reflection of their ability to clearly and logically produce complex statements.

Four Logical Relationships

Conjunctions can be divided into four sub-categories of logical relationships: addition, comparison, time, and consequence (Martin & Rose, 2007). As each is important, I will describe these further.

Below is an example of the logical relationship associated with addition:

Teacher: With integers and decimals, we can line their places up. Then how about fractions with the same denominators? Jim, how shall we line them up?

Jim: Line their denominators up *and* line their fraction lines up.

Here, in Jim’s statement, *and* signals the addition of “line their fraction lines up” to the previous activity, and serves to connect the 2 clauses within Jim’s statement.

Similar examples include *rather than* in the comparison logical relationship, *when* in the time logical relationship, and *because* in the consequence logical relationship. A complete list of conjunctions associated with the four logical relationships can be found in Table 1. Investigating these conjunction sub-categories is important because they show how these logical relationships are established in mathematical lessons. Analyzing these categories reflects how students speak, and helps us understand how they reveal their ideas.

Table 1

External and Internal Conjunctions with Different Logical Relations (Martin & Rose, 2007)

	Logical Relations	Tokens
External Conjunctions	Addition	and, besides, both ... and, nor, neither ... nor, or, either ... or, if not ... then
	Comparison	like, as if, whereas, while, instead of , in place of, rather than, except that, other than, apart from
	Time	after, since, now that, before, once, as soon as, until, as, while, when

Table 1 (cont.)

	Consequence	because, so, therefore, although, even though, but, however, by, thus, even by, but, if, then, provided that, as long as, even if, even then, unless, so that, in order to, in case, even so, without, lest, for fear of
Internal Conjunctions	Addition	further, furthermore, moreover, in addition, as well, besides, additionally, alternatively, nor, neither ... nor, now, well, alright, okay, anyway, anyhow, incidentally, by the way
	Comparison	similarly, again, whereas, while, that is, i.e., for example, for instance, in general, in particular, in short, in fact, indeed, at least, rather, by contrast, on the other hand
	Time	conversely, first, second, third, next, previously, finally, lastly, at the same time, still
	Consequence	thus, hence, accordingly, in conclusion, consequently, after all, anyway, anyhow, in any case, at any rate, admittedly, of course, needless to say, but, however, nevertheless, nonetheless, still

More importantly, if there is a large number of conjunctions, it would be unwise to investigate them individually across different lessons. Examining conjunctions categorized by four logical relationships can help us understand the big-picture use of conjunctions, and inform us of what logical relationship categories were mainly involved in mathematics lessons.

For instance, Young and Nguyen (2002) investigated the logical relationships expressed by conjunctions in science lessons. It was shown that most of the conjunctions were associated with consequential relationship, such as *because*, *so*, *if*, and *so that*, and with temporal relationship, expressed by conjunctions such as *before*, *after*, *when*, and *finally*. As an example, teachers frequently used *because* and *so*, conjunctions that indicate the consequence conjunction logical relationship, which showed that teachers mainly explained and drew conclusions from arguments during their science instruction.

González (2015) studied what logical relationships were involved in high school geometry classes, and found that the addition logical category was the most commonly used relationship by teachers. The most predominant conjunction in the addition category used by the teacher was *and* (Martin & Rose, 2003, p. 113). The teacher used *and* to connect clauses and smooth statements. Meanwhile, the teacher produced a number of conjunctions associated with the consequence logical relationship, such as *so* and *because*, to denote the causal relationships among statements. This suggested that the teacher was more explicit regarding the connection and combination of clauses, as demonstrated by the use of conjunctions with the addition logical relationship, as well as more explicit regarding the chain of consequences of activities in the argument, as demonstrated by the use of conjunctions associated with consequence logical relationship.

Similarly, González and Herbst (2013) also discussed how conjunctions expressing various logical relationships could serve to connect components of mathematical statements. For example, in a geometry lesson that González and Herbst examined, they found that students and teacher frequently used the conjunctions *if*, denoting the premises of events, and the conjunction *then*, denoting the consequences of events, both of which were frequently used conjunctions in daily mathematics lessons (O’Halloran, 2005, p. 124). In one episode (refer to Figure 1), the teacher stated “If these two [Points at angles *MPO* and *NOP*] are right angles [Waves hand up and down along *MP* and *NO*], why are these sides parallel, Anil?” Here, the teacher gave students the background information “if these two are right angles”, and proceeded to ask them to come up with ways to prove that the two sides of the rectangular are equal. *If* introduced the premise of the problem, and played a critical role in the teacher’s statement.

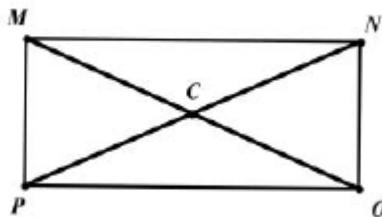


Figure 1. Homework problem (Redrawn following Boyd, Burrill, Cummins, Kanold, & Malloy, 1998, p. 309).

Furthermore, in a classical experiment, Sternberg (1979) tested students’ comprehension of logical connectives across different ages, from second-grade students to college students. For different scenarios (different shapes and fruits were shown to students), students were expected to evaluate the correctness of statements using different types of conjunctions, including *and*, *or*, *only if* and *if then*. It was found that across ages, it was more difficult for students to comprehend statements using consequence conjunctions, such as *only if* and *if then*, than addition

conjunctions, such as *and* and *or*, which suggested that linguistic factors, specifically the types of conjunctions used in this case, significantly contributed to problem difficulty. The study also demonstrated another equally important point: although students became more familiar with using conjunctions as they grew older, they still made mistakes when they evaluated the statements with different conjunctions. As such, the mastery of conjunctions is a continuous learning process. This study replicated Paris's (1973) findings at all age levels, which also showed that conjunctions such as *and* were the easiest type of relationship to understand. It needs to be noted that although these studies found significant differences in understanding some conjunctions, they did not examine all of the conjunctions within each logical relationship category. It would be excessive to jump to the conclusion that conjunctions expressing one type of logical relationship are more difficult for students to comprehend than those expressing another, but through these studies, we have reason to believe that conjunctions from different logical relationships serve different purposes, and it is necessary to differentiate conjunctions according to their corresponding logical relationships.

Conjunctions Used by Students as well as Teachers

Research supporting Sternberg's conclusions has been well documented (e.g., Neimark & Slotnick, 1970). The fact that students of varying ages comprehend conjunctions in different ways implies that elementary school students understand conjunctions in ways different from adults. As such, communication between students and their teachers risk being impaired due to their different understanding and use of conjunctions. This points to the importance of examining how teachers use conjunctions and whether or not the use of conjunctions by teachers and students is similar or different.

In addition, social learning theory has long argued for the modeling effects in classroom settings (e.g. Bandura, 1977), citing the idea that students learn by imitating and reproducing teachers' actions. As Allington and Cunningham (2007) pointed out, all children need, and some of them need more, modeling and demonstrations of how language is used. Thus when teachers use many conjunctions, it is possible that students produce a large number of conjunctions as well.

On the other hand, conjunctions can be used to enhance the effects of modeling. Fisher, Frey, and Lapp (2008) interviewed 25 expert teachers' modeling/demonstration strategies. It was found that focusing on the ways that speakers (i.e., teachers) organized the statements was one of the most effective modeling and learning practices for listeners (i.e., students). In particular, expert teachers agreed that relationships such as the cause effect relationship and the consequence relationship should receive attention in modeling practices, where a lot of them were expressed through conjunctions, such as *because*, *so*, *if*, and *then*.

Therefore, it is necessary to investigate the conjunctions used by both students and teachers, as it informs us of how those conjunctions are interrelated. However, it needs to be noted that the current examination of conjunctions focused on the correlation between the use of conjunctions by students and by the teacher, rather than a causal relationship in the use of conjunctions. The current investigation only studied the relationship through an observational data set, without experimental manipulations; thus no causal conclusions could be drawn. Specifically, I examined the correlation between the use of external conjunctions by the teacher and by students, as well as the correlation of the use of internal conjunctions by the teacher and by students. It has been shown that internal conjunctions are mostly used by person(s) controlling the discourse, so it may be expected that teachers will use internal conjunctions quite

frequently, but students will not; meanwhile, with social learning theory in mind, one would expect that modeling effects may lead students to imitate what teachers do, suggesting that students may follow teachers, and use many internal conjunctions if their teacher does so. Therefore, there arises the paradox, which demands empirical research to solve the puzzle, further suggesting the importance of the current study. To do so, I first looked at how frequently the teacher and students used conjunctions, and whether or not the frequencies were correlated. Second, I examined how teachers and students used internal and external conjunctions.

Conjunctions in English and Chinese

To make this a viable cross-linguistic investigation, I need to demonstrate sufficient comparability in the use of conjunctions across languages. To begin, English and Chinese share similar word order and sentence structure.

More important for this investigation, conjunctions are comparable in English and Chinese for at least three reasons. First, all of the English conjunctions, which are listed in Table 1, can be translated into Chinese conjunctions, and all of the Chinese conjunctions can be translated into English. For instance, *or* in English is equivalent to *或* in Chinese, and *和* in Chinese can be translated into *and* in English. Below is an example of a Chinese student's statements using conjunctions translated into English:

Teacher:	{分数单位}	{是}	{相同的},	{所以}
	{ The units of fractions }	{are}	{the same},	{so}
	{我们}	{可以}	{直接}	{把分子相加}。
	{we}	{can}	{directly}	{add up the numerators}.

For almost all of the statements in Chinese lessons, they can be translated into English word by word, including conjunctions. However, there is one exception, *and*, because in

Chinese, clauses can be connected without explicitly saying *and*. The details of tackling this issue will be fully discussed in the Method section.

Second, distinct from verbs or nouns in English, both English and Chinese conjunctions have fixed forms, and do not change when the contexts change. For example, *apple* (countable noun) has plural forms *apples*, and *change* (verb) has past tense *changed*, but conjunctions stay the same regardless of the contexts. For example, the English conjunction *but* does not change in different contexts, and similarly the Chinese conjunction *但是* stays the same in declarative sentences, interrogative sentences, or negative sentences.

Third, studies have applied SFL techniques and examined the use of cohesion and conjunction systems in a variety of languages in addition to English, such as Russian (Simmons, 1981), Hindi (Kachroo, 1984), Persian (Roberts, Barjasteh Delforooz, & Jahani, 2009), and Chinese (Hu, 2001). The development of SFL for both English and Chinese makes the analyses and comparisons of the present study possible (e.g. Li, 2007). In fact, Halliday's SFL framework was inspired by his study of the Chinese language, and Chinese scholars have had a long-standing interest in applying SFL techniques to the study of Chinese (e.g. Hu, Zhu, & Zhang, 1989; Hu, 2001; Li, 2007).

Hu (2001), following Halliday's conventions, discussed how conjunctions in Chinese, like in English, are used for elaboration, extension, and enhancement, and ultimately realized SFL's two metafunctions: textual and ideational functions. Similarly, Li (2007) stated that the system of conjunctions is a "complementary resource for the creation and interpretation of text" (pp. 226). Thus it is logically reasonable and technically plausible to compare the use of conjunctions in English and Chinese.

Overview of the Current Study

Although the analysis of conjunctions is a well-established technique in linguistics, only limited research has examined the use of conjunctions in mathematics teaching and learning. Also, previous research neither examined younger students, nor took a cross-cultural perspective. In addition, most of the empirical studies of conjunctions focused on the teacher's instructional role, and did not systematically examine discourse from the student perspective. Furthermore, most of the studies focused on a small amount of text such as individual episodes. The current study tried to fill these gaps by examining the use of conjunctions in 13 U.S. and 17 Chinese upper-elementary school mathematics lessons using mixed methods. In this study, I explored the density of conjunctions in general, as well as the density of different categories of conjunctions, seeking to reveal ways in which U.S. and Chinese students communicate the expression, organization, and connection of mathematical ideas. Moreover, I examined what type of conjunctions teachers used, and whether or not the use of conjunctions by students was correlated with the use of conjunctions by teachers.

Specifically, the current study investigated three interrelated issues:

1. Did the U.S. students or the Chinese students in this sample produce a higher density of conjunctions?

It was important to ask this question because conjunctions provide an intriguing window on how mathematical ideas are connected and expanded. In general, finding more common use of conjunctions in one site over the other could indicate more explicit connections across mathematical ideas in that site. No prior studies had been done to examine this, thus I had no a priori reason to expect that students would use conjunctions more in one site than the other.

2. Given that different conjunctions serve different functions, how were different categories of conjunctions produced by students similar or different between the U.S. and the Chinese lessons?

It was important not only to see where there might be more conjunctions, but also what sorts of conjunctions students used in their mathematical talk. To answer this question, I investigated the two different types of conjunctions, and also examined the logical relationships, so I ask:

- a. How frequently did students use external and internal conjunctions in the U.S. and Chinese classrooms? Within the same cultural sample, which type of conjunctions were more frequently used? Within each type of conjunctions, which cultural sample produced a higher density of conjunctions?

This would be important to uncover because internal conjunctions serve the purpose of connecting ideas across multiple turns, usually signaling the connection of larger idea units and the explicit organization of ideas across turns. Given that those with authority ought to do this more frequently than those with less authority, one should expect that teachers use internal conjunctions more than students (González & Herbst, 2013). One should also expect that the Chinese teachers use more internal conjunctions than the U.S. teachers because the Chinese teachers have a position of greater authority than the U.S. teachers, given Confucian-based culture (Wong, 2004). If this was the case, this should also result in Chinese students producing proportionately fewer internal conjunctions than U.S. students.

- b. How frequently did students use the four types of logical relationships in the U.S. classrooms and Chinese classrooms? Within the same cultural sample, which type(s) of logical relationships were more/less frequently used? Within each

logical relationship, which cultural sample produced a higher density of conjunctions?

Examining conjunctions categorized by four logical relationships could help us understand the big-picture use of conjunctions, and inform us of what logical relationship categories were mainly involved in mathematics lessons. Also, considering the previous findings that addition and consequence logical relationships predominated in high school science and mathematics lessons (González, 2015), I hypothesized that these two types of logical relationship categories were also frequently used in elementary schools, but I had no a priori reason to expect that students would use a certain type of logical relationship more in one site than the other.

3. How frequently did the U.S. and Chinese teachers in this sample use external and internal conjunctions?

Students and their teacher might have different understandings of conjunctions, thus it was equally important to investigate the use of conjunctions by their teacher.

a. Did the U.S. teachers or the Chinese teachers in this sample produce higher density of external and internal conjunctions?

More importantly, it was worthwhile to examine how the use of conjunctions by students and by their teacher were related.

b. Was there a relationship between the frequencies (as measured by lexical density) of conjunctions used by teachers and their students?

Given the modeling effects of Social Learning Theory, I hypothesized that there would be a positive correlation between the frequencies of conjunctions used by teachers and those by their students.

- c. Was there a relationship between the frequencies of external conjunctions used by teachers and their students?

For the same reason as above, I hypothesized that there was a positive correlation between the frequencies of external conjunctions used by teachers and that by their students.

- d. Was there a relationship between the frequencies of internal conjunctions used by teachers and their students?

Similarly, I hypothesized that there was a positive correlation between the frequencies of internal conjunctions used by teachers and that by their students. However, studies have also shown that internal conjunctions were mostly used by person(s) controlling the discourse (González & Herbst, 2013), so it might be expected that teachers would use internal conjunctions quite frequently, but students would not. Thus I hypothesized that the positive correlation between the frequencies of internal conjunctions used by teachers and those by their students would be diminished by this effect.

CHAPTER 3

METHOD

Data Sources

A cross-sectional dataset of a total of 30 lessons were used for analysis. The sample included 13 classrooms from 6 schools in university towns in or near a university community in the Midwest, and 17 classrooms from 8 schools in Beijing, China. One lesson was videotaped for each of the 30 teachers, and the U.S. and Chinese lessons were taken from typical classes. The U.S. classrooms had an average of 22 students, while those in China had an average of 55 students. Although the lessons sampled in this study do not represent U.S. or Chinese lessons as a whole, the richness of the classroom conversation observed in both locations provides valuable opportunities to understand how students talk and what they say.

To make a valid comparison of frequencies of conjunctions across lessons, I used lessons that focused on the same topic. In these fourth- and fifth-grade lessons, finding equivalent fractions and adding fractions of unlike denominators were concepts targeted for video recording. Each teacher was asked when they would teach the targeted lesson, and then researchers made an appointment with these teachers, coming into each classroom and videotaped the lessons. All of the lessons were recorded during the spring semester, which was the second semester of instruction in both countries. None of the schools investigated followed a year-round schedule. When the lessons were recorded, two cameras were placed in the classrooms, so that one captured the teacher's moves, and the other captured the class from the students' position. Teachers were informed that they were interested in mathematics teaching and learning, but the specific purpose of this study was not revealed to the teacher or students.

All of the lessons were transcribed. The Chinese lessons were translated into English and back-translated for accuracy by researchers who spoke both English and Chinese frequently. The transcripts form the corpus used in this data analysis.

Coding Strategies

Rules for identifying conjunctions. Analyses of conjunctions were conducted for all lessons. I followed Martin and Rose's (2007) routines and descriptions (see Table 1) to identify conjunctions. Because the focus of my dissertation was to understand how students expressed their mathematical ideas using conjunctions, the following rules were also applied to identify conjunctions.

First, conjunctions were only identified during instructional time. Time spent on classroom management was excluded, because I sought to gain an understanding only of how students and teachers communicated during mathematical instructional time. For this reason, I did not include conjunctions in non-mathematical discourse. Consider the following example:

Teacher: John, put down your pen *and* come to the blackboard.

Although the statement was generated during the mathematics lesson, it was not directly related to mathematics, thus this statement was not included in the analysis.

Second, terms listed in Table 1 were considered conjunctions if and only if they connected clauses, statements, or paragraphs. For instance, *so* is listed in Table 1 as a conjunction term, but in the statement "she is *so* smart," *so* was treated as an adverb rather than a conjunction. Similarly, *and* in "6 *and* 10 is 16" was also excluded, because it served as a mathematical operation rather than connecting clauses and students' ideas.

Third, restarts and fillers were excluded from analyses. Oftentimes, students repeated phrases, restarted their sentences, or otherwise used conjunctions when speaking, but not all of these instances represent conjunctions. Consider the following examples:

Kate: *So* it would be... *So* it would be... *So* it would be zero percent.

In this example, Kate used *so* three times. In the first two instances, Kate did not complete her idea, but did in the third instance “*so* it would be 0 percent.” Although she said *so* three times, *so* only served as a conjunction in the third instance. For the first two instances, *so* was treated as a restart; they neither connected students’ statements or their mathematical ideas. This rule applied equally in Chinese and English lessons.

Also, consider the following example:

Tracy: The denominator is *like* the bottom part of the fraction.

In this example, *like* was a quotative marker (filler word) in the statement because it did not connect clauses or statements. It could be deleted and the meaning of the sentence stayed the same. Counting these kinds of terms would inflate the frequency of conjunctions, masking the true relationships that students expressed.

Fourth, all Chinese conjunctions were translated into English so that conjunctions could be properly compared. However, the translation process of conjunctions from Chinese into English was not a one-to-one process. For example, each of the words *所以*, *因此*, and *因而* in Chinese can be translated as *so*, *thus*, or *therefore* in English. For the sake of clarity and consistency, all Chinese conjunctions were translated into the most frequently used word for that meaning in English—in this case, *so*. Because of this, the variety of conjunctions used in Chinese lessons could potentially be underestimated due to this somewhat arbitrary translation process. For this reason (among others), I did not examine the variety of conjunctions. Because the

translation of Chinese conjunctions did not change the categories (external conjunctions or internal conjunctions) or the logical relationships (addition, comparison, time, and consequence) into which these conjunctions fell, I could conduct these planned comparisons.

Fifth, efforts to count the conjunction *and* were handled based on contexts. During the translation process, a lot of Chinese sentences were translated into simple sentences without the conjunction *and* being counted. *And* is a widely used word in English, and often adds information to phrases or clauses occurring before the word *and*. However, the corresponding words in Chinese, *而且*, *并且*, and *且* are not as frequently used. As such, the frequency of conjunctions obtained from Chinese lessons could be underestimated. However, there were also some instances when *and* had to be added to make a translation from Chinese to English meaningful. Consider the following translation as an example:

Teacher:	{我们可不可以}	{分子和分子相加},
	{Can we}	{add up the numerators},
	{分母和分母相加}	{来计算}?
	{add up the denominators}	{to calculate}?

Although without the conjunction *and* the statement was acceptable in Chinese, *and* had to be added between the two clauses to make the English translation meaningful. Thus, as the use of *and* in Chinese is ambiguous in English translations, the inclusion of the conjunction *and* in Chinese translations into English were made based on the necessity of this term in the English translation. Note that *and* was added to ease the translation if and only if it was necessary.

Sixth, the identification of external and internal conjunctions was also based on contexts. Table 1 provides a guideline for locating these conjunctions, but determination of external and internal conjunctions was done case by case.

Seventh, conjunctions were coded for students and teacher separately, so that the correlation of the use of conjunctions could be established between the students and their teachers.

Lexical density of conjunctions. After the total number of conjunctions in each lesson was counted, the total number of words in each lesson was also counted, so that the rate of conjunctions could be calculated. Following Eggins (1994), Fang (2005), and González (2015), the study examined lexical density of conjunctions rather than counts of conjunctions, and it served as the dependent variable in the statistical analyses for this study. Lexical density of conjunctions was calculated as the number of conjunctions divided by the total number of words uttered by students or teachers. For example:

- Teacher: *Okay*, look at this question. How do we solve $1/2$ plus $1/3$?
Can they be added up directly (note: add up directly here means adding up without finding the common denominator)?
- Ashley: They cannot be added up directly, *because* their denominators are different.
- Teacher: Denominators are different, is that right?
- Students: Yes!

In this example, there was one internal conjunction, *okay*, used by the teacher, to help herself transition from discussing the previous question to the current one. The total number of words that the teacher uttered was 24. So the lexical density of conjunctions was $1/24$. There was also one external conjunction, *because*, produced by the student, to help her explain why $1/2$ and $1/3$ could not be added directly. The total number of words uttered by her and her classmates was 12, so the lexical density of conjunctions for the students was $1/12$.

External and internal conjunctions. I conducted analyses of external and internal conjunctions following Martin and Rose's (2007) routines and descriptions (see Table 1).

Conjunctions were coded separately for external and internal conjunctions.

External conjunctions describe what is happening, connecting small chunks of information (usually within a sentence), and can be found anywhere in the text. For example:

Teacher: 16 times 2. Why would you say 16 times 2?

Jim: *Because* 16 plus 16 equals 32, *and* 16 times 2 is 32.

In this example, *because* and *and* were used by the student, Jim, to give an explanation and discuss the cause of the event. They connected small chunks of information, and did not serve to help transition among different questions, contents, or topics. The student's statement was coded as incorporating two conjunctions.

Internal conjunctions are used when a new or different chunk of information is introduced. Many of the terms used to form internal conjunctions are the same as external conjunctions, such as *also* and *thus*. Therefore, the identification of internal conjunctions depends on the context, rather on the vocabulary used to communicate the connection across idea units. Here is an example of the use of internal conjunctions in a Chinese lesson:

Teacher: Who can tell us in brief how to add different-denominator fractions? Yi?

Yi: In the addition of fractions with different denominators, *first* we have the two fractions share the same denominator, and *next* do the calculation. *Next* you can do the fractions with different denominators.

In this example, *first*, *next*, and *then* were used to indicate and list steps to add fractions with different denominators. They were used to help the student, Yi, to explain the procedures of doing addition of fractions with different denominators, and connected large chunks of information. The student's statements contained three internal conjunctions in this example.

Logical relationships of conjunctions. Besides coding conjunctions for their status as external or internal, I also coded conjunctions for their logical relations: addition, comparison, time, and consequence. Here are examples of relationships set up by conjunctions:

Teacher: Okay, Tom said a cube is 3-dimensional and a square is flat.

 What is another way to say that a square is flat, Lisa?

Lisa: You hold it *and* it's just like flat on your hand.

In the example above, *and* functions to connect clauses, and the second clause was *added* to the first activity, thus it was coded as having an addition relationship.

Here is an example of a comparison relationship:

Teacher: $1/5$ equals to $5/15$, which equals to $2/20$. Is this right?

John: No.

Teacher: Why not?

John: From $1/5$ to $5/15$, the denominator is multiplied by 3 from
5 to 15, while the numerator is multiplied by 5 from 1 to 5.

 They are not multiplied by the same number.

A comparison relationship includes similarities and differences. In the example above, John used *while* to contrast the two ideas, and the differences of the change of numerators and denominators were made clear and explicit with the conjunction *while*.

Here is an example of a time relationship:

Teacher: Could you tell us how you calculated them? You please.

Crystal: *When* we do 17 plus 25, we line each place up.

In this example, *when* was used when several events happened at the same time. It indicated that “17 plus 25” and “we line each place up” happened simultaneously, thus was coded as being an example of a time relationship.

Below is an example of a consequence relationship:

Teacher: A fraction can have many different names and mean the same number or same amount. Lucy?

Lucy: Three-sixths can be one-half *because* it is half of something.

In this example, the student provided her explanation for “three-sixths can be one-half” by saying “it is half of something” and used *because* to connect the two clauses.

Note that each conjunction can be coded mutually exclusively as either external or internal, and mutually exclusively categorized into one of the four conjunction logical relationships.

Reliability

Reliability was established between me, who speaks both fluent English and Chinese, and another researcher, who is monolingual in English, and has substantial elementary school teaching experience, and thus observant of classroom discourse practices. Twenty percent of the transcript data were used to establish reliability, for both students’ statements and teachers’ statements. Any disagreements were discussed until we came to an agreement. The Cohen’s (1960) Kappa was 0.89, which was considered a very high reliability.

Statistical Modeling

Multilevel logistic regression was used to model the data because different types of conjunctions were nested within classrooms, and the response variable is dichotomous (i.e., a word is a conjunction or is not a conjunction). Lexical density is modeled as the probability that a word is a conjunction. When using logistic regression, I assumed that distribution of the response variable was binomial. In other words, I was modeling $P(\text{conjunction}) = \text{count of conjunctions} / \text{count of total words}$ (count of total words acts as “n” in the binomial distribution). The multilevel logistic regression models were fit by maximum likelihood estimation (Gaussian quadrature) using the SAS (version 9.4) generalized linear mixed models procedure. Explanatory variables included country, conjunction categories (including “external” and “internal”), the logical relationships (including “addition,” “comparison,” “time,” and “consequence”), and interaction terms. The equations took the following forms:

Level 1: Discourse

$$\begin{aligned} \text{logit}(P(\text{conjunction}))_{ij} = & \log\left(\frac{P(\text{conjunction})}{1-P(\text{conjunction})}\right) = \beta_{0j} + \beta_{1j}(\text{Chinese lessons}) + \\ & \beta_{2j}(\text{external conjunctions}) + \beta_{3j}(\text{addition relationship}) + \\ & \beta_{4j}(\text{comparison relationship}) + \beta_{5j}(\text{consequence relationship}) + \\ & \beta_{6j}(\text{Chinese lessons} * \text{external conjunctions}) + \beta_{7j}(\text{Chinese lessons} * \\ & \text{addition relationship}) + \beta_{8j}(\text{Chinese lessons} * \text{comparison relationship}) + \\ & \beta_{9j}(\text{Chinese lessons} * \text{consequence relationship}) . \end{aligned}$$

Level 2: Classroom

$$\beta_{0j} = \gamma_{00} + U_{0j}, \beta_{1j} = \gamma_{10}, \beta_{2j} = \gamma_{20}, \beta_{3j} = \gamma_{30}, \beta_{4j} = \gamma_{40}, \beta_{5j} = \gamma_{50}, \beta_{6j} = \gamma_{60},$$

$$\beta_{7j} = \gamma_{70}, \beta_{8j} = \gamma_{80}, \beta_{9j} = \gamma_{90}$$

It needs to be noted that the model construction was based upon statistical properties: the current model included variables that deserved to be investigated, but it was not necessarily the final model for the analysis, meaning model convergence was also considered. The next chapter reported results on the questions that I proposed at the end of chapter 2.

CHAPTER 4

RESULTS

In this section, I report the results based on the sequence of research questions that I proposed at the end of Chapter 2.

Did the U.S. or the Chinese students in this sample produce higher lexical density of conjunctions?

Descriptive statistics. The U.S. students and the Chinese students produced a total number of 1,069 conjunctions in 30 lessons: the U.S. students produced 196 conjunctions across 13 lessons, while the Chinese students produced 873 conjunctions across 17 lessons.

The U.S. students and the Chinese students produced a total number of 24,327 words in the sampled 30 lessons: the U.S. students produced 5,570 words across 13 lessons, while the Chinese students produced 18,757 conjunctions across 17 lessons.

The U.S. students and the Chinese students produced a conjunction density of .044 in the sampled 30 lessons: U.S. students produced a conjunction density of .035 (or 35 conjunctions every 1000 words, on average) across 13 lessons, while Chinese students produced a conjunction rate of .047 across 17 lessons.

Statistical tests. A multivariate T-test was conducted to examine the different use of conjunctions across U.S. and Chinese samples because the number of conjunctions, the number of total words, and the conjunction density were highly related variables Country was the only independent variable in this model. Table 2 shows correlations between the three dependent variables.

Table 2

Correlations Between the Number of Conjunctions, Words, and the Conjunction Density

Measure	1	2	3
1. Number of Conjunctions	—		
2. Number of Words	.91***	—	
3. Conjunction Density	.82***	.67***	—

*** $p < .001$.

A multivariate T-test indicated that, overall, there was a significant country effect on these three dependent variables, Hotelling $T = 1.21$, $F(2, 17) = 4.22$, $p < .001$. Thus, follow-up tests were performed to examine the number of conjunctions, the number of total words, and the conjunction density separately, with Bonferonni adjustments to control for Type I error.

It was found that, on average, the Chinese students produced more conjunctions than the U.S. students per lesson, $t(26) = 4.61$, $p < .001$. The effect size was very large (Cohen's $d = 1.64$) according to Cohen's (1988) convention. The descriptive statistics (i.e., means, standard deviations, t values, and effect sizes) of number of conjunctions, number of words, and conjunction density are reported in Table 3.

It was found that, on average, the Chinese students produced more words than the U.S. students per lesson, $t(28) = 5.70$, $p < .001$. The effect size was very large (Cohen's $d = 1.61$).

A z-test for whether the proportion of conjunction densities for Chinese and the proportion for U.S. students were the same indicated that Chinese students produced a higher density of conjunctions than the U.S. students ($z = 3.63, p < .001$). The effect size was very large (Cohen's $d = 1.05$).

Table 3

Different Use of Conjunctions across U.S. and Chinese Samples

	U.S.	Chinese	statistics	Effect Size
	<i>M (SD)</i>	<i>M (SD)</i>		<i>d</i>
Number of Conjunctions	15.08 (15.12)	51.35 (27.44)	$t = 4.61^{***}$	1.64
Number of Words	428.46 (342.89)	1103.35 (304.09)	$t = 5.70^{***}$	2.08
Conjunction Density	0.03 (0.02)	0.05 (0.01)	$z = 3.63^{***}$	1.05

*** $p < .001$.

How frequently did students use external and internal conjunctions in the U.S. and Chinese classrooms?

Descriptive statistics. The U.S. students and the Chinese students produced a total number of 802 external conjunctions in 30 lessons: the U.S. students produced 187 external conjunctions across 13 lessons, and the Chinese students produced 615 external conjunctions across 17 lessons.

The students across both samples produced a total of 267 internal conjunctions in 30 lessons: the U.S. students produced 9 internal conjunctions across 13 lessons, and the Chinese students produced 258 internal conjunctions across 17 lessons. Refer to Table 4 for average external and internal conjunction density across the sampled lessons.

Table 4

Means and Standard Deviations of External and Internal Conjunction Density

	U.S.	Chinese
	<i>M (SD)</i>	<i>M (SD)</i>
External Conjunctions	.029 (0.02)	.031 (0.01)
Internal Conjunctions	.001 (0.002)	.014 (0.01)

Statistical modeling. Multilevel logistic regression was used to examine the use of the two types of conjunctions across the U.S. and Chinese samples, because external and internal conjunctions were nested within each lesson, and led to dependencies of the data. Because I performed multiple significance tests of parameters, I used a Bonferonni adjustment to control for Type I errors.

Within the same type of conjunction. For external conjunctions, students in the Chinese sample had a significant higher probability of producing conjunctions than the U.S. sample, $t(28) = 3.04, p = .03$. For internal conjunctions, similarly, there was a significant higher probability of producing conjunctions in the Chinese sample than the U.S. sample, $t(28) = 7.89, p < .001$.

Within the U.S. sample and within the Chinese sample. Students in the U.S. sample had a higher probability of producing external conjunctions than internal conjunctions, $t(28) = 8.93, p$

< .001. Similarly, the Chinese students had a higher probability of producing external conjunctions than internal conjunctions, $t(28) = 11.76, p < .001$. Overall, across the two samples, students had a higher probability of producing external conjunctions than internal conjunctions, $t(28) = 8.93, p < .001$.

How frequently did students use the four logical relationships conjunctions in the U.S. and Chinese classrooms?

Descriptive statistics. The U.S. and the Chinese students produced a total of 294 conjunctions of addition logical relationship in 30 lessons: the U.S. students produced 83 conjunctions of addition logical relationship across 13 lessons; the Chinese students produced 211 conjunctions of addition logical relationship across 17 lessons.

The U.S. and the Chinese students produced a total of 62 conjunctions of comparison logical relationship in 30 lessons: the U.S. students produced 8 conjunctions of comparison logical relationship across 13 lessons, the Chinese students produced 54 conjunctions of comparison logical relationship across 17 lessons.

The U.S. students and the Chinese students produced a total of 464 conjunctions of consequence logical relationship in 30 lessons: the U.S. students produced 102 conjunctions of consequence logical relationship across 13 lessons; the Chinese students produced 362 conjunctions of consequence logical relationship across 17 lessons.

The U.S. students and the Chinese students produced a total of 306 conjunctions of time logical relationship in 30 lessons: the U.S. students produced 3 conjunctions of time logical relationship across 13 lessons; the Chinese students produced 246 conjunctions of time logical relationship across 17 lessons. Descriptive statistics for the conjunction density of four logical relationships produced by the U.S. and Chinese students can be found in Table 5.

Table 5

Means and Standard Deviations of Conjunction Density of the Four Types of Logical Relationships across the U.S. and Chinese Samples

	U.S.	Chinese
	<i>M (SD)</i>	<i>M (SD)</i>
Addition	.007 (0.008)	.005 (0.008)
Comparison	.001 (0.001)	.001 (0.002)
Consequence	.008 (0.010)	.009 (0.011)
Time	0 (0)	.007 (0.008)

Statistical modeling. Multilevel logistic regression was used to examine whether the conjunction density of the four types of logical relationships differed significantly across the U.S. and the Chinese lessons, and Bonferonni adjustments were made to the p-values.

Within the same type of conjunction. For conjunctions of the addition logical relationship, there was no difference between the conjunction density produced by the U.S. students and the Chinese students, $t(84) = 2.24, p = .11$. The Chinese students had a higher probability of producing conjunctions of comparison (logical relationship) than the U. S. students, $t(84) = 3.54, p < .01$. The Chinese students produced a significantly higher conjunction density of consequence (logical relationship) than the U. S. students, $t(84) = 3.92, p < .001$.

Students in the Chinese sample had a higher probability of producing conjunctions of time (logical relationship) than the U. S. students, $t(84) = 6.56, p < .001$.

Within the U.S. sample and within the Chinese sample. The U.S. students produced a similar conjunction density of consequence logical relationship and addition logical relationship, $t(84) = 3.92, p = .9822$. However, there was a lower probability of producing conjunctions of comparison (logical relationship) compared to conjunctions of consequence and addition (logical relationships), $t(84) = 6.79, p < .001$. The lowest probability of conjunctions was found in time (logical relationship), compared to other logical relationships in the U.S. sample, $t(84) = 4.43, p < .001$.

Chinese students had a higher probability of producing conjunctions of consequence (logical relationship) than other logical relationships, $t(84) = 12.42, p < .001$. Conjunctions of time (logical relationship), also quite frequently used in the Chinese lessons, were second to the conjunctions of consequence logical relationship, $t(84) = 4.7, p < .001$. The probability of addition (logical relationship) was lower compared to consequence and time (logical relationships), $t(84) = 4.34, p < .001$. The least used conjunctions were those of comparison (logical relationship) compared to others, $t(84) = 11.37, p < .001$.

How frequently did the U.S. teachers and the Chinese teachers in this sample use external and internal conjunctions?

Descriptive statistics. To answer this question, I first examined the frequency and density of external and internal conjunctions used by teachers in the U.S. and Chinese samples. In the U.S. lessons, teachers produced a total of 2,993 conjunctions: 1,941 external conjunctions and 1,052 internal conjunctions, and a total of 45,450 words. Refer to Table 6 for the means and standard deviations of the density of teacher conjunctions in the U.S. lessons.

In the Chinese lessons, teachers produced a total of 1,572 conjunctions: 767 external conjunctions and 805 internal conjunctions, and a total of 35,535 words. Also, refer to Table 6 for the means and standard deviations of the density of teacher conjunctions in the Chinese lessons.

Table 6

Means and Standard Deviations of the Density of External and Internal Conjunctions Produced by Teachers

	U.S.	Chinese
	<i>M (SD)</i>	<i>M (SD)</i>
External Conjunctions	.042 (0.014)	.021 (0.007)
Internal Conjunctions	.022 (0.009)	.023 (0.009)
Total Conjunctions	.064 (0.020)	.044 (0.012)

Statistical tests. Statistical tests were conducted within cultural samples and within types of conjunctions separately, and Bonferonni adjustments were made because multiple comparisons were made.

Within the same type of conjunction. For external conjunctions, there was a significantly higher probability of producing conjunctions by teachers in the U.S. sample than the Chinese sample $t(28) = 5.51, p < .001$. However, for internal conjunctions, the U.S. teachers and the Chinese teachers had comparable probabilities of producing conjunctions, $t(28) = 0.26, p = 1$.

Overall, the U.S. teachers had a higher probability of producing conjunctions than the Chinese teachers, $t(28) = 3.18, p < .01$.

Within the U.S. sample and within the Chinese sample. The U.S. teachers produced had a significant higher probability of producing external conjunctions than internal conjunctions, $t(28) = 16.30, p < .001$. Unlike the U.S. teachers, the Chinese teachers had similar probabilities of producing external and internal conjunctions, $t(28) = 0.97, p = 1$.

Correlations between conjunctions produced by teachers and students. Across both samples, there was no correlation between the density of total number of conjunctions produced by teachers and their students, $r(28) = -.003, p = .989$. Also, there was no correlation between the density of external conjunctions produced by teachers and their students, $r(28) = .124, p = .51$. However, there was a very strong negative correlation between the density of internal conjunctions produced by teachers and their students, $r(28) = -.563, p = .001$. In addition, there was a significant negative correlation between the density of internal conjunctions produced by students and the density of the total number of conjunctions produced by teachers. There was no significant correlation between the density of external conjunctions and internal conjunctions produced by teachers, nor was there a significant correlation between the density of external and internal conjunctions produced by students (Refer to Table 7).

Table 7

Correlations Between the Density of Total Number of Conjunctions, External Conjunction, and Internal Conjunctions Produced by Teachers and Students across Cultures

	Total Number of Conjunctions Produced by Teachers	Number of Internal Conjunctions Produced by Teachers	Number of External Conjunctions Produced by Teachers
Total Number of Conjunctions Produced by Students	-.003	-.071	.113
Internal Conjunctions Produced by Students	-.445*	-.563**	.005
External Conjunctions Produced by Students	.325	.335	.124

* $p < .05$. ** $p < .01$. *** $p < .001$.

CHAPTER 5

DISCUSSION

The results of the current study fill an important gap in extant research: I found evidence of different uses of conjunctions across different categories and logical relationships by both teachers and students, in upper elementary mathematics lessons, which had not been examined by previous studies. This study was also the first to adopt a quantitative method to examine the different uses of conjunctions in U.S. and Chinese lessons, using the SFL framework.

In this study, I tested the use of conjunctions across a sample of U.S. and Chinese lessons. Adopting the SFL perspective (Halliday & Hasan, 1976), I conceived of conjunctions as key linguistic resources that connect different components of teachers' and students' statements, which served to help them express their ideas clearly, coherently, and logically. Specifically, I examined how frequently (measured by conjunction density) U.S. and Chinese students used conjunctions. I studied the use of external and internal conjunctions, and the use of four logical relationships: addition, comparison, consequence, and time. Moreover, I looked at how frequently teachers used conjunctions of different categories and various logical relationships, and scrutinized how these choices were related to the use of conjunctions by students. In the remainder of this document, I discuss the use of conjunctions and how they inform cross-cultural learning and teaching practices.

The Density of Students' Use of Conjunctions across the U.S. and Chinese lessons

Chinese students had not only expressed themselves more, in terms of how many words they produced, when compared with their U.S. peers in mathematics lessons, but they also produced more conjunctions to connect the ideas. Because conjunctions are grammatical resources that help students speak clearly and logically, this is evidence that not only do Chinese

students have more to say than U.S. students, but also they could express their ideas more clearly and logically when they speak.

This result echoes prior investigations of the differences in mathematics teaching and learning across U.S. and Chinese lessons. In particular, past investigations have indicated that Chinese schools make efforts to engage their students in classroom discourse. The results fit in with reports that Chinese students, compared to their U.S. peers, are more likely to speak (Stigler & Perry, 1998) and generate more mathematical statements (Wang, Mingle, McConney, & Perry, 2011). This may be a result of the press for higher levels of learning (conceptual learning) found in Chinese mathematics lessons (e.g. Schleppenbach, Perry, Miller, Sims, & Fang, 2007). As such, it is not a surprise that Chinese students produced a higher density of conjunctions in the present study, especially given that the Cognitive Task Complexity Hypothesis (Robinson, 2007) suggests that higher frequency use of language units such as conjunctions may indicate that students are dealing with more complex tasks, or that more interactions are happening within the lessons. Thus, my findings are consistent with both existing theoretical support and empirical evidence; they also move beyond previous conclusions from previous cultural comparisons by looking at teaching and learning practices from a grammatical resource perspective.

Educational policies and documents (e.g., NCTM, 2000) endorse the importance of classroom discourse, and state that students' mathematics learning could be promoted if they communicate with their peers, teachers and others in a clear, coherent, and logical manner. Therefore, focusing on conjunctions—as a way to strengthen the clarity, coherence, and logic of students' statements about mathematics—can be useful to promote learning. However, data available for the current investigation did not allow me to examine the relationship between uses of conjunctions and learning; thus future research should bring in experimental features to

specifically examine how the use of conjunctions is associated with student mathematics learning.

Different Types of Conjunctions and Logical Relationships

I also looked at how frequently different types of conjunctions were produced in U.S. and Chinese lessons. External conjunctions are used to connect small chunks of information, while internal conjunctions connect large chunks of information (Martin & Rose, 2007). SFL theory and research posit that internal conjunctions are frequently used by the person(s) controlling the discourse (González & Herbst, 2013). Given that the Chinese students produced a significantly higher density of internal conjunctions than U.S. students, it seems that Chinese students have more control over classroom discourse than their U.S. peers. This is directly contrary to what is often believed should happen in Chinese lessons: under the influence of Confucianism, Chinese students are presumed to be silent and obedient to their teachers, wielding less power in classroom discourse and producing shorter statements than their U.S. peers (e.g., Leung, 2001). In fact, these findings are not unique. Li (2011) has found that Chinese teachers think a great deal about their students, and do not necessarily favor monologue-style instructions. Zhao and Ma (2007) further pointed out that Chinese teachers value student participation and make efforts to get students involved in classroom discourse. The fact that Chinese students produce more internal conjunctions than their U.S. peers could be a result of Chinese teachers' endeavors to provide students with opportunities to express themselves. An alternative explanation for the higher rate of internal conjunctions in the Chinese lessons is that Chinese students are required to speak more formally than U.S. students. Under such expectations, Chinese students could be more likely to produce internal conjunctions, which explicitly connect large chunks of information. Further studies need to look into this, and gain an increased understanding of the

reason for seeing different rates of internal conjunctions. It must be noted, though, that despite the work of Chinese teachers to engage students in communication, external conjunctions continue to dominate their students' classroom discourse. Because external conjunctions tend to connect small chunks of information, this indicates that students tend to provide information in small chunks rather than to give out a wealth of structured messages in a single statement. This holds true for both U.S. and Chinese students.

In looking at the logical relationships among conjunctions across U.S. and Chinese lessons, I found significantly more conjunctions across all logical relationships in Chinese lessons, compared with U.S. lessons, except in the case of the addition logical relationship, where U.S. students produced a similar density of conjunctions as Chinese students. These results are informative in two ways: First, it became clear that Chinese students did not rely on one type of logical relationships in their expressions. Instead, they produced a high density of conjunctions across all four logical relationships investigated here: addition, comparison, consequence, and time. Second, the contrast between the frequencies of conjunctions produced by students in the U.S. and Chinese samples was made clearer by the comparison. The addition logical relationship dominated the logical relationships of conjunctions in U.S. mathematics lessons; in contrast, this was among the least used in Chinese lessons.

Examining the use of conjunctions across logical relationships within each sample also implies at least three additional conclusions. First, in the U.S. lessons, students produced a vast amount of conjunctions of consequence logical relationship, such as *so*, *because*, *if*, and *then*. A similar amount of conjunctions of addition logical relationship was produced, because of the frequent use of *and*. These findings are in concert with a previous study that González (2015) conducted in U.S. high school geometry class, which indicates that the use of conjunctions could

be similar within a culture, regardless of student age. Second, in Chinese lessons, conjunctions of consequence logical relationship were also the most frequently used conjunctions. Thus, the consequence logical relationship was the most frequently used across both U.S. and Chinese samples. Note that these conjunctions express causes, means, conditions, and purposes (Martin & Rose, 2007). When students use logical conjunctions, they explain mathematical concepts and ideas, using words such as *because*; to give the result of an activity or provide reasoning process, using words such as *so*; and to give premises of an event or describe conditions and contexts, using words such as *if* and *then*. These communication features are also highlighted in NCTM *Principles and Standards of School Mathematics* (2000), which is evidence that students from both cultures are able to produce desirable classroom discourse. Third, an apparent cultural contrast lies in the use of the conjunctions with time logical relationship. Chinese students frequently used time logical conjunctions such as *first*, *second*, *next*, and *finally*, providing strong evidence that Chinese students have procedural concepts in mind, and can make statements that are structured and organized by sequences. On the contrary, U.S. students produced only 9 conjunctions with the time logical relationship over 13 lessons, indicating that they do not tend to explicitly express their mathematical ideas in a sequenced manner. Given the potential benefits of the explicit use of conjunctions, paying more attention to the previously less-noticed time relationship may contribute to more effective classroom discourse. Understanding this is critical to professional development because if these teachers know the different types of conjunctions that make mathematical meanings more explicit, they could be in the position to leverage this tool (time logical relationship) effectively.

Note that translations of discourse in the Chinese sample were used to compare with U.S. classroom discourse, so the comparison of conjunctions may not be strict, which is a potential

limitation of the study. Given that this study is one of the first to look into the use of conjunctions in mathematics lessons across cultural samples, more studies need to examine this method. However, this does not invalidate the current study, as the translations neither changed the type of conjunctions nor the logical relationship of conjunctions, the comparisons of which were the focus of the current investigation.

Teacher Conjunctions across Cultures and the Relationship between Teacher Conjunctions and Student Conjunctions

This study showed that the use of external and internal conjunctions by teachers generally was similar across U.S. and Chinese lessons. This may indicate that both U.S. and Chinese teachers place comparable attention on explaining detailed mathematical concepts (small chunks of information) and on organizing the structure and flow of their discourse (large chunks of information). In addition, both U.S. teachers and Chinese teachers produced similar amounts of internal conjunctions, indicating that they have similar power over classroom discourse. However, the U.S. teachers produced significantly more external conjunctions than the Chinese teachers did, suggesting that they generated more small chunks of information, which possibly is an indication of more teacher talk among U.S. than among Chinese teachers.

The relationship between teacher conjunctions and student conjunctions was examined through correlational analysis. A major finding was that the use of teacher internal conjunctions was negatively associated with the use of student internal conjunctions. An implication of this is that when teachers step back, teachers afford students relatively greater authority and provide students greater opportunity to generate structured and organized discourse. Therefore, from a linguistic perspective, this study lends considerable empirical support to previous research and documents that have found advantages in student-centered lessons (e.g., Cai & Wang, 2010).

Note that the correlational analysis aggregated the U.S. and Chinese lessons because of the small sample size. The small size is a potential limitation of the current investigation, and a larger number of lessons should be examined to draw affirmative conclusions. However, given the intensive labor of coding discourse using SFL, the current study is one of the few that examined the use of conjunctions quantitatively at this scale. Further studies could look into ways to ease the coding of discourse using SFL, so that larger-scale studies are plausible.

A related limitation of the study is that only students from Beijing were included in the Chinese sample. The differences of what we observed from these samples could be attributable to specific geographical features rather than cultural differences. Thus, the differences we observed should be interpreted with caution, and more studies in other locations in both countries would be necessary before making a generalized conclusion.

Conclusions

Previous papers drawing on SFL (e.g., González & Herbst, 2013) have examined the use of conjunctions through examining fragmented episodes, because coding grammatical resources is a labor-intensive task requiring both the identification of specific linguistic markers and an understanding of the contexts in which these markers are located. The current investigation represents a new contribution to this body of work given the reliance on quantitative methods—in particular, general and generalized linear mixed modeling statistical techniques—to ground its results in a relatively large sample of lessons, allowing for conclusions that may be generalized to larger student populations, in both the United States and in China.

Evidence from the study, from a linguistics perspective, supports the notion that U.S. students and Chinese students express mathematics differently. Moreover, the findings presented in the study also lend weight to the assertion that we cannot simply assume that Chinese students

are more silent than their peers in other countries because of the tradition of Confucianism. In addition, student talk and teacher talk are related, indicating that students discourse may be influenced and shaped by teachers. Hence, conjunctions are not only grammatical resources; they are also measures that can be relied upon to effectively examine mathematics teaching and learning practices, as well as possible tools to strengthen classroom discourse in key periods for students' mathematics development.

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