SURVEY OF NATIVE ENGLISH SPEAKERS AND SPANISH-SPEAKING ENGLISH LANGUAGE LEARNERS IN TERTIARY INTRODUCTORY STATISTICS

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ABSTRACT

The framework of linguistic register and case study research on Spanish-speaking English language learners (ELLs) learning statistics informed the construction of a quantitative instrument, the Communication, Language, And Statistics Survey (CLASS). CLASS aims to assess whether ELLs and non-ELLs approach the learning of statistics differently with respect to the distinctive linguistic features of the field of statistics and with respect to language resources they bring to the class. The CLASS was administered to all (n = 137) students in an introductory statistics literacy course at a university with a majority Mexican-American student body. Findings suggest ELLs often have distinctive patterns in how they experience aspects of statistics instruction (e.g., wait time) as well as movement between mathematics/statistics and everyday registers.

Keywords**:** *Statistics education research; Register; Context*

1. INTRODUCTION

This study involves Spanish-speaking ELLs (English language learners) learning introductory statistics. We use the term ELL for English language learner and non-ELL for a native English speaker. An ELL speaks English "with enough limitations that he or she cannot fully participate in mainstream English instruction." (Goldenberg, 2008, p. 10). Increased need for ELL research comes from considerations of equity (e.g., Abedi, Hofstetter, & Lord, 2004; LaCelle-Peterson & Rivera, 1994; National Council of Teachers of Mathematics, 2008; Ochoa & Pearl, 2010) and demographic trends. As for the latter, Goldenberg (2008) relates that the fraction of U.S. public school K-12 students who are ELLs has gone from 1/20 (in 1990) to 1/9 (in 2008) and is projected to be 1/4 by 2028. An example implication for college teachers is that the College Board reported that the 1.5 million college-bound students who took the SAT in 2009 were more diverse than any group before and a quarter reported that English was not their first language at home.

There have been some expository and didactic articles (e.g., Hubbard, 1991; Wood, 1990) but not empirical research about ELLs learning statistics. There have been a few research studies about

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language issues in learning statistics (e.g., Kaplan, Fisher, & Rogness, 2009, 2010; Lavy & Masiach-Eizenberg, 2009) or probability (e.g., Green, 1984), but these did not involve students learning in a second language. There have been a few research studies about second language learners learning probability (Kazima, 2006; Phillip & Wright, 1977), but probability is only a limited and increasingly deemphasized part of the introductory statistics curriculum and those studies did not involve Spanish -- the dominant language of 80% of ELLs in the United States (Goldenberg, 2008), and the world's most common non-English language other than Chinese. And although there are many other languages spoken by ELLs, no other single language besides Spanish comprises more than about 3% of ELLs in the United States (Abedi et al., 2004), and any native language translations of curriculum or assessments are generally available only in Spanish. Given the dearth of research on Spanish-speaking ELLs learning introductory statistics, the study of Lesser and Winsor (2009) was a much-needed initial contribution and stimulus for further work.

The core research question of the current study is whether ELLs and non-ELLs approach the learning of statistics differently with respect to the distinctive linguistic features of the field of statistics and with respect to the language resources they bring to the class. The research team includes a research statistician with interests in statistics education and Spanish, a mathematics/statistics education researcher, an applied linguist specializing in bilingualism, and a mathematics education graduate student researcher. The latter two authors grew up in México as native Spanish speakers who also experienced the Mexican educational system, as did many students at the participants' university. We first provide in Section 2 background that closely informed the current quantitative study described in Section 3.

2. PRIOR RESEARCH ON ELLs

Research on ELLs has consistently demonstrated interdependence of first and second language development. Cummins (1979) hypothesized that language and literacy development in the first language (L1) is a predictor of second language (L2) acquisition. In a recent review of relevant studies, Goldenberg and Coleman (2010) note that five major meta-analyses have shown that, particularly for learning reading, "teaching students to read in their home language can boost reading achievement in the second language by a total of about 12-15 percentile points over two to three years" (p. 27).

Whereas the above finding especially impacts younger learners, Ovando, Combs and Collier (2006) argue that insights regarding transfer hold for all learners: "Academic skills, literacy development, concept formation, subject knowledge, and learning strategies all transfer from first to second language and the vocabulary and communicative patterns are developed in L2 to express that academic knowledge" (p. 130). Similarly, Collier (1995) and Thomas and Collier (1997) propose a conceptual model of academic language acquisition. Academic language is not acquired in isolation, but in socio-cultural and academic context. In their model, language acquisition in an academic context comprises four major interdependent components: sociocultural factors, academic development, language development, and cognitive development.

Gibbons (2009) also notes that non-integrated approaches in which L2 acquisition is isolated from content area instruction are problematic. Gibbons argues that "language and content cannot be separated: concepts and knowledge on the one hand, and subject-specific language, literacy, and vocabulary on the other are interdependent" (p. 10). Similarly, Colombo and Furbush (2009) propose an integrated approach to content-area instruction where every lesson is simultaneously a content-area lesson and an English language development lesson. As an example, they describe an eighth-grade probability teacher's use of language-oriented techniques such as word walls and posted metacognitive (essential language) questions.

2.1. REGISTER

A *register* is a variety of language used in a specific situation. Within any particular language, there are many distinct registers, including everyday conversation, mathematics, statistics, and so forth. For example, the word "range" could be the difference between maximum and minimum values (statistics register), the set of values output by a function (mathematics/algebra register), the span of notes that can be produced (music register), the distance an aircraft can fly (aviation register), a controlled environment where golfers or marksmen can practice (sports register), a kitchen stove (everyday register), and so forth. Moschkovich (2002) argues that ELLs learn academic content by making multiple meanings for words, not just acquiring a list of words, and she states, "Unlike the notion of lexicon, the notion of register depends on the situational use of much more than lexical items and includes phonology, morphology, syntax, and semantics as well as non-linguistic behavior" (p. 194). Register theory proposes that situational context shapes the linguistic choices people make in the context of a situation (Eggins, 2004). Halliday and Matthiessen (2004) contend that three main dimensions of a situation account for how a register varies: the topic (or the *field*), the social relationship of the people in the interaction (or the *tenor*), and the role that language itself is playing in the interaction (or the *mode*). According to Eggins (2004), each dimension of register varies with several factors. *Field* varies on a continuum of technicality, with some topics indexing more technical areas of knowledge than others. *Tenor* varies on the continua of power, contact, and affective involvement, with some social relationships being more formal than others. *Mode* varies on the continua of spatial and interpersonal distance so that oral language has different linguistic characteristics than written language does.

For example, the *field* aspect of the register of mathematics favors highly technical meanings, which can be seen immediately in the lexical choices. For instance, Cuevas (2005) notes that *equal*, *rational*, *irrational*, *column*, and *table* all have technical meanings in the mathematics register that are different in everyday registers, and students must become proficient in this usage. Schleppegrell (2007) adds that technicality can also be conveyed in grammatical choices in mathematical texts including long, dense noun phrases and relational and attributive phrases, such as "the volume of a rectangular prism with sides 8, 10, and 12 cm" (p. 143). A statistics counterpart would be "the upper quartile of a normal distribution with mean 75 and standard deviation 10."

Research on the register of mathematics has focused on formal classroom contexts in which social relationships (teacher to student) impact language choices. For instance, Veel (1999) discusses the example of commands, such as a teacher giving instructions on problem solving. Finally, the *mode* dimension can impact language choices as well. In oral interactions, there are frequent opportunities for immediate feedback, and dialogic, co-construction of ideas whereas in writing, a writer expands and develops ideas as a monologue. Mathematical writing, moreover, characteristically draws on multiple forms of representation, including symbolic and visual representations (O'Halloran, 2005). According to Schleppegrell (2007), the mathematics register is challenging for all students, and especially for students with few opportunities to use academic registers outside school, including "speakers of nonstandard varieties of English and students for whom English is a second (or other) language" (p. 153).

Although there have been investigations into the register of mathematics, there is a dearth of information regarding the register of statistics. Educators have considered the importance of using the language (i.e., register) of statistics in teaching (e.g., Parke, 2008; Rangecroft, 2002; Rumsey, 2002). However, the present study is unique in its focus on ELLs.

2.2. MOVEMENT AMONG REGISTERS

A number of researchers have noted that students might be confused by the difference in meaning in everyday registers and in the academic statistics register. Colombo and Furbush (2009) note that polysemous words (words with multiple meaning) in mathematics are exemplified by terms such as *absolute*, *formula*, and *law*. Kaplan et al. (2009, 2010) define words that lack a core meaning as lexically ambiguous and suggest that ambiguous words such as "spread" (Kaplan et al., 2012) should be avoided. Lesser and Winsor (2009) note how students may be distracted by their prior familiarity with a term in the everyday register when they are then exposed to that same word with a different or more technical meaning in the academic statistics register. Examples they mention include *normal*, *random*, *correlation*, and *significant*. Pfannkuch (2011) gives the example of learners referring to "the average student," possibly in imitation of usage encountered in the everyday media. Hersh (1997) suggests that the inclusive "or" used in probability is difficult to embrace when almost all colloquial uses of "or" are exclusive.

In a few cases, there can be interference when the statistics word has a different (or even conflicting) meaning in an academic register of mathematics (especially algebra), which is typically in place *before* encountering many words (or a full course) in statistics. Specific examples in Lesser and Winsor (2009) include *variation* (which is deterministic in the context of direct, inverse, or joint variation), *range* (i.e., of a mathematical function), *estimate*, and *independent* (i.e., of a variable plotted on the horizontal axis). Another collection of examples between statistics, everyday, and other academic registers appears in Anderson-Cook, Lu, and Morzinski (2010). Related discussion of lexical ambiguity in statistics education appears in Kaplan et al. (2009, 2010).

Whereas ambiguity could be problematic in a field attuned to precision such as mathematics, scholars such as Barwell (2005) argue that the view that ambiguity is a problem to be avoided could be problematic itself. Some ambiguity can actually be a resource for discussion between teacher and students. Using a discursive approach, he shows how ambiguity might be used as a resource to promote dialog between teachers and students. (An example in statistics might be discussing the different lay, slang, and academic uses of the word *random*: Fisher, Kaplan, & Rogness, 2010) Likewise, Leung (2005) notes that developing technical meanings of the field of mathematics is not a linear process. Students constantly draw on everyday meanings to construct the technical meanings of the mathematics register, and weaning students off everyday language in mathematics classrooms could be counterproductive. Movement between registers is therefore a necessity for students, and teachers might guide students in that process.

2.3. ROLE OF CONTEXT

In register theory, the concept of field is used to capture the way in which language varies according the topic being discussed. As a contextual variable, field impacts word choices, as when the word *random* is used to convey a technical meaning in the field of statistics that is different in other fields. However, the field of statistics does often draw on everyday meanings within academic exchanges to contextualize statistical problems. Writers may refer to meanings that they assume are “common knowledge.”

It is therefore not surprising that context was an emergent theme in Lesser and Winsor (2009), given the special role context plays in statistics (Cobb & Moore, 1997; Huberty, 2000; Moore, 1988). Examples of data context discussed by Lesser and Winsor (2009) include “ski resort” and the use of the word “tails” in reference to a side of a coin. Students from México may find these references opaque. For instance, many are not used to “heads and tails,” but rather eagle, seal, or sun. In other Latin American countries, the sides of a coin might be described with shield, crown, face, or cross.

Many students might be confused by “real-world” references in written scenarios. They might not be familiar with the context that produced the data or statistics question as well as by the social context of the statistics classroom where they are learning the material. This correlates well with the respective distinctions used by Pfannkuch (2011) of data-context and learning-experience-context. Learning-experience-context, in turn, is broken down by Pfannkuch to include historical context (e.g., prior statistical knowledge of students and teacher), social context (e.g., interactions between students and teacher), and task-context (e.g., task sequence, motivating story). Recent teaching experiments (Langrall, 2010) and case study research (Gil & Ben-Zvi, 2011; Pfannkuch, 2011) vividly illustrate how context can play a major role in middle school students developing or using statistical inferential reasoning. Ross (1983) showed that pre-service teachers’ performance on items assessing probability rules could be improved through the use of context adapted to student background.

3. METHOD

3.1. SETTING AND PARTICIPANTS

The research site is a moderately large doctoral/research university located in a large city in the southwestern United States. Roughly 76% of the student population (and of the city) is Hispanic and about 10% of the Hispanic student population is Mexican nationals who commute across the border to take courses. A distinctive feature of this university is thus the high likelihood that a sample of students yields critical masses of both non-ELLs and Spanish-speaking ELLs.

The participants were all students attending the first day of the introductory statistics course in each of the university's five fall 2009 sections. The first day was chosen for two reasons: (1) to remove possible influence of different teaching styles (e.g., their strategy for addressing language issues) by the different instructors of the sections, and (2) to minimize intrusion into class time as the first day of class is often the only day teachers do not plan a full day of instruction.

The course used the statistics literacy approach of Utts (2005). This course is required only for pre-service elementary and middle school teachers, and most enrolled are pre-service elementary teachers, with some pre-service middle or high school teachers, and a few non-education majors taking the course as a newly-established option towards satisfying the university's core curriculum requirements. As Table 2 indicates, over 80% were some kind of pre-service teacher and 70% of the pre-service teachers were pre-service elementary teachers. About 85% of the survey participants were sophomores or juniors.

No compensation was offered for the survey, which took 20 minutes of class time. All n = 137 students attending that first class agreed to participate and no one withdrew later. The students were predominantly Hispanic (mirroring the demographic of the university student body) and an even larger proportion was female (mirroring the demographic of the population of pre-service teachers of younger students). In particular, the official enrollment for the five sections combined was about 87% female. The modal gender and ethnicity of the 137 survey participants (and of this university) match the gender and ethnicity (female and Hispanic, respectively) of the respondents in the Lesser and Winsor (2009) case study.

Of the 137 respondents, 53 self-identified as ELL (of these, 51 reported a mother tongue of Spanish and the two reporting a different native language were dropped from the analysis), 83 self-identified as non-ELL, and one did not self-identify either way (and was dropped). Because roughly three-quarters of the items were designed to be answered by both ELLs and non-ELLs, the researchers were able to administer a single survey discreetly to the entire sample, with a simple instruction that all items after item number 53 were to be answered only by ELLs (six non-ELLs answered these anyway, and those items of their surveys were ignored because they had self-identified as non-ELL already).

3.2. CONSTRUCTION OF THE SURVEY ITEMS

Over several summer 2009 meetings, the research team designed the *Communication, Language, And Statistics Survey* (CLASS) survey instrument. The version of the CLASS completed by students in the current study is presented in the Appendix. The items were designed to align well with register theory (see Section 2.1) and with Lesser and Winsor (2009), especially its Sections 3 and 5 and interview protocol. Item 47 uses the word *survey* (from Lesser & Winsor) as an example of phonology, which is included in the notion of register. This is, of course, simply one of many homograph words (where syllabic stress determines whether the word is an adjective, verb, or noun) that statistics courses use such as: *affect*, *aggregate*, *approximate*, *attribute*, *compound*, *contrast*, *coordinate*, *decrease*, *estimate*, *increase*, *record*, *reject*, and *subject*. The only item not connected directly to Lesser and Winsor was item 34, which we describe now. Because Spanish (unlike English) has adjectives following their nouns (e.g., male smokers would get translated as *fumadores masculinos*), it was conjectured that this might interact differently with identifying part-whole relationships (e.g., 20% of males are smokers vs. 20% of smokers are males), the very specific grammar of which has been detailed in Schield (2001).

The wording of many items was simplified or otherwise made more accessible to ELLs based on feedback from the fourth author, who is herself an ELL. For example, what is now item 10 had the following stem in the first draft of the instrument: "Adding more narrative explanations or alternative phrasing/wording in a textbook…" Another change informed by this colleague was adding an "I don't understand"-type option to certain items (items 4, 35-38, 41-43). The addition of that option allows distinguishing responses reflecting language-based difficulties and those suggesting a lack of knowledge about the statistical concept.

Virtually all items (except, for example, item 3 – the estimated percentage of the course material already known) were put into multiple-choice or Likert-response format to facilitate data entry and analysis. After two iterations, the researchers resolved all half-dozen initial disagreements to reach consensus on which items to classify as relevant only to ELLs and which items as relevant to all students. Having reached consensus, the researchers were then able to order the items so that all the items in common appeared first (so that no one would be "singled out" as an ELL by whether or not they turned pages right away) and then the ELL-only items appeared at the end. Grouping the items also avoided the possible confusion of having multiple places involving a "skip."

The pilot version of the survey was administered on June 26, 2009 in an algebraic reasoning/connections course for pre-service middle school teachers taught by a colleague of the authors. After the researchers discussed the feedback from the 31 pre-service teachers who took the pilot survey, several items were reworded to increase clarity or focus (Valenzuela, 2009). For example, item 24 used to begin with "If I did not know what a word means on a statistics test…" but was reworded to distinguish everyday from academic vocabulary. A few items were deleted because they were effectively covered by other items, and the researchers wanted to make sure the time needed for the survey would not exceed 20 minutes. A few items were revisited in a way that affected whether they would be ELL-only items. For example, what is now item 27 on the CLASS instrument (see the Appendix) originally contained an example from the university region's culture: "It would be helpful if statistics class could include examples that connect to culture, such as *toma todo* -- a Mexican game of chance involving a six-sided top called a pirinola." However, it was found that a nontrivial fraction of Spanish-speaking or Hispanic students are unfamiliar with *toma todo*. By deleting the specific cultural reference, the researchers could reclassify the item as an item for all. In general, any item that could be written as either ELL-only or as an item for all was usually written to be universal to increase the number of items for comparisons. For example, item 27 originally targeted the particular cultural background of many Spanish-speaking ELLs, but was rewritten to include whatever one's culture is.

Table 1. Classification of CLASS instrument items

Category	Nominal items	Numerical items
Deciphering Academic Register	4F, 6F, 7F,8M	11F, 12F, 19F, 23F, 46F, 49F, *70*
Student Practices/Beliefs	9T, *63, 64*	24M, 25M, 26M, 27F, 28M, 52T
Teaching Strategies	10F, *66*	13F, 20T, 21M, 22M, 29F, 30F, 32M, 33M, *71, 72*
Context	5F	18F, 31F, 45F, 47F, 48F, 50F, 51F
Student Background	1, 2, *53-55, 56a, 56b, 62*	3
Content	34F-44F	
Transfer between Academic Registers	*65, 67*	*57-61, 68, 69*
Textbook		14M-17M

F (Field), M (Mode), and T (Tenor) refer to the dimensions of register for each item

Table 1 lists the question numbers of the items (except those from the ELL-only portion of the CLASS) grouped by category, separated by whether the items are nominal or numerical, and flagged by dimension of register. Because the focus of the current paper is comparing ELLs to non-ELLs, analysis of the 18 items administered only to ELLs (italicized in Table 1) is not presented. The nominal items were generally multiple-choice items that either solicited background information or assessed content items that had a correct answer. All of the numerical items were ordinal (Likert) items, except the ratio-level item 3. The majority of the items in Table 1 reflect the category concepts that emerged from the qualitative study of Lesser and Winsor (2009) and/or the dimensions of register previously discussed. Some of the items may reflect multiple dimensions of register, but are classified according to the dominant dimension as independently classified by the research team with an 86.2% initial agreement and 100% agreement after discussion. It was recognized, however, that the survey also included some self-contained items designed to test isolated hypotheses (e.g., about specific wording choices in a textbook) and were not intended to be part of a larger construct.

4. FINDINGS

4.1. BACKGROUND

To contextualize findings, descriptive statistics on student backgrounds and characteristics are provided in Table 2. Fisher's exact tests for homogeneity demonstrate that ELLs were not significantly different from non-ELLs on year in school (item 1 $p = 0.3754$) or future teaching grade-band (item 2 $p = 0.1129$). There is also no significant difference ($\chi^2 = 2.676$, $p = 0.613$) when comparing the distributions for self-reported prior knowledge (item 3, after grouping the reported values into categories of 0%, 1-20%, 21-40%, 41-60%, 61+%), or by using the raw values as continuous data ($t = -1.022$, $df = 132$, $p = 0.3084$). The fact that there was no significant difference between ELLs and non-ELLs on any background item measured makes attributing observed differences to ELL status plausible.

Table 2. Descriptive statistics on respondent backgrounds

	ELL Count (%)	non-ELL Count (%)	Overall Count (%)
Year in School (Item 1)			
Freshman	2 (3.8%)	3 (3.6%)	5 (3.7%)
Sophomore	15 (26.4%)	32 (38.6%)	46 (33.8%)
Junior	33 (62.3%)	37 (44.6%)	70 (51.5%)
Senior	4 (7.6%)	10 (12.1%)	14 (10.3%)
Graduate School	0 (0.0%)	1 (1.2%)	1 (0.7%)
Pre-Service Teacher (Item 2)			
Elementary School	28 (52.8%)	50 (60.2%)	78 (57.4%)
Middle School	9 (17.0%)	19 (22.9%)	28 (20.6%)
High School	4 (7.6%)	1 (1.2%)	5 (3.7%)
Other	10 (18.9%)	7 (8.4%)	17 (12.5%)
No response	2 (3.8%)	6 (7.2%)	8 (5.9%)
Prior knowledge of material (Item 3)			
0%	11 (20.8%)	11 (13.3%)	22 (16.2%)
1% - 20%	14 (26.4%)	22 (26.5%)	36 (26.5%)
21% - 40%	15 (28.3%)	25 (30.1%)	40 (29.4%)
41% - 60%	11 (20.8%)	17 (20.5%)	28 (20.6%)
61% - 80%	2 (3.8%)	8 (9.6%)	10 (7.4%)
81% -100%	0 (0.0%)	0 (0.0%)	0 (0.0%)

Additionally, items 53-56 describe ELLs' language background. The 51 (Spanish-speaking) ELLs surveyed were taught entirely or almost entirely in Spanish for a mean of 5.593 years (SD = 4.927 years), with the grade level for receiving instruction entirely or almost entirely in Spanish centered at the fourth year of instruction (mean = 4.431, SD = 2.65) based on $n = 51$ and for the 19-year span from pre-kindergarten through the end of college, which centers instruction in Spanish in the early part of *Primaria*. Of course, it is unsurprising that the English-oriented instruction was more common in later grades as the most common pattern among ELLs was to be taught primarily in Spanish for grades 1 through j and then primarily in English from grade j+1 forward.

Before presenting the results of this study, we note that "I don't know" responses play a role. Aggregating all nine items (i.e., 4, 34-38, 41-43) that offered some kind of "I don't understand" (or "I have no idea") option, ELLs gave that option 15.6% of the time, which was twice as often as non-ELLs (7.5%) and this difference in rate was statistically significant ($z = 4.16$, $p < 0.0001$) for 51 ELLs and 83 non-ELLs across 9 items. Because, as reported earlier, prior knowledge of statistics was similar for ELL and non-ELL respondents and because the instrument was given at the first meeting of the semester, the authors conjecture any difference in content questions is due largely to language-related issues. All calculations in Section 4 are performed using the R software (R Development Core Team, 2012), utilizing the ordinal package (Christensen, 2012).

4.2. COMPARISON BETWEEN ELL AND NON-ELL GROUPS

A proportional odds model is utilized to analyze the scores for the 30 items of the CLASS (contained in Table 3) that address issues related to the dimensions of register and, correspondingly, deciphering the register, teaching strategies, textbook language, student practices, and context. This model provides estimates of the probability that a subject responds with a rating of j (j = 1, ... ,7) or more or, alternatively, the results of the model may be summarized utilizing odds ratios. This model is appropriate because the responses of these items range from 1 to 7 and have meaningful ordering (Agresti, 2002), and the model will allow appropriate examination of how ELL status may affect the response pattern on each item of the CLASS. These items were administered to ELLs and non-ELLs and hence an indicator variable indicating ELL status is included as a covariate in the model.

In Table 3, point estimates and corresponding 95% confidence intervals for odds ratios resulting from the proportional odds model are reported in order to address the statistical and practical signifi-

Table 3. Odds ratios for ELLs versus non-ELLs

Register Dimension	*Category*	*Item*	*Odds Ratio for ELL status with 95% CIs*	*Odds Ratio of positive response for ELL status with 95% CIs*
Field	Context	18	1.942 (0.708, 5.327)	0.690 (0.250, 1.902)
Field	Context	31	1.853 (0.680, 5.049)	0.658 (0.240, 1.803)
Field	Context	45[2]	0.653 (0.243, 1.756)	0.232 (0.086, 0.628)
Field	Context	47[1]	3.153 (1.148, 8.660)	1.120 (0.406, 3.087)
Field	Context	48[2]	0.762 (0.283, 2.053)	0.271 (0.100, 0.734)
Field	Context	50[1]	6.534 (2.403, 17.770)	2.320 (0.852, 6.320)
Field	Context	51[2]	0.721 (0.268, 1.939)	0.255 (0.094, 0.694)
Field	Deciphering register	11[2]	0.991 (0.362, 2.713)	0.352 (0.128, 0.970)
Field	Deciphering register	12[1,2]	11.574 (4.176, 32.080)	4.111 (1.484, 11.39)
Field	Deciphering register	19[2]	0.594 (0.218, 1.613)	0.211 (0.077, 0.577)
Field	Deciphering register	23	2.183 (0.795, 5.995)	0.776 (0.281, 2.142)
Field	Deciphering register	46	1.559 (0.575, 4.227)	0.554 (0.203, 1.511)
Field	Deciphering register	49[1,2]	13.548 (4.933, 37.210)	4.811 (1.755, 13.19)
Field	Student Practices	27	2.173 (0.805, 5.865)	0.771 (0.284, 2.095)
Field	Teaching Strategies	13[1,2]	8.795 (3.207, 24.123)	3.123 (1.139, 8.565)
Field	Teaching Strategy	29[2]	0.832 (0.306, 2.261)	0.296 (0.108, 0.809)
Field	Teaching Strategy	30[2]	0.458 (0.169, 1.240)	0.163 (0.060, 0.444)
Mode	Student Practices	24[1]	2.818 (1.013, 7.835)	1.000 (0.358, 2.797)
Mode	Student Practices	25[1,2]	10.610 (3.802, 29.608)	3.768 (1.352, 10.50)
Mode	Student Practices	26	1.214 (0.448, 3.288)	0.431 (0.158, 1.176)
Mode	Student Practices	28[2]	0.758 (0.280, 2.049)	0.269 (0.099, 0.733)
Mode	Teaching Strategy	21[2]	0.513 (0.187, 1.406)	0.182 (0.066, 0.503)
Mode	Teaching Strategy	22[1]	3.876 (1.433, 10.480)	1.377 (0.508, 3.733)
Mode	Teaching Strategy	32[2]	0.475 (0.175, 1.286)	0.169 (0.062, 0.460)
Mode	Teaching Strategy	33[2]	0.552 (0.202, 1.510)	0.196 (0.071, 0.540)
Mode	Textbook	14[1]	3.448 (1.255, 9.471)	1.224 (0.444, 3.376)
Mode	Textbook	15[2]	0.918 (0.329, 2.565)	0.326 (0.116, 0.917)
Mode	Textbook	16[1]	6.025 (2.214, 16.392)	2.140 (0.786, 5.829)
Mode	Textbook	17	2.030 (0.741, 5.563)	0.722 (0.262, 1.987)
Tenor	Student Practices	52[1,2]	15.134 (5.511, 41.557)	5.374 (1.962, 14.72)
Tenor	Teaching Strategy	20	1.378 (0.492, 3.861)	0.490 (0.174, 1.379)

[1]Item exhibits familywise statistical significance for odds ratio comparing response for ELLs versus non-ELLs
[2]Item exhibits familywise statistical significance for odds ratio comparing positive response for ELLs versus non-ELLs

cance of the observed effects. The 95% Bonferroni-adjusted simultaneous confidence intervals for the odds ratios given in Table 3 compare the responses of ELLs versus non-ELLs. The first set of odds ratio intervals (columns 4 and 5) compare the odds of a one-unit increase in the item score for ELLs to that for non-ELLs. Whenever the confidence interval for the odds ratio is above 1, ELLs have higher odds of a higher agreement level response to the item than do non-ELLs. Correspondingly, whenever the interval is less than 1, ELLs have lower odds of a higher agreement level response to the item than do non-ELLs. For example, the estimated odds ratio for item 13 implies that the odds of ELLs responding with a one-unit increase on the Likert scale is nearly nine times the odds of non-ELLs doing so.

The second set of point estimates and 95% simultaneous confidence intervals for the constant cumulative odds ratios (columns 6 and 7) in Table 3 compare the odds of a positive response (i.e., responding with an “above-neutral” rating of 5, 6, or 7 on an item) for ELLs to non-ELLs (Agresti, 2002, pp. 276–277). Thus, whenever the interval is above 1, then the odds of a positive rating is higher for ELLs than for non-ELLs. Similarly, if the interval is below 1, then the odds of ELLs having a positive rating is lower than for non-ELLs. This second set of odds ratios enables comparisons between the groups to a reference “location” on the scale that has interpretable meaning. For example, the estimated odds ratio for item 13 implies that the odds of ELLs responding with a positive rating is over three times the odds of non-ELLs responding with a positive rating.

In general, whenever a confidence interval for the one-unit increase does not contain 1, it implies that one of the groups in general is more likely to rate the item higher. However, this does not imply that the said group is more likely to respond positively (i.e., with a 5, 6, or 7) to the item. An example of this kind of scenario occurring is when both groups tend to give non-positive responses, but differ mainly with respect to the degree of negativity. For each of the sets of odds ratios, multiplicity is controlled using a Bonferroni critical point for the set of 30 odds ratios. This protects strongly against familywise Type I errors for each set of inferences.

Except for item 41, all other items in the content category (items 34-40, 42-44) have only one correct answer and so binary logistic regression models were used to examine the proportion of ELLs versus non-ELLs selecting the correct answer. Table 4 provides lower and upper bounds for Bonferroni-adjusted familywise confidence intervals for the odds ratio for a correct response.

Table 4: Confidence bounds for odds ratios comparing ELLs and non-ELLs for content items

Item	*Estimated Odds Ratios with 95% Confidence Intervals* *Estimate (Lower, Upper)*
34	0.800 (0.368, 1.740)
35*	0.046 (0.005, 0.428)
36	0.927 (0.308, 2.791)
37	2.890 (0.914, 9.138)
38*	0.189 (0.047, 0.763)
39*	0.132 (0.028, 0.623)
40*	0.101 (0.019, 0.541)
41	0.758 (0.248, 2.318)
42	1.400 (0.465, 4.213)
43	3.167 (0.990, 10.132)
44	0.958 (0.317, 2.895)

*Odds ratio is familywise statistically significant

Items 4–10 have nominal level responses with no “correct” answer. Hence, baseline-category logits model the probability of each multinomial response level based on ELL status. Once controlled for multiplicity, none of the items 4–10 show evidence of difference in the responses between ELL and non-ELLs.

4.3. THE REGISTER DIMENSION OF FIELD

Field dimension refers to changes in language use observed, depending on the topic. The field of statistics encodes technical and specialized meanings. Moreover, the field of statistics generally contextualizes technical meanings in real-life applicable settings.

Context The items dealing with context and how it relates to statistical results, formulae, and concepts demonstrate a consistent pattern of response for the ELL and non-ELL groups, respectively. Note that the second set of intervals for the odds ratio of a positive response for ELL versus non-ELL respondents are all below 1 for items 45, 48, and 51 (see Table 3). This indicates that non-ELLs have a greater tendency than ELLs to agree that context assists with understanding statistical concepts, formulae, or results.

In contrast to results for items 45, 48, and 51, the set of items asking about confusion about multiple uses or meanings of words used in statistics (including the word *statistics*) demonstrate that ELLs have higher odds of a one-unit increase in the response than non-ELLs do. Items 47 and 50 ask whether it is confusing that specific terms (e.g., survey, statistics) commonly utilized in statistics have multiple meanings in English. The odds ratios comparing ELLs to non-ELLs are significantly higher than 1, thus indicating that ELLs tend to provide a higher response on the Likert scale than non-ELLs (see Table 3). This indicates that participating ELLs report more difficulty managing context-dependent, polysemic meanings of words in the field of statistics.

Content Item 41 revealed some cultural differences as most non-ELLs viewed “defendant is innocent” as a courtroom’s null hypothesis (consistent with the American system of justice), whereas the modal ELL response was “defendant is guilty” (consistent with the Napoleonic code of justice practiced in countries such as México, as reported in the 2008 documentary *Presunto Culpable*).

In general, ELLs have lower odds than non-ELLs of correct responses on content items 35, 38, 39, and 40, even when controlling for multiplicity (see Table 4). These items demonstrate statistically significant differences in the odds of a correct answer for ELL and non-ELL students and depend on understanding the statistical meaning of words such as range, normal, correlation, and random.

Deciphering the register Within the dimension of field, items specifically considering how students move between academic (e.g., statistics) and everyday registers show some evidence of differences between ELLs and non-ELLs. In particular, item 12 asks whether it is hard for the student to tell when they do not understand a concept because of the difficulty with the language used in a mathematics/statistics class. This item provides evidence that ELLs have higher odds than non-ELLs of responding with a more affirmative score and that, in general, ELLs have higher odds than non-ELLs of responding positively to this item. Item 49 also shows evidence that ELLs provide a more affirmative or positive response than non-ELLs. This item asks whether it is confusing when words that look and sound similar (mean, median, mode) all get introduced in the same lesson.

Items 11 and 19 each show evidence that non-ELLs have higher odds of responding positively than ELLs (see Table 3). Item 11 asks whether the student is able to understand a multi-word phrase used in mathematics/statistics as long as the individual words composing the phrase are known. Non-ELLs have higher odds of responding positively to this item than ELLs (see Table 3). Item 19 states that understanding the language of statistics means knowing what statistical terms and symbols mean and being able to read statistical graphics. Non-ELLs also have greater odds of responding positively to this statement (see Table 3).

Teaching strategies Because the target population is mostly preservice teachers, one item specifically refers to their future careers as teachers by asking whether they will be able to tell when a student understands a concept but just has a problem with the language. For both sets of the odds ratio intervals, ELLs have higher odds of either a one-unit increase in the score or of a positive response than non-ELLs. Items 29 and 30 also show evidence of differing odds when comparing ELLs to non-ELLs. Both items ask whether it is helpful to explicitly relate everyday versus statistical concepts or words. For both items, non-ELLs demonstrate higher odds of responding positively than ELLs. See Table 3 for all analysis results associated with these items.

4.4. THE REGISTER DIMENSION OF MODE

Mode dimension captures variation in register owing to the role language is playing in the interaction; it refers to how language varies in speech and writing. ELLs' answers here suggest an awareness of mode.

Student practices When asked whether a student would ask a professor during a test to clarify the wording on an exam, ELLs have higher odds of a one-unit increase in the response than non-ELLs. However, ELLs do not exhibit overall higher odds of a positive response than non-ELLs. On a similar item (number 28: whether they expect that a professor would help them with the wording of a question on an exam if asked), non-ELLs exhibit higher odds of responding positively to this item than ELLs (see Table 3). This suggests that ELLs may be more likely to think the professor would not help them if they needed clarification about exam wording. Item 25, asking whether the student believes that a professor thinks he/she knows less than he/she really does because it takes time to express thoughts into words, provides evidence that ELLs have higher odds of both a one-unit increase in the response and a general positive response to this item than non-ELLs (see Table 3).

Teaching strategies Item 21 asks whether using graphic organizers or pictures is an effective way to organize a student's thinking in statistics. Non-ELLs respond more often with a positive response than ELLs for this item (see Table 3). Item 32 asks whether it is helpful in a statistics classroom for discussion to go beyond vocabulary definitions and include everyday communication about statistical concepts. Non-ELLs have higher odds of responding positively to this item as well. Another item about teaching, item 33, asks whether it is helpful when the instructor points out how a new word or symbol should be pronounced. Again, non-ELLs have higher odds of responding positively to this item than ELLs (see Table 3). Another item dealing with the mode of communication when teaching, item 22, asks whether professors wait a sufficient amount of time after asking a question for the student to think about what the question means and think of an answer. Generally, ELL and non-ELLs indicated that professors do not wait enough time. Even so, ELLs have higher odds of a one-unit increase in response to this item than non-ELLs (see Table 3).

Textbook Mode dimension items that deal specifically with how textbooks communicate statistical ideas also show some evidence of different responses for ELLs and non-ELLs. ELLs have higher odds of a one-unit increase in the response than non-ELLs for items 14 and 16. These items both provide technical sounding definitions for defining the median and least squares line, respectively. Item 15 provides an everyday context (the median of a road) for explaining the concept of the median in statistics. More non-ELLs responded positively when asked whether that definition was understandable than ELLs (see Table 3). These are interesting results that may provide some insight into how to better relate statistical concepts to everyday concepts for ELLs.

In summary, ELLs respond differently than native English speakers, as shown in their responses to items related to writing on exams, speaking in class, modeling pronunciation, and reading language in textbooks.

4.5. THE REGISTER DIMENSION OF TENOR

Tenor dimension captures change in language owing to the social relationship in which language is used. Being used mostly in academic settings, the register of statistics tends to encode more formal social relationships.

Student practices Only a few items tap the interpersonal relationships in a statistics classroom and hence address the register dimension of tenor. Item 52 asks whether a student pretends that they understand what is going on in class when an instructor is looking towards them. ELLs show very strong evidence that they have higher odds of either a one-unit increase in the response as well as higher odds of a positive response overall than non-ELLs (see Table 3). This provides some evidence that the dynamic between ELLs and their statistics instructors may differ from non-ELLs and their instructors. Thus, the formal social relationship in academic settings might especially impact ELLs.

5. DISCUSSION

Overall, the data analysis of this paper suggests that ELLs and non-ELLs sometimes perceive or encounter statistical language the same way. This has implications for curriculum and instruction, potentially both for ELLs and non-ELLs. If ELLs have different dynamics when experiencing statistics in the academic register in English, have different practices/beliefs, and respond differently to context and to certain teaching strategies, then instructors should know and be aware of what changes to instruction are helpful.

5.1. FIELD

Content The courtroom analogy for hypothesis testing is often used in statistics textbooks, is the most developed analogy in the Martin (2003) collection, and appears elsewhere in statistics pedagogical literature (e.g., Porkess & Mason, 2012). Although it was raised in Lesser and Winsor (2009), it was not actually part of their interviews, so it was an important step to add it to the CLASS instrument (item 41 of the Appendix).

Although the language is an imperfect proxy for culture or national origin, it is striking on this item how ELLs and non-ELLs had a significantly (p = 0.006) different response pattern due to more ELLs saying that they did not understand the question. It should be noted that the odds of getting this item correct for ELLs versus non-ELLs is not significantly different than 1 (see Table 4). Hence, non-ELLs did not get the question correct significantly more often than ELLs, but the distribution of choices was still very different. In particular, 19% of ELLs replied to the question with an “I do not understand the question” response whereas only 2% of non-ELLs gave this response. In light of the nontrivial fraction of students whose intuition is not aligned with the traditional textbook view of this analogy, it seems wise for instructors to consider either an alternative analogy (e.g., the medical testing analogy) or an explicit unpacking of the statistical and cultural assumptions behind the asymmetry of the courtroom analogy for hypothesis testing. The cultural assumption in the courtroom analogy is acknowledged in some textbooks (e.g., Utts, 2005, p. 414) but not in others (e.g., Perkowski & Perkowski, 2007, p. 307).

We note that cultural disconnects with American textbooks are not limited to English-speaking countries, as there are many countries (e.g., Oman; see Abdelbasit, 2010) whose official language is not English where tertiary statistics is taught in English, usually from American textbooks.

With item 35 (identifying the range for a dataset), the modal ELL response by far was “I have no idea” and only two ELLs answered correctly. Interestingly, the most common answer for ELLs besides ‘I have no idea’ was the value corresponding to the maximum of the dataset. One possible explanation for this is that the Spanish words for *rank* and *range* are the same word (rango) and the maximum value of a dataset may be thought of as its rank. The Spanish word ‘rango’ can also be related to the English words class and grade, and one’s ‘year in school’ might also be thought of as one’s ‘rank.’ The non-ELLs had 17 correct responses, but almost as many (15) responses that suggested confusion between range and sample size, consistent with the ELLs interviewed in Lesser and Winsor (2009). The main contributions for the significant chi-square value came from the non-ELLs’ greater tendency to select the (wrong) answer of sample size, the ELLs’ greater tendency to select “I have no idea,” and the non-ELLs’ greater tendency to select the correct answer.

Another item, assessing a student’s ability to determine how many numbers are at least 6 from the set {1, 2, 3, 4, 6, 6, 13}, also shows evidence that the odds of a correct answer are significantly higher for non-ELLs than for ELLs. The phrase “at least” can be translated into Spanish as “al menos” or “por lo menos.” The data suggest that ELLs are over twice as likely to misinterpret phrases such as “at least.” This suggests some ELLs are focusing on the word “least” in the phrase “at least” and making the mistake of counting the numbers “less” than 6.

Item 39, which asks which of the terms normal, random, and correlation have meanings in statistics that differ from everyday usage, also exhibited higher odds of a correct answer for non-ELL students versus ELLs. The most frequent answer for non-ELLs was the correct answer (which states that normal and random have meanings that differ for the everyday and statistics registers). For ELLs, however, two answers tied for the most frequent response: the response that correlation is the only terms having differing meanings, and the response saying random and correlation have differing meanings and normal does not. Perhaps ELLs misunderstood this to be asking which items are technical statistics terms that are not common in the everyday register.

The item asking for the statistical meaning of the word *parameter* (item 40) also yields the results that non-ELLs have higher odds of responding correctly to this item. For this CLASS item, 29.4% of ELLs responded with the incorrect answer "a measurement" whereas only 15.7% of non-ELLs did. This result may be unsurprising in light of the Lesser and Winsor (2009) discussion and conjecture for an interviewee associating *parameter* with measuring a rectangle's perimeter.

Context Now, we consider items examining how students interpret context within the field (i.e., topic) dimension. Items 45, 48, and 51 suggest that context helps non-ELLs significantly *more* than it helps ELLs. This is counterintuitive because context is generally the most important clue to deduce the meaning of a word or sentence (Chastain, 1988). A conjecture that emerged from negative case analysis (Miles & Huberman, 1994) is that it is possible that some ELLs interpreted the item to mean that understanding the context is sufficient to then be able to answer the question, or it is possible that there is a completely different reason for this pattern. Ultimately, the research team felt that context was simply not a well-defined word, because it could refer to the present physical setting (e.g., Are you in a statistics class or mathematics class? Are you speaking to a classmate or a professor?) or to the scenario from which the data or statistics question came. Additional discussion of the multiplicities and importance of context appears in Goldin (1998).

Items 47 and 50 also deal with context within the register dimension of field, but do not explicitly use the term "context." Instead, these items ask whether it is confusing when statistics terms exhibit polysemy within the statistics register. ELLs have higher odds of responding with a single unit increase in the scale for both of these items. This has practical teaching implications as it suggests that ELLs may benefit from pointing out the polysemy of words such as *survey* and *statistics*. For example, when introducing survey construction in class, it may be helpful to point out that the word "survey" may be a verb or a noun and provide examples of both uses of the word.

Deciphering the register We note that ELLs are not always the ones at a disadvantage when using the everyday English register. Bilingualism can be a resource for ELLs with Spanish helping them make more connections to their everyday world and engage in more active explorations and discussions of the problem (Dominguez, 2011). For example, the words *edifice*, *facile*, *felicity*, *pensive*, and *confounded* are not extremely common words in the everyday English register even for native English speakers, but a Spanish-speaking ELL would be more likely than a monolingual English speaker to guess (correctly) the meaning because those words look very similar to words that are quite common in the everyday Spanish register (the respective cognates *edificio*, *fácil*, *felicidad*, *pensar*, *confundido*). Also, there are some mathematical or statistical terms whose meaning is clearer in Spanish. For example, the word *percent* in Spanish is "por ciento" and *ciento* is Spanish for 100, so the Spanish reinforces more explicitly than English that percent is a ratio whose denominator is 100. Perhaps the common Spanish word *media* for half makes it seem natural that the *mediana* divides the dataset in half. The Spanish counterpart to the idiomatic phrase "in the long run" is "en el largo plaza," which translates to "in the long term." The word *term* is arguably more meaningful or clear than *run*. ("Run" appears in diverse ways within mathematics/statistics: "run an experiment," "a run of 10 heads," "slope is rise over run," etc.)

Given that this was the first day of class, it is unlikely that students had already heard the statistical use of the word *normal*, for example, and therefore not be in a position to assess whether the meaning in one register differed with that in another (e.g., Kruskal, 1978). Alternatively, the differential response pattern could be a reflection of ELLs not having heard as many of these words in everyday English due to having a smaller everyday English register. It is also possible that the number of choices with convoluted wording such as "a & c, but not b" were more confusing to ELLs, especially in light of the experimental design studies discussed by Abedi et al. (2004) that identify the differential effect of test items' construct-irrelevant linguistic complexity and how minor rewording of those items can affect student performance. A limitation of an anonymous quantitative survey, of course, is that we were not able to member check and test these conjectures. As an aside, we note that confusion can happen not only with statistics terms but also with ordinary actions in the specific context of a statistics classroom, such as being asked to "draw a counter." A student may or may not be familiar with a colored plastic chip being described as a counter or may assume the task is to draw a picture of a chip rather than to pick a chip.

Item 49 reflects the statement by an ELL interviewed in Lesser and Winsor (2009) that it was challenging being presented in the same day's lesson with three measures of location [mean, median, mode] so similar (in English or Spanish) to each other and to words from everyday usage, and this potential for confusion is supported by Table 1 of that paper. This item implies that ELLs more often affirmed this item than non-ELLs. Similarly, for item 12, ELLs were more likely than non-ELLs to agree with the statement that it is hard to tell when they don't understand a concept because of the language used in mathematics and statistics classes. For this item, the language could be context-related or content-related. What these items have in common is that ELLs exhibit higher odds of reporting that they may experience confusion due to language based issues when first approaching statistical content. Students who know more than one language may be more aware of language issues than those who do not, as attested by the body of literature on bilinguals' meta-linguistic awareness (Bialystok, 2001). Bilinguals generally outperform monolinguals on measures of meta-linguistic awareness (García, 2009). This implies that it would be beneficial for instructors to spend more time discussing the language-based aspects of statistical ideas, particularly when introducing the concepts. For students who are bilingual, explicit discussion of how the language of statistics works may be beneficial.

Items 11 and 19 both ask something about how well students understand statistical language. In particular, item 11 asks whether a multi-word phrase is understood if the individual words are understood and item 19 asks whether knowing statistical terms and symbols and reading graphs is involved in understanding the basic language of statistics. For both of these items non-ELLs exhibit higher odds of a positive answer than ELLs. These results also suggest that ELLs generally may be more aware than the comparison group of language itself. This may be why ELLs realize that a multi-word phrase can be more than its component parts. Many ELLs might be more aware than non-ELLs of the difficulties involved in this aspect.

The results of this analysis suggest that the statistics register construes technical, field-specific meaning. Participating ELLs report more awareness of this register dimension and there is some evidence that ELLs identify language as a challenge when learning statistical concepts.

5.2. MODE

Content Based on the difficulty an interviewee had with the question "In what grades, if any, were you taught in Spanish only?" in Section 5.1 in Lesser and Winsor (2009), it was interesting to investigate empirically (item 14 versus 15) the possible benefit of using more streamlined, direct, everyday-style language that minimizes clauses, passive voice, and parenthetical remarks and, secondarily, the possible benefit of items (item 16 versus 17) that call attention to word choice. From Table 3, we see that ELLs had higher odds of a one-unit increase in the scores of items 14 and 16 (items giving a highly technical definition) when compared to non-ELLs. However, ELLs had the same odds of a positive response to these items than non-ELLs and for both groups only a small minority of the responses was either *Strongly Agree* or *Very Strongly Agree*. In contrast to items 14 and 16, items 15 and 17 both utilize more direct wording. For item 15 (defining the first quartile), non-ELLs have higher odds of a positive response than ELLs. Though theorized as a method for making instruction more interpretable for ELLs, more direct and simple wording of concepts appears to affect non-ELL comprehension more significantly.

Teaching strategies The results of item 22 imply that the recommendation of "wait time" from Lesser and Winsor (2009) played out differently between ELL and non-ELL students. An instructor who is used to teaching only non-ELLs might not have the awareness, intention, or habit to increase her wait time when teaching a class with ELLs (Fischer & Perez, 2008; Gibbons, 1998). Instructors would also want to be sure to avoid the pitfall of assessing ELLs with items lower on Bloom's taxonomy than items used to assess non-ELLs (Gomez & Kurz, 2011). Items 22 (a "teaching strategy" item) and 25 (a "student practices/beliefs" item) both relate to wait time and support the major recommendation (Lesser & Winsor, 2009) that providing adequate wait time is especially important for ELLs.

Other items concerning teaching strategies and how they relate to the mode dimension of register include 21, 32, and 33. These items all indicate that non-ELLs have higher odds of a positive response than ELLs. Item 21 asks about the usefulness of graphic organizers or pictures for organizing thinking. Item 32 asks about the effectiveness of going beyond definitions to include real communication about concepts, and item 33 asks whether it is helpful when the teacher or textbook points out how to pronounce a new word or symbol in statistics. These results appear to be counter to what most statistics educators might expect, and may well reflect the opinion of Spanish-speaking ELLs. However, it is also possible that the language utilized in these items was familiar primarily to the non-ELL audience and could be confounding these results.

Student practices Arguably the most important result regarding student practices and the mode of communication involves item 25 (asking whether the student believes the professor thinks he/she knows less than he/she really does because it takes a while to express thoughts in words). For this item, ELLs demonstrate much higher odds of either a one-unit increase or a positive score than non-ELLs. Aspects of tenor are also involved in this item because the perceived relationship between the professor and student may be affecting the way the students respond to this item. However, regardless of the reasons behind these results, providing adequate wait time is a way to provide the additional time ELLs may need to formulate a response to a question. Additionally, providing non-time constrained methods (such as out-of-class response papers or discussion boards) for communicating understanding could also be helpful.

5.3. TENOR

Student practices The result for item 52 is that, relative to non-ELLs, "it is not unusual for ELLs to feign understanding so that they do not draw unwanted attention to themselves in class" (Pappamihiel & Mihai, 2006, p. 41). This item exhibits higher odds for ELLs versus non-ELLs for both a one-unit increase in the response and for a general affirmative response and indicates a noteworthy behavioral difference between ELL and non-ELL students.

5.4. LIMITATIONS AND DELIMITATIONS

We made a delimitation (as did Lesser & Winsor, 2009, p. 20) of focusing on Spanish-speaking ELLs. This delimitation is supported in Section 1 and turned out to have negligible effect on the present study because of the 137 survey respondents, only two identified as an ELL with a native language other than Spanish. A limitation is that it is not clear how to interpret missing answers to the few items that had more than five nonresponses for the ELL group (this did not happen with any items for the non-ELL group). In particular, item 55 (circle the grade-level years you were taught entirely or almost entirely in Spanish) had seven cases of nonresponse (13%), and there is no way to know how much of this was simply because some of the students had no instruction in Spanish, didn't remember some of the years, or were confused by the format of the item. Item 56 (indicating which years they were taught entirely or almost entirely in English) had 40 cases of nonresponse (75%), and there is no way to know how much of this was simply because some of the students had no bilingual instruction. Fortunately, it will be straightforward in a revision of the CLASS instrument to add a "no years" option to these two items to correct this oversight. Item 62 had six cases of nonresponse (11%), and there is no way to know how much of this was due, for example, to a student feeling that two areas were equally the most challenging or perhaps that none were challenging.

Another type of limitation was self-reporting. The prior knowledge of students (item 3) was self-reported because researchers were not able to have instructors relinquish an additional amount of class time to administer an additional instrument (e.g., an appropriate set of CAOS items), but this is something that could be revisited in a future study. Also, the research team was forced to rely on participants rating their own language proficiency on item 54 (based on the ILR and ACTFL language scales) rather than, say, having a third-party language expert assess it. It is possible students operationalized some scale points differently or had a different assumption about whether having a native language other than English makes one a lifelong ELL even if one attains the English proficiency of a native English speaker. (In the "other direction," research linguist Kerrie Kephart (personal communication, October 21, 2009) notes: "in a sense, we're all ELLs…to the extent that we continually add to our vocabularies and learn new ways of using language…throughout our lifetimes….") Indeed, of the 53 respondents that self-identified as ELL, the modal response (by 20 respondents) was to give the highest rating ("able to speak like an educated native speaker") on item 54 (one of the additional items that only ELLs were asked to answer). Completing the left-skewed distribution were 13 who said "9," 13 who said "8," 5 who said "7," one who said "4," and one who said "3." A further source of confusion is that six of the 83 who self-identified as non-ELLs did the ELL-only part of the survey anyway. Future research will use a process that makes a sharper distinction between ELL and non-ELL.

It was deemed appropriate that ELLs rate their own proficiency for several reasons: (1) the presence of a scale with meaningful descriptors for each level, (2) students were being asked questions on the CLASS instrument that were about their perceptions and experiences rather than an external measure of their raw performance, and (3) having a student's language proficiency formally assessed in a rigorous way would not only take more time per person than the CLASS instrument itself, but also there is no single validated protocol that is universally used by professionals (e.g., Abedi et al., 2004), much less one specific to a particular academic subject such as statistics. Local school districts typically are approved to use different assessment instruments to assess, for example, a student's ability to read and write than to assess a student's ability to speak. However, item 54 on the instrument comes from a scale that focuses on speaking. It might be assumed that the ability to speak represents a more advanced level of communication than the ability to read because speaking in class or carrying on a conversation in real time requires more proficiency than being able to read a textbook outside of class, and the greater focus with our research is applications to the classroom.

At one point, the researchers were going to explore the correlation between "degree of ELL-ness" and responses to certain items. However, there was not enough variation over enough values on the scale to justify treating the scale as approximately continuous. In retrospect, this is not surprising because it is unlikely someone would be able to succeed or even attain the language score (e.g., TOEFL) to enter college if they were truly in the lower half of the scale.

5.5. FUTURE DIRECTIONS FOR RESEARCH

The items of the CLASS instrument will be revised and trimmed by using factorial models to validate the latent structure of the instrument. Most items are straightforward with high face validity (e.g., 15) but some of the items (e.g., 26) reflect broad psychological constructs that require future validation. After revising the CLASS instrument (based on the information gained in this paper and the construct validation), this quantitative survey work is being replicated with different and larger populations using the revised instrument. An example of revised wording is rewriting the "context" items to invoke but not use the actual word *context* for reasons discussed in Section 5.1.

Perhaps another future study can start with a confidential survey and then conduct (qualitative) focus groups and interviews from representative students that were surveyed, and therefore integrate the qualitative and quantitative aspects in the same stage. Having qualitative and quantitative data working together can help illuminate why certain answers were chosen. For example, is it a bigger stretch in item 4 for ELLs to access *confounded* from their everyday English register or to relate it to the Spanish cognate *confundido*, a word more common in the Spanish register than confounded is in the English register?

6. IMPLICATIONS FOR TEACHING

This study allows us to see whether there is empirical quantitative evidence to support some or all of the eight recommendations identified and discussed by Lesser and Winsor (2009). Table 5 summarizes those recommendations, aligns them to the related dimension of register, and briefly summarizes any empirical support provided by the current study. Use of the CLASS instrument could efficiently help teachers make a more informed decision on which pedagogical changes might make the biggest difference with the mix of language and culture backgrounds in their particular group of students.

Table 5. Evidence of support for teaching recommendations

Teaching recommendation	*Dimension of Register*	*Related evidence from this study*
Increase awareness when there are multiple registers for one word	Field	ELLs found register confusion more problematic than non-ELLs
Emphasize the statement or setup of a problem	Field	ELLs agreed less often that the context is helpful in understanding statistical concepts and there is some evidence that the context, rather than statistical content, is more confusing for ELLs
Recognize multiple terminologies for one concept	Field	ELLs expressed more confusion (and are more likely to ask for help on exams) than non-ELLs with mathematical/statistical language, but this includes more situations than distinguishing among multiple terminologies.
Use vocabulary activities	Field	ELLs expressed more confusion than non-ELLs about statistical vocabulary
Provide contextualized instruction	Field	ELLs show evidence of difficulty understanding the context of statistical problems
Provide adequate wait time	Mode	ELLs perceive there is not enough wait time provided more than non-ELLs
Provide multiple modes and representations	Mode	No support found
Group work	Tenor	No support found

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APPENDIX: COMMUNICATION, LANGUAGE, AND STATISTICS SURVEY (CLASS)

Permission is required to use the CLASS survey. Contact either of the first two authors for the Terms of Use and current version of the instrument.

1. What year in school are you? a) freshman b) sophomore c) junior d) senior e) graduate student

2. What kind of pre-service teacher are you? a) elementary school b) middle school c) high school d) other:_______

3. About what percent of the material in this introductory statistics course do you estimate you already know? _________ (whatever number it is between 0% and 100% is okay-- just take your best guess)

4. Which one of these statements best describes your reaction to the following example:
   "In everyday usage, someone who is confounded is confused or mixed up. In statistics, confounded variables have their effects mixed together so that it's hard to tell what effect is due to each variable separately."
   a) I was familiar with the everyday use of the word 'confounded' and the first sentence helped me understand the second one.
   b) I was familiar with the everyday use of the word 'confounded', but the first sentence did not help me understand the second one.
   c) I was not familiar with the everyday use of the word 'confounded' but the first sentence helped me understand the second one.
   d) I was not familiar with the everyday use of the word 'confounded', and the first sentence did not help me understand the second one.
   e) I did not understand the *italicized* wording or what this question is asking.

5. What happens when context is added to the explanations of a concept?
   a) it usually makes it easier because it adds more ways or chances to understand
   b) sometimes it makes it easier, sometimes it makes it harder
   c) it makes no difference at all
   d) it usually makes it harder because there's now more words to have to read and understand

6. The statistical or mathematical meaning of a word is more confusing to you when:
   a) it has a different meaning of that same word used in an everyday usage
   b) it has the same meaning of that same word used in an everyday usage
   c) that word is not used at all in an everyday usage

7. Connections to everyday language are most helpful to you when they happen:
   a) before the technical academic terms are introduced
   b) after the technical academic terms are introduced
   c) at the same time the technical academic terms are introduced
   d) there is no difference

8. The most difficult part of problem solving for you is:
   a) defining and setting up the problem
   b) solving the problem (after I understand the question)
   c) explaining what the answer means
   d) all of the above are equally difficult

9. If a mathematics or statistics instructor uses a word or phrase that you don't know, what are you most likely to do?
   a) keep listening and try to figure it out from what is said next
   b) raise hand and ask the professor at that moment during class
   c) ask the professor when class is over
   d) stop listening to the professor for a minute while you turn and ask a neighbor
   e) consult an aid such as a math/statistics dictionary
   f) other, please specify_______________________

10. When a teacher or textbook offers more than one way of explaining or describing an important statistical concept, you find it: a) very helpful b) somewhat helpful c) somewhat confusing d) very confusing

[note: for items 11-33 on the CLASS instrument, respondents indicated their level of agreement (or disagreement) with the statement by choosing one of the following 7 options: very strongly disagree, strongly disagree, disagree, neutral, agree, strongly agree, very strongly agree. For space reasons, we do not repeat this scale for each item.]

11. I will be able to understand a multi-word phrase used in mathematics/statistics as long as I know each of the individual words in the phrase.

12. It is hard for me to tell when I don't understand a concept because of difficulty with the language used in mathematical/statistical class.

13. When I am a teacher, it will sometimes be hard to tell when a student doesn't understand the concept and when the student does understand the concept but just has a problem with the language.

14. The following description for finding something called the "first quartile" is written in a way that is understandable to me: "Arrange the observations in increasing order and locate the median M in the ordered list of observations. The first quartile is the median of the observations whose position in the ordered list is to the left of the location of the overall median."

15. The following description for finding something called the "first quartile" is written in a way that is understandable to me: "Use the median to split the ordered data set into two halves – an upper half and a lower half. The first quartile is the median of the lower half."

16. The following description for something called the "least-squares regression line" is written in a way that is understandable to me: "The least-squares regression line is the line that makes the sum of the *squares* of the vertical distances of the data points from the line the *least* value possible."

17. The following description for something called the "least-squares regression line" is written in a way that is understandable to me: "The least-squares regression line is the line that makes the sum of the squares of the vertical distances of the data points from the line as small as possible."

18. Reading examples of statistics in the mass media (such as a daily newspaper) helps me understand statistics concepts.

19. Understanding the basic language of statistics involves knowing what statistical terms and symbols mean and being able to read statistical graphs.

20. Working in groups helps me understand statistics concepts.

21. Using graphic organizers or pictures to organize my thinking is useful to me in statistics.

22. Professors often do not wait enough time after asking a question for me to think about what the question means, and think of an answer.

23. I have sometimes not been able to answer a test question when I knew the concept only because I did not recognize the language that was used.

24. If I did not understand the wording on a statistics test question (and if the wording was not a direct part of what was being tested), I would go up and quietly ask the professor during the test.

25. When a professor asks me a question, I believe that he/she thinks I know less than I really do because it takes me a while to express my thoughts into words.

26. There are times I am not able to think of the correct academic words to describe something, but I am still able to communicate my understanding using gestures, pictures, or objects.

27. It would be helpful if statistics class could include examples that connect to my cultural background.

28. I expect that if I asked a question about wording on a statistics test that the professor would help me understand the wording as long as it was not a direct part of what was being tested.

29. It is helpful to distinguish statistics terms from words that may be unrelated but that sound the same or almost the same (e.g., discreet and discrete; complement and compliment; median and medium).

30. It is helpful to see connections made between statistics words and real-world objects or situations, such as this example: "just as a median divides a road into two halves (with opposite directions of travel), a median divides a dataset into two halves."

31. There is a big difference between how statistical concepts are expressed in a statistics textbook and how they are expressed in major news sources (e.g., CNN, newspapers, etc.).

32. It is important to have discussions in class that go beyond vocabulary definitions to include real communication about statistical concepts.

33. It is helpful when a teacher or a textbook takes the time to say how a new word or symbol is supposed to be pronounced.

34. In the table below, what fraction of males would you say are smokers?
a) 4/6 b) 4/10 c) 4/16 d) 4/20 e) 4/30 f) 4/40 g) I have no idea

	Smoker	Nonsmoker
Male	4	16
Female	6	14

35. What is the <u>range</u> of the dataset {1, 2, 3, 4, 6, 6, 13}?
a) 2 b) 3 c) 4 d) 5 e) 6 f) 7 g) 12 h) 13 i) I have no idea

36. What is the <u>mode</u> of the dataset {1, 2, 3, 4, 6, 6, 13}?
a) 2 b) 3 c) 4 d) 5 e) 6 f) 7 g) 12 h) 13 i) I have no idea

37. What is the <u>median</u> of the dataset {1, 2, 3, 4, 6, 6, 13}?
a) 2 b) 3 c) 4 d) 5 e) 6 f) 7 g) 12 h) 13 i) I have no idea

38. How many numbers in the dataset {1, 2, 3, 4, 6, 6, 13} are at least 6?
a) 2 b) 3 c) 4 d) 5 e) 6 f) 7 g) 12 h) 13 i) I have no idea

39. Which of these words can have a meaning in statistics that differs from everyday usage?
a) normal b) random c) correlation d) a & b, but not c e) a & c, but not b
f) b & c, but not a g) a, b & c

40. In statistics, a parameter is (take your best guess if you don't know):
a) a measurement b) a boundary c) a population characteristic to be estimated
d) a constraint e) the number of values in a dataset

41. In statistics, the "null hypothesis" is what we assume is true until there is significant evidence found against it. What would you say is the null hypothesis for a trial in a court of law?
a) the defendant is innocent b) the defendant is guilty
c) it could be either of the above, depending on what culture you are from
d) I do not understand the question

42. The phrase "not all group averages are equal" tells us that:
a) some group averages are equal b) some group averages are not equal
c) all group averages are not equal d) I do not understand the question

43. The phrase "we failed to reject the null hypothesis" tells us that
a) we rejected the null hypothesis b) we did not reject the null hypothesis
c) I do not understand the question

44. If someone drives at a constant speed of 50 mph, we can write the equation Miles Travelled = 50*(Hours Driving), which is called "direct variation" in algebra class.
    a) This use of the word "variation" seems similar to the way we say there is "variation" in a set of data.
    b) This use of the word "variation" seems different from the way we say there is "variation" in a set of data.

[*note: the comment before item 11 applies also to items 45-52*]

45. Knowing the context helps me understand the meaning of words in a sentence involving statistical concepts.

46. It is confusing to me that some statistics words have several associated slightly different words such as random, randomized, and randomization.

47. It is confusing to me that some statistics words are pronounced in different ways depending on the context, such as emphasizing the first syllable of survey (*SURvey*) when it's a noun and the second syllable (*surVEY*) when it's a verb.

48. Knowing the context helps me understand the meaning of a statistical formula.

49. It is confusing to me when words that look and sound similar (mean, median, mode) all get introduced in the same lesson.

50. It is confusing to me the word "statistics" can refer to quantities computed from a dataset, but can also refer to the scientific discipline or area of study I'm taking a course in.

51. Knowing the context helps me understand the meaning of a statistical result.

52. If I don't understand what is going on in class, I will pretend that I understand when the instructor is looking towards me.

53. What is your mother tongue? a) English b) Spanish c) other:___________

If your answer to question #53 was "a" (English), you're now DONE with this survey.
If it was "b", please CONTINUE and answer the remaining questions on this survey.
If it was "c", please CONTINUE and answer the remaining questions on this survey (substituting your own mother tongue when you see the word "Spanish").
===

54. Using the (0-10) scale below, give the number that best describes your proficiency with the English language___________

Level	Description
10	Able to speak like an educated native speaker
9	Able to speak with a great deal of fluency, grammatical accuracy, precision of vocabulary and idiomaticity
8	Able to speak the language with sufficient structural accuracy and vocabulary to participate effectively in most formal or informal conversations
7	Able to satisfy most work requirements and show some ability to communicate on concrete topics
6	Able to satisfy routine social demands and limited work requirements
5	Able to satisfy most survival needs and limited social demands
4	Able to satisfy most survival needs and some limited social demands
3	Able to satisfy most survival needs and minimum courtesy requirements
2	Able to satisfy immediate need with learned utterances
1	Able to operate in only a very limited capacity
0	Unable to function in the spoken language

55. Circle the grade-level years you were taught entirely or almost entirely in Spanish:

JARDIN			PRIMARIA						SECUNDARIA			PREPARATORIA			ESCUELA SUPERIOR			
1	2	3	1	2	3	4	5	6	1	2	3	1	2	3	1	2	3	4

56. Circle the grade-level years you were taught entirely or almost entirely in English:
(Put a star next to any year where you were taught in a bilingual program with roughly equal amounts of English and Spanish)

PreK	KIN	ELEMENTARY SCHOOL						MIDDLE SCHOOL		HIGH SCHOOL				FRESH	SOPH	JUN	SENIOR
1	2	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4

[*note: the comment before item 11 applies also to items 57-61*]

57. I can correctly use mathematics terms and phrases in English.

58. I can correctly use mathematics terms and phrases in Spanish.

59. I can correctly use statistics terms and phrases in English.

60. I can correctly use statistics terms and phrases in Spanish.

61. When I understand a statistics concept in one language, it is easy to use that concept in another language.

62. In a classroom, which of these is most challenging for you?
a) reading b) writing c) listening d) speaking

63. When you work in groups in mathematics or statistics class, how do you usually talk with your group members if your group members are bilingual (and could speak in Spanish or English)?
a) completely in Spanish b) mostly in Spanish c) about as much in Spanish as in English
d) mostly in English e) completely in English

64. When you work by yourself on a statistics problem, how do you usually think?
a) completely in Spanish b) mostly in Spanish c) about as much in Spanish as in English
d) mostly in English e) completely in English

65. When you know a word in Spanish that relates to the word you're trying to learn in English, you usually find this to be: a) helpful b) confusing c) sometimes a, sometimes b

66. Have you ever seen an English-Spanish handbook of mathematics/statistics terms? (This handbook does not give definitions or examples, but allows you to look up in one language what the term is in the other language.)
a) yes, I have seen this kind of resource
b) I have heard of this kind of resource, but have not seen one
c) I have not heard of this resource and have never seen one
d) I am not sure

67. Which of these statements best describes what you already know about probability or statistics?
a) All of what I already know about probability or statistics was learned in Spanish.
b) Most of what I already know about probability or statistics was learned in Spanish.
c) About half of what I already know about probability or statistics was learned in Spanish.
d) Most of what I already know about probability or statistics was learned in English.
e) All of what I already know about probability or statistics was learned in English.
f) None of the above, because I do not know anything about probability or statistics.

[note: the comment before item 11 applies also to items 68-72]

68. If I learn a statistics concept in English, I can easily transfer it to Spanish.

69. If I learn a statistics concept in Spanish, I can easily transfer it to English.

70. When a professor asks a question, I usually translate it into Spanish for myself, and then translate the answer back into English.

71. When I take a statistics test, I believe it would make a big difference if I had access to a list of matching statistics terms in Spanish and English.

72. When I take a statistics test, I believe it would make a big difference if I had access to a general English-Spanish dictionary to translate the “everyday” words used.