A spoonful of science can make science writing more hedged

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Abstract

The present paper focuses on the acquisition of hedging techniques by first-year undergraduate students at the University of Tokyo in Japan. One of the major difficulties faced by aspiring science writers lies in positioning their arguments in relation to the preexisting literature. This originates from the fact that writing in the field of natural sciences is built around the evaluation of uncertainty pertaining to an experimental analysis. In addition to the display of statistical estimators (e.g. p-value), the level of confidence inherent to scientific findings is generally communicated through hedging. Hedging allows authors to communicate the credibility of their statements so as to persuade the audience of the soundness of their interpretations while ensuring that these statements remain within the context that is accepted by their scientific community. Hedging is often used in the Discussion section of scientific reports and, to a lesser extent, in the Introduction. Second language learners of English face difficulties when writing these sections due to the use of hedges. Using a qualitative analysis of 20 student papers we found that students express uncertainty in relation to scientific information differently when dealing with their own experimental data compared to results in the literature. We argue that completing an actual scientific experiment within a science writing class is important to provide the context in which the theoretical rules of hedging are applied.

Keywords: Science writing; hedging; nature of science; experiment; second language acquisition

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Introduction

Specialized English language courses have multiplied during the past forty years in order to allow students to bridge their language competence and discipline-specific contents more practically (Liu, Chiu, Lin, & Barrett, 2014). These courses, classified as English for Specific Purposes (ESP), have had a strong impact on adapting the curriculum to the concrete needs of students (Hyland, 2007). In Japan, the ESP movement has only developed since the 1990’s in reaction to universities establishing numerous specialized courses. ESP courses aim to provide students both with formal writing skills and discipline-specific materials that students have been shown to lack in their "General English" curricula (Gosden, 1996).

At the University of Tokyo, a science ESP program is required for all science students entering their first year of undergraduate studies. This program is called Active Learning of English for Science Students (ALESS) and is uniquely characterized by the fact that students are required to complete an experiment of their own design as part of their English writing task. Over a semester, students engage actively in a research that is investigating a problem that they have not studied in their high school science classes. Individually or in small groups, they learn from their instructors different aspects of scientific writing and apply these elements to write a research paper in a typical scientific format. The ALESS faculty includes scientists as well as linguists in order to balance the teaching between the science and language components.

ALESS aims at developing in students an approach to writing about scientific methodologies for autonomous inquiry. Such an approach relies heavily on students' ability to evaluate and present the data they have obtained during their experiment. Therefore, rather than just applying rules discovered during lectures as a template for future writing, ALESS promotes a concrete practice of scientific communication that is attuned to students' language needs. Considering that the majority of first year undergraduates in Japan have never written a scientific report in English (or any extensive writing in English) prior to ALESS, several aspects of scientific writing are completely new to them and it is essential for the program to establish a clear framework in which these aspects are analyzed and drilled.

The present paper focuses on one aspect that apprentice science writers, especially second language (L2) learners, find difficult to master. Hedging is an important component of communicating scientific findings (Horn, 2001) but past studies have shown that L2 learners face difficulties when confronted with the variety and the specificity of hedges at their disposal (Bitchener & Basturkmen, 2006; Channell, 1994). In particular, this study examines the impact of an experimental component in the writing course on students' understanding of the hedging process by comparing the way students communicate about past research and their own data. In this paper, we argue that the learning of hedging is always connected to the scientific context in which the content is written, and that adding an experimental component to the science writing course provides students with an authentic and clearly defined context that allows them to recognize and appropriately express uncertainty in their own scientific writing.

Hedging in science writing courses

Use of hedging to communicate scientific findings

One of the major difficulties faced by aspiring science writers lies in the positioning of their arguments in relation to the preexisting literature. Hedging allows authors to communicate the credibility of their statements so as to persuade the audience of the soundness of their interpretations while ensuring that these statements remain within the context that is accepted by their scientific community (Hyland, 1996). The misuse of hedging can mislead readers about the uncertainty associated with their claims and, therefore, an appropriately hedged statement needs to be carefully crafted to allow a new piece of information to become general knowledge about a specific discipline.

Within the context of a scientific report based on experimental data, hedging is often used in the Discussion section and, to a lesser extent, in the Introduction (Day & Gastel, 2012). In the

Discussion, hedging is employed to make links between the results and the literature, explain the meaning of the data and propose alternate interpretations for key results. In the Introduction, hedging is generally used to highlight the existing gaps of knowledge within the literature in order to justify the study. Hedging is thus a linguistic element that is necessary for any apprentice science writer to master.

To be able to use hedging appropriately, apprentice writers should be able to ascertain the level of confidence attached to scientific data and subsequently choose the adequate lexical and syntactic tools to express it. This critical evaluation of information is usually lacking from the traditional high school science curriculum due to science being taught through verification-type activities (Clough, 1997) or research projects where students have little ownership of the data produced (Moss, Abrams, & Kull, 1998). As an alternative, this problem could be addressed by asking students to solve scientific problems of their own choosing through an experimental procedure (Nikolova & Stefanova, 2014). This "hands-on" approach has yet to be applied generally to science writing courses despite the fact that it seem to yield positive results within science classes in terms of students understanding better the nature of science (McComas, Almazroa & Clough, 1998; Norris & Phillips, 1994; Tsai, 1999).

Use of hedging to express the uncertainty of scientific data

Scientists mostly use hedges in two circumstances: communicating the findings obtained in previous research, and introducing the author's interpretations about their own experimental results (Hyland, 1996). As such, hedges are not solely used to reduce the strength of scientific claims; they are also used to establish the opinion of the writer with respect to their peers in the research field and the existing body of knowledge gathered so far.

As the information presented in scientific publications depends both on the accuracy of the experimental data and the expectations of the experimenter, hedged statements reflect the limitations of the experimental setup as well as the intellectual filters that bias interpretation. When citing hedged statements, attention should be dedicated to respecting the level of hedging in the original publication while integrating their own point of view (Horn, 2001).

Hedging is therefore a powerful tool for revealing the voice of the writer in a scientific publication. Apprentice writers, both native speakers (L1) and non-native speakers (L2) of English, often face similar conceptual obstacles when estimating their level of confidence through hedging due to the multi-faceted nature of scientific information. For first year undergraduate L2 students in Japan, one technical barrier to understanding the practice of hedging in science writing is the widespread use of science textbooks where hedging is less frequent (Burrough-Boenisch, 2005), thus presenting science as a series of verified facts (Myers, 1992). Students who use their textbooks as guidelines therefore suffer from an excess of generalization in their statements.

Language difficulties in Japanese L2 learners

Previous studies have reported that, among Chinese L2 students, the inability to hedge was a factor participating in the low evaluation of Discussion sections by supervisors (Bitchener & Basturkmen, 2006). This is understandable because hedging acknowledges the concept that scientific facts are social constructs (Knorr-Cetina, 2013) that differ drastically from the objective observation of nature that students have in mind. Channell (1994) emphasized that second language learners need to be guided through the process of hedging as it is one of the essential aspects of writing within the scientific community, and her conclusions are corroborated by several studies that focused on L2 writers (Hinkel, 1997, 1999, 2002, 2005; Jordan, 1997). In addition to the complexity of scientific information, Japanese L2 writers face additional obstacles related to the level of nuance associated with the variety of hedges available in English.

Among the linguistic tools available to form hedged sentences, Hyland (1996) distinguished three types: (1) hedges as adjectives or adverbs, (2) hedges as verbs, and (3) hedges as modals. In addition to the hedges defined by Hyland, specific expressions and phrases (e.g. significant results) are recurrent in scientific articles and writers need to familiarize themselves with these phrases through extensive reading (Shirato & Stapleton, 2007). These elements can be used individually or in combination to convey the evaluation of scientists' claims. Hyland and Milton (1997) noted that second language learners face difficulties applying hedges to communicate their opinion with an adequate level of certainty. Hinkel connected this problem to the lack of emphasis on hedging in English as Second Language (ESL) textbooks, and this is even more extreme when considering the relative rarity of textbooks dedicated to science writing (Hinkel, 2005).

For this study, we posited that conducting an experiment during the timespan of the writing course would allow students to confront the uncertainties inherent in the acquisition of the scientific knowledge and relate these uncertainties to the expression of their interpretations in their writingwritten productions. As a result, we would expect students to more accurately assess the level of confidence attached to their own claims in comparison to that attached to the reporting of past findings.

Methodology

The 20 writing samples examined in the present study were randomly chosen from reports that were submitted as a final assignment for the ALESS course taken over one 13-week semester between April 1st 2015 and July 31st 2015. These reports account for approximately 50% of the students' final grade. Writers of the reports were Japanese first-year undergraduate students, and were supervised by the authors for the entire duration of the course. All were science students but had not yet chosen their specific major. They all were intermediate second language users of English and had studied English for at least six years in Japanese schools, using a grammar-translation methodology.

ALESS is a science writing course uniquely characterized by the fact that students are required to write a 6-10 page paper reporting the findings they obtained through a scientific experiment of their own design. Over the course of 13 weeks, students enrolled in this program experience various steps of the scientific methodology including formulating hypotheses, conducting an experimental protocol and interpreting results. In the meanwhile, class activities focus on the writing of students' papers and provide an occasion for apprentice writers to receive feedback from instructors (Appendix 1). Activities consist of application exercises targeting specific rules of sentence structure or grammar, guided examinations of excerpts of published papers and eventually practice writings accompanied by peer discussions and teacher feedback (Appendix 2). Students' papers follow an IMRaD (Introduction, Methods, Results and Discussion) format and each teacher covers all the aspects of this template using materials that they design themselves. The sequence of the teaching is also left to the discretion of the instructor. Through these multiple exposures to examples of published writing as well as personalized feedback, students are guided towards the completion of their own research papers.

For each of the 20 submitted papers, the use of hedges was examined in the Introduction and Discussion sections. Because the nature of hedging is dependent upon the particulars of each students' own experiment and the previous research each student cited, a qualitative method of analysis was used. This comprises what could be called a *parallel case study* (Yin, 2003), with each of the 20 papers being a single, small-scale case study. Each statement in the Introduction and Discussion sections was examined for the use or lack of hedging, while referring to the related Method or Results sections of the students' papers, and to the cited published research as needed. This qualitative analysis followed the methodology of *guided theory* (Richards, 2003), where each example encountered in the data is examined in context and evaluated in light of the hypothesized theory. As deviant cases are encountered, the theory is updated as needed to take these into account. Although this method starts with a hypothesis, the final explanation is emergent from the data—a hallmark of qualitative research (Richards, 2003).

For the Introduction and Discussion sections of the students papers examined in this study, each statement was examined in context, using the hedging taxonomy of Hyland (1996). In this taxonomy, scientific statements are separated first into *factive* and *non-factive* (subsequently *hedged*) statements. Hedged statements are then subdivided into *content-oriented*—where the accuracy of the reported phenomenon is appropriately described, and *reader-oriented*—where the reader is given options and allowed to choose the most persuasive conclusion. In each case, the writer's use or lack of use of hedging was examined in relation to the experimental procedure and results, or in relation to the previous research cited, in order to arrive at a satisfactory explanation for the trends in students' use of hedging.

Results and Discussion

The results from our analysis showed that first-year undergraduate students in the University of Tokyo share overall similarities in their approach to communicating scientific findings. Particularly, they seem to distinguish the reporting of past research published in the literature from the reporting of their own results through a distinctive use of hedging. The detailed list of hedges considered for this study appears in Hyland (1998). We coded the verbs that were at the core of the claims.

Students tend to treat published research findings as definite truths

Out of a the set of 20 student papers, a contextual examination of the expressions used to report past findings showed that students often introduced these results through over-generalizations either without (see example 1) or with (see example 2) an associated reference.

These days, we often <u>suffer</u> from noises such as cars, airplanes and construction sites. (1)

The dissolving of Al^{3+} and heavy metal ions which are harmful to plants <u>causes</u> the damage of trees (Amthor, 1984). (2)

These sweeping statements were usually written with the present tense, marker of general truths (Swales & Feak, 2004). Other students however correctly distinguished general truths from more punctual scientific results (3).

> *Furthermore another research suggests that maize from magnetically exposed seeds <u>did photosynthesis</u> more actively (Anand et al., 2012).* (3)

Instructors presented several examples of introduction or discussion sections in class and highlighted the use of the present tense in situations where the information communicated is common knowledge or when the particular phenomenon has been clearly demonstrated in past research. During class activities, practice exercises have targeted the distinction between the use of the past tense to describe experimental data and that of the present tense to present information belonging to general knowledge. Therefore, one explanation for the high frequency of over-generalizing claims could be that students consider published results as definitive proof and purposefully write these findings following the format of general truths. This stance towards past literature is also observed when students are positioning their results within the existing body of knowledge to either support or nuance their personal claims. In example (4), from a student Introduction section, the student uses present tense for both the cited findings of the previous research, and the application of that study to the explanation of their own findings, although *propose* serves to hedge this to some extent.

> *[Both aerobic and non-aerobic exercises increase cortisol levels which…] <u>leads</u> to the decrease of the ability of memorization (Kirschbaum et al., 1996)[see (Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996)]. Thus, we <u>propose</u> that non-aerobic exercise <u>decreases</u> the ability of memorization.* (4)

It is therefore crucial for instructors to evaluate whether a lack of hedging results from misunderstanding the teaching points raised in class or failing to evaluate the level of uncertainty in the data that was used in their argument.

Students hedge their claims more when reporting their own results

In contrast to the way they reported past research, students displayed a tendency to modulate the strength of their claims when they related their own personal data. These "toned down" statements generally pertained to the technical difficulties that students faced during their experiments, such as an insufficient amount of data, extraneous variables or inability to appropriately control constant parameters. Students usually followed a sequential approach to reporting their results, from a synthetic presentation of data patterns to their interpretations of the experimental results.

In presenting their own data, students showed comparable difficulties as in reporting past findings. Some statements could be interpreted as over-generalizing the results (5), but a large number of students showed a more appropriate use of the past tense to report their findings (6).

> *The results <u>indicate</u> that the ability of memorization <u>decreases</u> by the increase of the heart rate with non-aerobic exercise.* (5)

> *Contrary to our expectation, the positive correlation between heart rate and short term memory <u>was not</u> significant in this study.* (6)

In some instances, sentences were more problematic to classify as they mixed factive and hedged statements (7).

There is the possibility that the difference between the pH level of water does not affect the speed of water absorption well. (7)

Beyond the straight presentation of their data, the discussion section is also the part of a scientific report where interpretations that give meaning to the data are proposed (Pechenik, 2004). These interpretations are essentially lenses through which writers perceive the data and reveal their personal understanding of the patterns that were detected during the description of the results. This level of abstraction is classically distinguished by a greater degree of hedging (8) and the use of the present tense (Swales & Feak, 2004).

The mechanism of memory improvement might be explained by activation of brain function during physical exercise. (8)

The higher degree of hedging associated with students presenting their data as compared to their reporting of pre-existing findings suggests that students associated these two situations with distinct levels of uncertainty that reveal their position towards the scientific information. The experimental component in the ALESS writing course therefore highlights the gap that exists in students' minds between the information they obtain from references and that they produce themselves. Attracting students' attention to this differential treatment during collaborative peer reviews in class can allow them to re-evaluate the hedging associated with these claims.

Unclear hedges in student papers

Hyland and Milton (1997) have described the use of hedging in L2 learners as "problematic" due to 1) the variety of meanings associated with the lexical items used as hedges, 2) the difficulty for L2 learners to acknowledge their readers in their texts, 3) the diversity of means through which hedging is achieved, and 4) the lack of exposure to the specific contexts in which hedges are used. Our examination of student papers suggests that the lack of clarity in their hedged statements lies also at the level of the information that they want to convey, specifically in the negotiation of meaning between writers and readers.

Among the various hedges introducing scientific information, judgement verbs (*think, believe*, *know*) and evidential verbs (*show, say, suggest*) both allow writers to express a certain level of epistemic modality about propositions (Horn, 2001). In the present sample of student writings, students often used strong evidential verbs (*show*, *indicate, demonstrate*) to report findings (9).

Like this, some researchers showed that the color of light has variety effects on growth of plants. (9)

Anyway, we suggest that red light may promote transpiration of plants. (10)

Other writers selected more tentative verbs (*report, suggest*, *propose*) (10) but whether or not students were aware of the semantic distinction between these two classes of verbs remains unclear as the statement following the main verb often lacked further markers of hedging (11).

Thus, we propose that non-aerobic exercise decreases the ability of memorization temporarily in the same way as aerobic exercise. (11)

Such unclear use of evidential verbs likely stems from the lack of exposure to literature that Hyland and Milton (1997) highlighted. Students indeed seem to use these verbs interchangeably without perceiving their nuances. Therefore improvement may only be possible through more extensive reading than the short duration of this course (one semester) allows.

Among the other possible hedges, the L2 students in this study conveyed hedges mostly through the use of modal verbs (*can, could, may, might*). Other elements, such as adverbs (*probably, possibly, likely)* or formulaic expressions (*there is a possibility that*), were used much less frequently. This lack of diversity observed in L2 science students' language supports past findings on non-scientific texts (Hinkel, 2005; Hyland & Milton, 1997) and may originate as well from a lack of exposure to contextualized contents.

However, it is interesting to consider that the diversity of hedges and their overall strength increased generally between the introduction section (mostly focusing on the positioning of students' research within the existing knowledge) and the discussion section (focusing on the interpretation and critical analysis of students' results). This observation suggests that students might choose to present their own findings in a way that is more nuanced rather than just being limited by the extent of their lexicon or syntactic library. In addition, peer review exercises in class revealed that students were able to criticize their classmates about their experiments, showing that a lack of critical thinking or the maintenance of 'face' (Gosden, 1996) is not an issue here. As a result, unclear hedging or lack of hedging may be connected not only to the language abilities of the students, but also to the relationship they perceive to exist between themselves, the source of information, and the reader.

The role of hedging as a tool promoting the smooth communication of scientific claims within a community of peers has been highlighted by various authors (Bitchener & Basturkmen, 2006; Gosden, 1996; Horn, 2001; Hyland, 1996). In the context of the ALESS program, it is necessary to assess what this community is, in order to understand the difficulties that students confront when writing their claims. First-year students have minimal experience conducting research and interacting with the work of professional scientists, and therefore would not likely consider themselves to be peers in the community of researchers that is the source of published research papers. On the other hand, students would much more likely consider their classmates to be their peers, and therefore are more able to critically analyze the work of their classmates than the work of professional scientists.

Conclusion

This study examined the relationship between hedging in students' texts and their understanding of the tentativeness of scientific findings through the completion of an actual scientific experiment of their own choosing. It revealed that first-year students commonly over-generalize the nature of scientific findings, especially when they are obtained through an examination of the existing literature. The differential treatment observed between the data collected by students and the data collected by professional researchers highlighted the fact that students do not define themselves as belonging to the scientific community yet and acknowledge published scientific data as comparable to the information available in textbooks. The addition of a practical scientific component to science writing courses has therefore the potential to raise students' awareness about the nature of science as well as to demonstrate the role of hedging within the scientific community.

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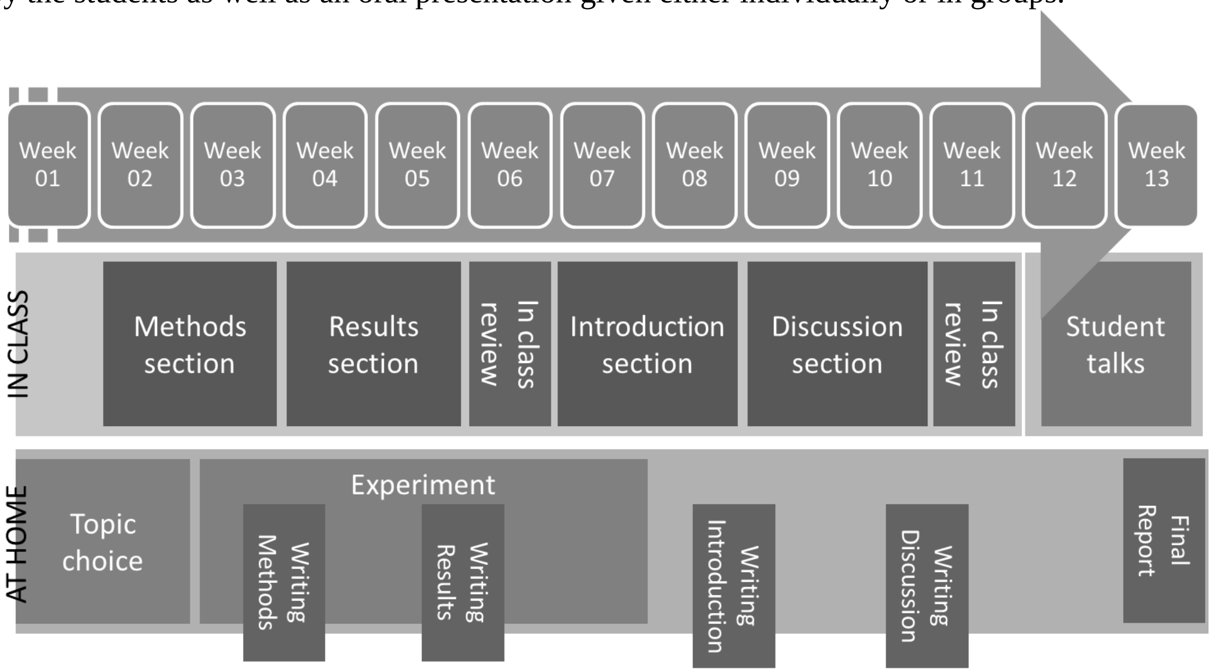
Appendix 1: Timeline for the ALESS course

The Active Learning of English for Science Students is a one 13-week-long mandatory course that all first-year science students have to take upon entering the University of Tokyo in Japan. During the 13-week timespan, students learn to write a basic scientific report (Introduction, Methods, Results and Discussion) including data that they have gathered by conducting a simple experiment of their own design. The scientific experiment is planned and carried out entirely by the students, who can receive support from teaching assistants at a laboratory specifically attached to the ALESS program. In class, instructors cover various aspects of the writing process and guide students through class activities and personalized feedback. Below is an example of a breakdown for the 13-week course showing the sequential approach to the various sections of a science report. Both the workflows in class and outside of class are indicated. In this example, the Methods and Results sections are written before the Introduction in order to more closely align with the conducting of the experiment, and in order to have students write sections that they generally find easier earlier in the course. At the end of the course, grades depend on the final report submitted by the students as well as an oral presentation given either individually or in groups.



Appendix 2: Example of class activity about control experiments

The exercise presented below is part of a series of activities conducted by the authors during the class scheduled on Week 3 of the course during the lesson dedicated to the Methods section of scientific papers. The goal of the exercise is to familiarize students with the notion of control experiments and therefore addresses both an issue of vocabulary and a more general description of the ways used to constraining variables in scientific inquiries.

During the exercise, students are first introduced to the concept of a control experiment. They are then split into small groups looking at actual scientific data and are tasked with answering three questions: 1) between A and B, which group is the control group?, 2) considering only the group B (with insecticide), what do you think is the effect of insecticide on the respiratory capacity of frogs? 3) by comparing the results in groups A and B, what is the effect of insecticide?

Text C: Control experiment

Hiebert, S. M. (2007). Teaching simple experimental design to undergraduates: do your students understand the basics?. Advances in physiology education, 31(1), 82-92.

"The rate of oxygen consumption (VO_2) of 20 frogs is measured in the wild and frogs are then collected and divided into two groups (A and B) back in the laboratory. The group B (10 frogs) is placed in an aquarium with insecticide and the VO_2 is measured again after 4 weeks for all the frogs (with and without insecticide)."