Simulating the Research Laboratory: Using Science to Teach English in ALESS

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Introduction

Universities in Japan and other non-English speaking countries around the world are focusing on English education as a core discipline with the aim of bolstering internationally competitive students (Altbach, 2004; Hashimoto, 2011). Nevertheless, classroom activities at the high school level are often tailored, despite criticisms, to the demands of university entrance exams including memorizing vocabulary, learning grammar rules and reading simple texts (Buck, 1988; Butler & Iino, 2005). Hence, English language education at the University level in Japan should smooth the transition between classroom activities that emphasize grammar and reading, and becoming comfortable utilizing the knowledge to perform more functional and communicative tasks (Butler & Iino, 2005). Currently, the progressive expansion of English education in Japan relies less on traditional textbook-based undergraduate programs taught in Japanese (Hashimoto, 2011) to learn idiomatic phrases and practice grammatical translations of text (Hino, 1988), as this style of studying has been argued to not lead to proficiency (Berwick & Ross, 1989; Buck, 1988). Many programs now incorporate previously omitted facets such as speaking and listening (Hashimoto, 2011) within targeted, content-based curriculums aiming to teach practical English for special purposes such as academic writing and communication (Gally, 2009; Gally, 2011).

One such content-based English curriculum is the Active Learning of English for Science Students (ALESS) Program at the University of Tokyo (Gally, 2009; Gally, 2011; Middleton, 2013), which is taught entirely in English and aims to incorporate the

full spectrum of the life of a scientist simulated in one semester, with the students designing and performing experiments, analyzing data, writing a paper in the IMRaD style format (Sollaci & Pereira, 2004), and formally presenting their findings. The program strives to give students freedom while conducting these simulated activities in the classroom with hopes to motivate them towards impactful, rewarding, and autonomous learning. This paper examines the various approaches through which the ALESS Program aims to replicate and immerse the students in the real-life experiences of research scientists, and then suggests how two additional scientific situations could be further incorporated into the practical teaching of English.

English Language Education at the University Level

Foreign Language Education

Despite varied curriculum requirements, foreign language education is mandatory in many universities around the world, with the aim of increasing global awareness in students (Calvin & Rider, 2004). Notably, many students in Japan also take a second foreign language such as Chinese, Korean, German, French, Spanish, or Russian after entering university (MEXT, 2013). Students also study English for at least six years before entering university (Butler & Iino, 2005; Hashimoto, 2011), and the length of study of the English language, the most widely studied foreign language in the world (Altbach, 2004), highlights Japan's recognition of its global significance and the attempt to encourage its transition from the status of a foreign language to the second working language in Japan.

English for Science Students

Language has an indispensable function for students of science (Seah, Clarke, & Hart, 2014). As Yore et al. (2004) convincingly reasons, it is:

> an essential technology and thus an integral part of science and science literacy, particularly written language. Language is a means of doing science and of constructing science understandings; language is also an end, a fundamen-

> tal goal of science literacy, in that it is used to communicate about inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed actions. Thus, science is a process of inquiry conducted through the use of language that establishes knowledge claims based on arguments that draw on the available evidence and canonical science. (p. 348)

Uniting the principles that learning the language of science is critical in performing well in science and that the language of communication in both academia and research in the natural sciences is predominantly English (Nunan, 2003), many universities across the world now offer classes for science students that are taught entirely in English and modeled around the use of authentic scientific texts (Gally, 2009; Gally, 2011; Parkinson & Adendorff, 2004). The use of genuine research articles, as opposed to textbooks, in these programs naturally teaches specialized linguistic observations, stimulates discussions, and develops conceptual understandings (Seah et al., 2014) which will foster students' awareness of the language of science in preparation for the time when they enter the realm of scientific research.

Realism in the ALESS Program I: Authenticity of Activities

Brief Summary of the Program

ALESS is a compulsory one-semester course that began in 2008 for all first year science students during which they are fully immersed in English and initiated into an active, self-motivated acquirement of knowledge, rather than examination-based learning. Each semester, around 1000 students are placed into small classes, comprised of approximately 15 students, which directs them towards the creative, independent thinking required in the next four years and beyond of their academic and research careers. Grades are based largely on the quality of the students' final papers and presentations, which are products of the practical activities they have completed in class during the semester including designing and performing experiments, anal-

ysis of the data, and drafts of their IMRaD style papers. Thus, each component of scientific inquiry is incorporated into the performance and the outcome of the graded final reports and presentations. This section of the paper introduces the unique realism of the ALESS Program by exploring several typical ALESS activities that are explicitly modeled on authentic scientific practices, before examining an additional sense of realism in the ALESS Program based on more abstract principles of scientific research in the following section.

Designing and Performing Experiments

One of the first activities for students in the ALESS Program is designing a simple experiment that can be performed in a couple of weeks. Variations by teacher notwithstanding, students are generally allowed to select any topic of their choice, and there is a great deal of diversity among the students' interests (see Middleton, 2012). This initial decision in choosing their project is important for motivational purposes, as consequent activities in the semester will often be based around their experiment. Students are discouraged from conducting observational experiments, and they are guided instead towards designing tests to manipulate certain parameters and obtain quantitative results. The experiments are often quite simple; they are not unlike those that students have performed during their summer vacations as part of their *jiyu-kenkyu* homework (Andoh & Umino, 2008) in elementary school; although for ALESS classes students need to form a working hypothesis, identify experimental variables, and identify the purpose and significance of their experiment in a social context. Simply-designed experiments are acceptable and appropriate, but it is essential that students do not know or cannot easily find out the result of their experiment, in order to nurture the genuine pursuit of scientific inquiry (Hofstein & Lunetta, 2004).

In a short ALESS video made for students to introduce some of the criteria for ALESS experiments (Middleton 2013), students are encouraged to keep an organized and detailed record in a bound notebook during their experiments "because loose pages might get lost," and to take notes using a pen "so that nothing can be changed later" (ALESS Program, 2012). This ostensibly simple and commonsensical practice is in fact a fundamental

component of actual scientific research. In research, laboratory notebooks are kept by researchers to systematically document all experiments and every step taken on a daily basis in one location. There are many personal systematic variations, but these permanently bound notebooks usually contain much more than raw data as they are used to protect intellectual property for a chronicled proof-of-rights to patents or to preserve integrity and prevent fraud (Nickla & Boehm, 2011). It is common to include drawings, clippings, photographs of experiments, or print-outs of data in laboratory notebooks, as well as references that influenced the direction of the experiments. In my experience of working as a scientist in research laboratories in Japan and the United States, notebooks are often referenced during meetings and in more casual daily conversations to problem-solve or give advice; for convenience, researchers leave a few blank pages for a table of contents in each notebook. Moreover, as notebooks belong to the university or research institution, organization and clarity are critical so that they can be utilized as reference guides in the future.

In the actual research laboratory, scientists typically do not have complete freedom to study from an unlimited source of imagination. Each laboratory has its own specialty and its own niche in a seemingly vast number of fields. As such, in ALESS classes, some instructors have tried to give their students a more realistic experience: for instance, by limiting the available topics to three specific themes. In the laboratory, experiments performed are usually quite specific but the trajectory of the investigation is never rigid and sometimes changes; and similar to some ALESS experiments, there are occasionally dead-ends, where the experiment has failed to produce any clear or noteworthy results. Although for a researcher, thoughts of publications usually come after many different experiments have been performed and a paper is constructed around various sets of data, in the classroom, IMRaD structured papers can be sufficiently composed with just one set of results, regardless of the outcome. Even when a student's experiment has failed, they are encouraged to write their papers using their results as it can still lead to an insightful discussion section. While there are limitations to recreating an authentic research setting within the ALESS Program, the simulated environment is readily able to

accommodate the unpredictable outcomes of students' experiments so that they are all able to write their final papers.

Searching for Academic Papers

One significant aspect of research in every field is to find relevant papers about a given subject and stay up-to-date on current research. Some laboratory groups facilitate this process with journal clubs where members bring noteworthy or exciting papers and present them to the rest of the group. The purpose is to encourage laboratory members to stay updated on topics outside of the group's research focus. It is effective as each member often has various interests outside of their research area and diverse articles or topics will be noticed when browsing casually. By sharing information, all members can remain updated on novel technologies or skills and may also discover new topics that they could otherwise have missed in the massive volumes of information available.

As searching for academic papers is an essential and regular activity for a scientific researcher, in ALESS classes, some instructors spend one entire class period teaching students how to search for academic research papers online. This activity allows students to find and cite papers that are related to their experimental choices so that they can compare various experimental methods, compare their results with that of related research, and understand the overall importance of their experiment. This exercise also allows students to practice extracting important information by simply reading abstracts and looking at figures and legends, for instance. Obtaining thousands of hits for a search with even several keywords is initially a striking experience and students quickly learn that choosing appropriate keywords is critical. The importance of using *English* keywords for these searches is also emphasized, because as much as 98% or more of research papers published in various fields are written in English (Nunan, 2003). The experience of discovering that authentic scientific papers are readily accessible for everyone and the confidence acquired by understanding the structure of such papers makes this a valuable exercise. It is also one of the students' first direct interactions with the world of scientific research.

Writing a Research Paper Based on Actual Experiments

Ideally, in order to write an academic paper in English, one should be exposed to and read as many research papers as possible. This occurs naturally while performing research; a researcher may read several review papers to appreciate the comprehensive overview of a particular field of study, including its history, current understanding, controversies, and complications. Communications or letters, often only a few pages long and without the conventional IMRaD subheadings, are also read in order to learn about the most groundbreaking or pressing topics in a certain field. However, in the ALESS classroom, due to the variety of topics chosen by the students and the time restrictions of the class, it is impractical to thoroughly analyze the papers that the students have found themselves, or even to read one exemplary academic paper in depth. The best alternative established for ALESS is for instructors to provide simple representations of each section of an IMRaD style research article to illustrate the objectives and the key contents of each section.

The models of the research articles provided to students allow them to understand that each section should be written according to certain criteria, and equally importantly, in a thoughtful, clear, logical, and persuasive manner. The papers are not necessarily written in the chronological order of the experiments, especially if to do so would sacrifice clarity and rationality, as the main aim of research papers is to convince the audience that the research presented is important and valid while emphasizing the motivation and the significance of the results. Briefly, the introduction section should elucidate the specific aim of the research as well as the scientific context. The methods section should be detailed to ensure reproducibility and clearly-organized, although not necessarily by the mere listing of objects that were used. In addition, a rationale should be given for each step of the procedure if it is not apparent. The results should also be shown in the clearest way possible to help the reader quickly understand the key information and avoid erroneous interpretations or incorrect assumptions. Finally, the discussion should be critically thought-out and deliberated from as many angles as the students can explore, and it should persuade the reader of their conclusions. By fulfilling these criteria, the students' final

papers should be clear and convincing, and writing the entire paper themselves will enhance understanding of the necessary elements and rhetoric of an IMRaD style research paper (Rivard, 1994). Although the final paper accounts for 50% of their grade, it is not based on the quality or difficulty of the students' experiments, nor is it based on the number of words or the number of figures; instead, it is assessed holistically on the incorporation of the given criteria, the attention to mechanical details of composition, and the persuasiveness of the arguments — all essential factors of effective communication.

Audience-Centered Communication

Subsequently, in contemplating, discussing, and writing their papers, students learn the necessity of targeting a specific audience and considering the needs, expectations, and predicted knowledge of their readers and listeners to effectively communicate their ideas. In class, the students spend time each week discussing their topics with their classmates, and these discussions are comparable to most research laboratories, which consist of a combination of technical staff, graduate students, post-doctoral researchers, senior researchers, and a principal investigator who get together for weekly group meetings and sub-group meetings to find solutions to specific problems or to consider future directions. In both cases, group members with differing interests and levels of involvement eventually become familiar with the experiment and the rationale behind it, but the discussions provide a valuable opportunity to practice and learn how to effectively address groups with varying knowledge of a topic.

Contrary to the group discussions with scholars in the same field, research articles are often written for the non-specialist, targeting a broad range of scientific researchers from various fields. Comparably, although the discussions in class are with classmates who quickly become well-informed on their topic, the target audience for students' final papers and presentations is the general public with little or no specialized knowledge of their topic. In both situations, the target audience must be considered in order to write effectively and with purpose. Because the unambiguous audience for assignments prepared in a classroom setting is the instructor, conveying ideas for an imagined audience requires some effort. Unlike classmates or their instructor,

an arbitrary reader will need to be encouraged and persuaded to read a paper or listen to a presentation. Moreover, predicting the imagined readers' interpretation and leading them to the desired conclusions requires careful planning, persuasive justifications and definitions for technical words and phrases. Through comparison and evaluation of example articles from popular science magazines (Parkinson & Adendorff, 2004) and original research articles on equivalent subjects, and by receiving peer reviews from their classmates, the students are trained to develop their papers and presentations with the general audience in mind.

Peer Reviews

A valuable activity that is performed frequently in the ALESS Program is peer review (Lee, 2010). In the classroom, two students exchange their written homework and give each other comments on what was effective and what can be improved. The purpose of the peer review activity is three-fold. It is an opportunity for students to confirm understanding of the assignment and provides an extra writing sample of a particular section of a scientific paper. Peer reviews also encourage classroom collaboration, to directly receive and offer ideas to help one another improve their work. Many teachers choose to have the last peer review of the final version of the student papers performed anonymously as homework, as this allows students to write comments freely and suggest many changes unreservedly. This anonymity again simulates actual scientific practice: in this case, peer review where the decision of publishing a paper is influenced by anonymous reviewers who, without conflicts of interests, carefully scrutinize and evaluate the work for quality control.

Realism in the ALESS Program II: Principles of Scientific Practices

As indicated in the previous section, the ALESS Program is structured around a series of activities that are directly modeled on actual scientific practices, and this active style of teaching is one of the major strengths of the ALESS Program. However, there is an additional sense of realism that is integral to the program: the way in which students become immersed in more

general, yet defining principles of scientific practice. This section identifies three such principles that are implicit throughout the ALESS Program.

Collaboration and Social Interactions

In the laboratory, each scientist is responsible for projects or parts of a larger project but a significant proportion of the work, from the initial conception of the project and training in unfamiliar laboratory techniques, to developing a new plan and analyzing data, is rarely performed alone. Instead, there is typically a principle investigator who guides researchers, along with coworkers and collaborators (Hara, Solomon, Kim, & Sonnenwald, 2003) who provide additional support. This type of collaborative work is accentuated in the active teaching style of ALESS. The typical non-lecture classes which incorporate group activities naturally lead to students learning to work collaboratively and productively, communicate and discuss their ideas effectively, compromise, debate, and also indirectly learn to become independent and confident thinkers.

The principle of collaboration is further strengthened by the extensive external resources available to ALESS students outside of the classroom (Middleton, 2013). In addition to the motivation and support provided by their teacher and classmates, the students have access to the ALESS Lab: a science laboratory run by a research scientist with the assistance of many science graduate students, where they can borrow equipment, receive advice about designing their experiments or analyzing data, and obtain any other help related to their experiment. Therefore, in their first year, students have an opportunity to meet and interact with their future selves in a research laboratory. Whereas instructors or teaching assistants who are giving or influencing their grades may seem unapproachable, the Lab provides an opportunity to interact with scientists in a non-judging environment and creates a vision of what can be achieved.

Similarly, the Komaba Writers' Studio (KWS) (Gally, 2010) is staffed by bilingual or multilingual graduate students, and here, the first year students of ALESS can receive assistance in writing, speaking, and listening practice. The accessibility and welcoming atmosphere of the KWS encourages nearly 700 consultations each semester. As the instructors are not provided information

about the students who have been to the ALESS Lab or the KWS until after the semester has ended and grades have been submitted, it allows students to communicate with young scholars who are at various levels of their study in a safe and sanctioned setting where they receive help. Crucially, this interaction indirectly makes the students aware that it is acceptable and encouraged to reach out for help when necessary, and that asking for advice improves the quality of work. Therefore, in addition to the beneficial experiences of learning about different perspectives and meeting positive role-models, these experiences of collaborative work provide essential preparation for life as a scientist.

Motivations and Limitations

There are further parallels between scientific research and science in the classroom regarding motivations for success and circumstantial limitations. One of the undeniable motivations in research is competition, primarily for funding, results, publications, and fame. Analogously, in ALESS class, students may often have assessment in the back of their minds due the importance of grades in advancing to their department of choice for their 3rd and 4th year education. Furthermore, exemplary student papers are chosen to be published in the *ALESS Collection*, a magazine of student papers printed each year, which acts as an additional source of inspiration and motivation for the students (Middleton, 2013).

There are also time limitations for both scientists and ALESS students. The students are only given a few weeks to design and perform experiments, and researchers are under pressure to produce results and publish as soon as possible due to the competitive nature of science and fear of getting anticipated or "scooped" (Hagstrom, 1974). Similar to the funding restrictions experienced by researchers, monetary considerations are also of concern to students. Students may borrow some equipment from the ALESS Lab, which is well-stocked with common general supplies found in most wet laboratories including a pure water system, chemicals, beakers and flasks, and most recently an autoclave, but inevitably, many students decide to pursue research that requires some, but limited, spending. Even in the classroom setting, students learn that science always takes place in a social context, where the pressures of real life, such as time

and money, constantly intrude on scientific investigation. This is a realistic factor that science students must learn to become accustomed to, even and especially when it causes them to compromise and realign their academic ideals.

English in Transient Situations: Listening and Speaking

Although the two main ideas behind learning English for science research may be to eventually study abroad and effectively read and write research papers, as a researcher, there are many more opportunities to use English in daily life without leaving the country. Seminars in English at research institutes and universities are occasions for everyone to learn about a new topic, and even conferences held in Japan often require all speakers to present in English. At any given time, there are many foreign scholars who visit laboratories temporarily to give seminars or who stay for a few days or even years as a collaborator (Altbach, 1989). Furthermore, approximately one in five researchers are foreign at a national science research institute in Japan (RIKEN, n.d.), and the national target is to increase the number of foreign scholars from approximately 7% (Cabinet Office, 2012) to 30% by the year 2030 (Cyranoski, 2013). Being able to read and write research articles written in English is important, but being able to communicate in a transient situation is equally essential and more difficult to practice (Matsuda & Friedrich, 2011). ALESS, a class taught entirely in English, provides a place for the students to listen and speak in English and practice effective communication that will become critical in a collaborative scientific environment (Hara et al., 2003).

Proposals for Innovations

The ALESS Program effectively unifies experiences of realistic scientific practice with several core principles of scientific research. There are inevitably limitations to the scientific authenticity of the ALESS Program, but in a course designed to teach English to students studying diverse fields of science, thoroughly reproducing every aspect of scientific research is not crucial. Especially in the case of first-year university students, there will, undoubtedly, be numerous opportunities for students to learn necessary aspects of scientific research in other science classes or when they ultimately join a research group. However,

two modifications may alleviate the transition to authentic scientific research and may provide additional scientific value to the current ALESS Program.

As meaningful science practice first requires an understanding of the fundamental science principles (Edelson, 1998), the first feasible addition is to introduce literature review papers on current and familiar topics to broaden the scientific aspects of the program. Literature reviews are comprehensive summaries of a field of study, and are targeted towards a more general audience with fewer undefined technical words and phrases, more expansive background information as well as overviews on the current and projected research. Initially exploring a less demanding review paper may provide a less daunting introduction to scientific papers, and encouraging students to design experiments related to the review paper topic may enhance focus on the social or global significance of the investigation. As review papers are typically targeted towards a more general audience than a specialized IMRaD-style research article, they would also present a more expansive introduction to the various types of scientific publications. Moreover, this type of paper can be utilized as a supplemental avenue to lead into a discussion on the concept of audience-centered writing. Thus, the incorporation of literature reviews may provide several advantageous outcomes.

Another possible modification is to integrate a relatively new paper-free concept of open notebooks, also known as e-notebooks (Butler, 2005). Open notebooks are the technologically advanced transformation of the traditional laboratory notebooks to store information and progress of research. Management of research data is a crucial skill to master as a researcher, and proponents maintain that some of the benefits of keeping electronic and openly available notebooks include, for instance, easier searches of past entries using keywords, rapid mining of data and organization of results, ease of distance collaborations, and fewer instances of scientific fraud due to scrutiny of data by other researchers (Coles, Frey, Bird, Whitby, & Day, 2013). If applied to ALESS, it will allow easier tracking of the experimental design and setup, the progress of experiments, compilation of raw data, and the analysis of the results. In addition, if the notebooks are localized and available at any time for all of the members of an experiment group, the instructor, classmates (for peer

review), and the teaching assistants at the ALESS Lab, it will facilitate communication and collaboration. Providing access to experimental designs, modifications, and problems encountered may also inspire new approaches among other experiment groups and promote friendly competition, and importantly, prevent falsification of data or results.

Conclusion

The purpose of ALESS is not to provide a fully realistic science laboratory experience but to expose students to carefully selected simulated activities which act as a vehicle to motivate and provide meaningful content for the students' language learning. The overall objectives are enriching and effective because they are universal in modern scientific inquiry: to impart the importance of English and provide students with as much time as possible to practice communication while giving them extensive support, and to expose students to correspondingly essential scientific principles, such as collaboration, which cannot be acquired from reading textbooks. Consequently, the ALESS Program effectively introduces the concept of scientific research and its processes while also accomplishing the task of teaching scientific language.

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