ENGLISH FOR SCIENCES IN A JAPANESE UNIVERSITY:
EXPRESSING CHEMICAL ELEMENTS, COMPOUNDS AND MATHEMATICAL EQUATIONS
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ABSTRACT
Improving ability in reading, listening, writing and speaking English in sciences or scientific English (SE) is one of the main concerns for students with a non-native English background in communication. As part of our university curriculum in learning SE, acquired abilities (AAs) of first-year (Yr-1: n=26) and Yr-3 (n=124) Japanese students (JSs) learning pharmaceutical sciences were respectively examined on expressing chemical elements/compounds and mathematical equations before and after lecture. Yr-1 JSs were asked to write answers for: section i) spoken names of chemical elements; ii) names of chemical compounds with given chemical formulae; and iii) chemical formulae for given names of compounds, while Yr-3 JSs were asked to listen and express mathematical equations in writing. After the pre-lecture test session, lectures on basics of expressing chemical elements/compounds and mathematical equations for the different student groups were conducted separately at different times (with the same 1-week lapse for the subsequent lecture): students were drilled on listening and understanding relevant fields. On the day of subsequent lecture, students were given the same questions before lecture in a similar manner described above. The mean pre- and post-lecture scores of the 2 different groups were respectively compared with the Wilcoxon signed-rank test, where differences with p<0.001 were considered statistically significant. The mean scores (pre-lecture vs post-lecture) of Yr-1 JSs were significantly improved: i.e. Section i) (1.8±0.98 vs 3.0±1.11); ii) (0.7±1.19 vs 2.0±1.84); and iii) (2.9±0.93 vs 3.8±0.91); and the mean post-lecture scores (7.1±1.81) were significantly higher than pre-lecture scores (2.7±1.72) in Yr-3 JSs: i.e. AAs in SE of JSs significantly improved. The results of the present study suggest that JSs will graduate and display adequate ability at collaborative meetings and international conferences, at least in part on contents involving chemical compounds and mathematical expressions, via effective and functional communication with proper guidance and continuous SE-learning.
Field of Research: Scientific English, mathematical expressions, chemical elements, compounds

1. Introduction
Many Japanese university students and scientists have difficulty in handling scientific English (SE) or English for special purpose (ESP), as the Japanese educational system does not incorporate SE teaching in primary and secondary schools. SE, which is different from literary or everyday English (Barnes, 1969; Gardner, 1974; White, 1988; Muralidhar, 1991), requires understanding, learning and acquirement of various technical terms relevant to different specialties.
Although taught at the tertiary level, SE teaching is non-systematic, non-regulated and randomized, producing undergraduates who often feel resigned and inadequate in comprehension and communication at collaborative research meetings and scientific conferences (Foong, 2010). This expounds why Japanese scientists find it so difficult to
communicate in global collaborative research and to present their findings at international meetings and conferences, where English is the lingua franca. In addition, they find it a task to read, understand and to review scientific literature and published manuscripts as they are not well equipped with non-literary SE expressions and basics of scientific or technical terms, which often are based on Greek and Latin roots. Although there have seven Nobel Prizes being awarded to Japanese scientists, all would not have been recognized without going to English-speaking countries for pre- and post-doctorate research work and training after completing their graduate studies in Japan, indicating the importance of SE-learning. Recent inward-looking young Japanese students (JSs) have further aggravated the SE inadequacy scenario (Open Doors 2010 International Studies in the U.S.), despite the good intention of the Japanese government trying to globalize interactive communication among young Japanese scientists (Foong, 2010).

In an affirmative attempt to resolve this unhealthy and helpless SE communication handicap, we embark on a stepwise-stepup tertiary education (SSTE) system to help young university students following a course in pharmaceutical sciences to acquire the groundwork of SE basics in order to facilitate their future endeavors in pursuing scientific challenges. Of the various SE aspects, the present study elucidated the acquirement ability of JSs in understanding and expressing chemical element/compounds and mathematic equations. The results revealed that the acquired abilities (AAs) of JSs to acquire listening, understanding and expressing the basics of mathematics- and chemistry-based aspects of SE was significantly improved after teaching.

2. Subjects and Methods

2.1 Subjects
A class of naive Yr-1 students (n=26) of either gender (age range: 18 - 19 yr) following a course in pharmaceutical sciences from our university were randomized from 16 classes, and tested on expressing chemical elements and compound. In another study, 2 (n=124) of eight Yr-3 classes of students of either gender (age range: 20 - 21 yr) following the same coursework were randomized in the same university participated in expressing mathematical equations. Yr-1 JSs were taught literary English in their high-school days. In addition to secondary levels, Yr-3 JSs followed 2 previous academic years of literary English at the tertiary level. The results of 2 classes in Yr-3 were pooled for statistical analysis. Although the present aspects of science had previously been taught in Japanese, Yr-1 and Yr-3 JSs participated in these two studies received respective guidance and teaching on expressing of chemical elements/compounds and mathematical equations in English for the first time.

2.2 Assessing AAs in expressing chemical elements/compounds
Expressing chemical elements/compounds: Yr-1 JSs were given a test that required: i) written answers (spellings with symbols) after listening to names of elements read by 3 different regional (American, British and Malaysian) English-speaking narrators (tape played twice for listening); ii) written answers for compounds (names, spelling) with given chemical formulae; and iii) written answers for chemical formulae with given names of chemical compounds. The test lasted 15 minutes (min) and each section contained 5 questions. After the pre-lecture test session, students were taught the names of essentially important elements in the Periodic Table of Chemical Elements, and expressions for names and chemical formulae of chemical compounds commonly used in laboratories. Students were told to review their lecture by listening to chemical element-enunciating compact disc (CD) attached to the textbook, and expressions of names/formulae for chemical compounds described in the textbook without any other information. On the day of subsequent lecture (1-week lapse), the same test with the same time interval (see above) was given before lecture. The mean pre- and post-lecture
scores were then determined and compared statistically. Students who had participated in either test, or were 1 min late for either test, or felt unwell during the test were excluded from the study. The score for each question was rated as 1 (total score: 15).

2.2 Assessing AAs in expressing mathematical equations
Expressing mathematical equations: Yr-3 JSs were tested on the expression of mathematical equations in a similar manner: viz., they were given 10 questions with various aspects of mathematical equations involving numerals, decimals, fractions, powers, Greek alphabets (lower/upper cases), with and without parentheses, and signs/symbols for equal (=) plus or minus (±), square root of (√), cube root of, greater/more than (>), smaller/less than (<), not more than (≧), not less than (≦), greater/more than or equal to (≧), lower/less than or equal to (≦), to the base of (subscript), integrals (∫), differentiation, and degrees in Celsius (°C)/Fahrenheit (°F), etc. In the test, a tape /CD with 3 different regional (American, British and Malaysian) English-speaking narrators reading 10 different mathematical equations was used (to familiarize JSs with regional differences in English enunciation). The tape/CD with the different mathematical expressions was played twice. Students were asked to listen to the tape/CD and expressed the answers of mathematical equations in a written form. After the 15-min listening test session for understanding, a brief lecture on the above contents was conducted, and students were told to review contents of the lecture without any further information. On the day before the subsequent lecture (1-week lapse), the same test (tape/CD played twice) was conducted within the same allotted time (15 min). The mean pre- and post-lecture scores were then determined and compared statistically. Students who had participated in either test, or were 1 min late for either test, or felt unwell during the test were excluded from the study. The score of each question was rated as 1 (total score: 10).

2.3 Statistical analysis
All data were represented as the mean ± standard deviation (mean ± SD). Statistical analyses were performed using the Wilcoxon signed-rank test (R 2.15.1 for Mac OS X; The R Foundation for Statistical Computing, Vienna, Austria). Differences between the mean pre- and post-lecture scores for the respective tests on expressing chemical elements/compounds (Yr-1 JSs) and mathematical equations (Yr-3 JSs) were verified accordingly, and differences where P <0.001 were considered statistically significant both student groups.

3. Results

3.1 Expressing chemical elements/chemical compounds
The mean (pre-lecture vs post-lecture) scores of Yr-1 JSs were significantly (p <0.001) improved in the 3 sections in understanding and expressing chemical elements/compounds after lecture: viz., the ability to write out names and symbols of chemical elements after listening to the names of elements was markedly enhanced (1.8 ± 0.98 vs 3.0 ± 1.11) in Section i); the ability to spell out the names of chemical compounds was significantly elevated (0.7 ± 1.19 vs 2.0 ± 1.84) in Section ii); and the ability to formulate chemical compounds with given names of compounds was significantly improved (2.9 ± 0.93 vs 3.8 ± 0.91) in Section iii) (Table 1).
Table 1: Mean scores of the test on expressing chemical elements and compounds of 15 different questions (each section: 5 questions) before and after lecture: Data are represented by the mean ± SD, and differences where p < 0.001 are considered statistically significant (*).

<table>
<thead>
<tr>
<th>Section</th>
<th>No. of questions</th>
<th>Before lecture</th>
<th>After lecture</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>1.8 ± 0.98</td>
<td>3.0 ± 1.11*</td>
<td>0.000373</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.7 ± 1.19</td>
<td>2.0 ± 1.84*</td>
<td>0.0005967</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>2.9 ± 0.93</td>
<td>3.8 ± 0.91*</td>
<td>0.0003498</td>
</tr>
</tbody>
</table>

3.2 Expressing mathematical equations

In a tendency similar to Yr-1 JSs, the mean post-lecture scores (7.1±1.81) were significantly higher than pre-lecture scores (2.7±1.72) in Yr-3 JSs as well (Fig. 1). JSs participated in the study appeared to have gained better understanding of mathematical symbols and signs used in the 10 questions, and were capable of expressing the different mathematical equations after lecture.

Figure 1: Mean pre- and post-lecture scores of Yr-3 students in the test on expressing mathematical equations: Pooled data of 2 different Yr-3 classes are expressed as the mean ± SD, and differences where p <0.001 (*) are considered statistically significant. Acquisition ability of students in understanding the expressions of mathematical equations had significantly improved after lecture.

4. Discussions

Apart from its use to name, describe, record, compare, explain, analyze, design, evaluate, and theorize how the natural world appears to us (Wellington & Osborne, 2001), SE is a form of English required for expressing observations, reasoning, valuation, analysis data, and common communication in science-orientated disciplines, with functional use of technical terms and typical expressions relevant to transmitting scientific concepts and discoveries (Lemke, 1990; Foong, 2010).

SE may be acquired in a gradual and spontaneous manner by first learning the basics and thereafter develop the relevant contents to higher levels and forms of functional communication (Fang & Schleppegrell, 2008; de Oliveria & Dodds, 2010). In English-speaking schools, SE is acquired through a gradual and continuous time-related exposure and daily use of the medium through instructions, teaching/learning tools and verbal/written communication in their primary, secondary and tertiary educational systems: viz., learning processes of the United States, United Kingdom and other English-speaking countries. However, a special tailored education system is required in non-native English schools, or where English is not the medium of instructions, and where students have problems coping with scientific terminology (Muralidhar, 1991, Foong, 2010). Due to these handicaps, JSs are
disadvantageously placed in SE-based functional communication when compared to their English-speaking contemporaries. In other words, a proper, stepwise/stepup and constructive educational program/curriculum is needed in the case of teaching SE to JSs.

SE-learning resembles, in certain manners, learning a new version of the English language, and it involves language development and conceptual development in sciences (The National Curriculum for England, 1999). In SE, we rely on a combination and interactive use of words, pictures, diagrams, images, animations, chemical element/compounds, mathematical equations, graphs, tables and charts in describing findings, observations, concept and discoveries. In the gradual SE-learning process in English-speaking nations, where the learning process is exposed over time in a gradual and consistent manner, students learn to do, interpret, think, prove, argue, valuate and convince others of their formulated concepts using SE in a spontaneous, natural and time-related stepwise/stepup fashion. However, the current trend of SE-learning in Japan is brief, opportunistic, randomized, inadequate and limited in terms of exposure, time and content even at the tertiary level, not to mention the near-complete non-exposure in primary or secondary schools. Despite keen efforts to improve SE-learning by many in science-orientated academic communities of Japan, this inadequate and limited approach in Japan appeared to have changed little over the past decades, probably due to insufficient educational funds, unavailable time-slots in educational curricula, non-systematic teaching materials/tools, a limited number of competent and well-trained SE-teaching staff, and lack of a reliable and productive educational system for SE-learning per se, and other miscellaneous factors. In addition to repetition/memory in SE-learning, recent years have seen development of useful and systematic teaching materials/tools incorporating juxtaposition and visual/structural learning (The problem with textbook learning; http://www.flowofhistory.com/theory/textbook_learning) for JSs (Foong, 2010).

In Japan, SE-learning is only offered to science-orientated students either in Yr 2 or 3 of the 4-yr and 6-yr degree courses, although literary English is offered before Yr-2 and Yr-3, respectively. Except for certain progressive tertiary institutions, many universities still continue to offer JSs only literary English for science-based courses, making young Japanese graduates feel disadvantageous, resigned and inadequate in global-stage activity after graduation.

As such, we have ventured to design and initiated officially an SSTE system for SE-learning in our university in 2012. SE-learning in pharmaceutical sciences involves multifaceted aspects of science: viz., learning the SE basics, molding and integrating the overlapping of different disciplines such as economics, mathematics, physicochemical sciences, engineering, technology, medicine as well as natural and life sciences through juxtaposition teaching and visual/structural learning. Simple basics treated as non-essentials for English-speaking schools can be task-learning for JSs. Therefore, our SSTE system provides a gentle foundation for initiating SE-learning for JSs or non-native English learners, where the basic contents in secondary schools of English-speaking countries are initially incorporated, follow up by stepwise-stepup development of learning the various higher levels, forms and aspects of the SE language (such as technical terms, illustration- and result-based manuscript writing) with time.

In the present study, where we elucidated the AAs of JSs in listening and understanding expressions of chemical elements/compounds and mathematical equations, the results indicate that freshmen (Yr-1) and Yr-3 JSs of the 6-yr degree pharmaceutical science course could significantly (p <0.001) improve their AAs in listening and understanding of SE contents related to the 2 aspects tested in this study. According to feedback from the test results and test-participating students, JSs were able to overcome regional differences in SE enunciation with regular exposure and repeated listening practice using attached CDs and reading of contents in the textbook per se.

Although JSs have studied the names of chemical elements in the Periodic Table at secondary
levels, practiced naming chemical compounds based on their formulae and vice versa in Japanese, the results of the tests indicated that JSs were not well prepared for similar contents in SE. Therefore, similar to the English language serving as a barrier in learning sciences (Wellington & Osborne, 2001), SE itself is also a barrier for JSs to express their thoughts in scientific communication, and understand findings and discoveries written in international journals and published scientific manuscripts. For JSs having been taught and trained in SE, their AAs in listening and understanding the basic expressions of chemical elements/compounds were significantly (p <0.001) improved (Table 1). Revision and further training would surely have JSs completely grasped the more concrete details of chemistry-orientated SE in various higher forms of functional communication.

In a similar trend, mathematical equations are not at all new to participating JSs in this study. However, they were again ill-prepared when mathematical equations were read in English as reflected in the present study, where in fact they knew the answers well if spoken in Japanese. The SE language barrier – in terms of listening and understanding - is gain being encountered in this SE aspect. However, with lectures given on simple components making up the mathematical equations (e.g. numerals with decimals, powers, fractions, etc.; see ‘Subjects and methods”), they significantly (p <0.001) improved their AAs and understanding to express tested mathematical equations (Fig. 1). Further practice and continuous training in SE with such basics is definitely going to equip these young JSs with a higher ability to handle higher levels and forms of mathematical expressions.

The results of this study indicate that when appropriate instructions on learning to express chemical elements/compounds and mathematical equations in SE were given verbally/non-verbally, JSs significantly improved their listening AAs and skills in acquiring the expressions of chemical elements/compounds and mathematical equations. The SSTE system-based teaching program used in this study may most likely to enable JSs to be placed in a more comfortable position in science communication than the present stance. Although we have investigated and found useful outcomes in AAs of participating JSs attributable to SE-teaching on the present two aspects of SE involving chemical elements/compounds and mathematical expressions, SE involving grammars, 3-dimensional expressions, coining scientific terms from Greek and Latin, scientific manuscript-writing, and other aspects warrant follow-up studies to assess if our SSTE system of SE education could effectively serve a useful and constructive purpose in preparing young JSs to challenge future scientific endeavors.

5. Conclusions
The results indicate that appropriate teaching and guidance of SE given to JSs significantly improved their AAs in expressing chemical elements/compounds and mathematical equations. In other words, JSs will graduate and display adequate ability at globally collaborative meetings and international conferences, at least in part on contents involving chemical compounds and mathematical expressions as demonstrated in the present study, via effective and functional communication with proper guidance, learning tools and continuous SE-learning.

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