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Abstract

The purpose of this study is to compare and analyze the scientific communication skills of Korean and Australian university students and identify areas that need improvement. As a result of the analysis, it was found that Korean students had higher overall science communication skills than Australian students. However, as a result of analyzing scientific communication skills by field, the type of legitimacy was higher among Australian university students than Korean university students. On the other hand, Korean university students showed higher ability to express letters and visual images than Australian university students. In addition, through a correlation analysis on the types and forms of scientific communication skills, it was possible to confirm the characteristics of scientific communication skills of university students in both countries. This study is significant in that it provides insight into the understanding of the characteristics of scientific communication skills of Korean and Australian university students.

Introduction

Scientific communication skills are addressed as one of the important educational goals in science curricula in many countries (Kulgemeyer & Schecker, 2013). Scientific communication skills aim to share and develop the process and results of scientific problem solving, and many countries explicitly stipulate scientific communication ability as an essential element for scientific knowledge (Chung et al., 2016). Communication skills refer to the skills of conveying or sharing thoughts about acquired knowledge (Kivunja, 2015), and scientific communication skills consists of information search and acquisition skills, scientific reading, listening and observation, scientific letter, information expression and knowledge expression, etc. (Spektor-Levy et al., 2008; Spektor-Levy et al., 2009). Burns et al. (2003) defined that in the field of science communication, science communication skills are

- knowing information and knowledge of science (awareness),
- feeling and enjoying science (enjoyment),
- having an interest in participating in science activities (interest),
- having opinions on issues related to science (opinions), and
- the process of appropriately using functions, media, activities, and conversations in order to understand the contents and processes of science (understanding).

Kulgemeyer and Schecker (2013) define four aspects of scientific communication: scientific content and information (factual content), the context in which science content and information is introduced (context), the form of language chosen by the communicators of scientific content and information (code), and a way to present scientific content and information (representation form).

Teaching these scientific communication skills has been reported to be beneficial both socially and personally (Poronnik & Moni, 2006; Besley & Tanner, 2011; Bray, France, & Gilbert, 2011). Through scientific communication, which converts complex science into language and concepts that can be understood by non-scientific audiences such as politicians, industry experts, and educators, as well as the general public, the culture and knowledge of science can be absorbed into the culture of the wider community (Aikenhead 2001; Burns, O'Connor, & Stocklmayer, 2003; Edmondston et al. 2010), which may also help with advances in science and technology (Moni et al., 2007; Brownell et al., 2013; Kuchel et al., 2014). In addition, scientific communication skills can help students participate in the social decision-making process, effectively participate in cooperative learning, or have a positive effect on learning scientific contents (Kulgemeyer & Schecker, 2013).

Teaching scientific communication skills to university students has been shown to significantly improve communication skills as well as promote critical understanding of scientific literature (Brownell et al., 2013). In addition, assignments to evaluate scientific communication skills in university courses may lead to quantitative reasoning, interpretation of scientific results, learning of core science competencies, and improvement of communication skills (Kuchel et al., 2014). In this context, educational efforts to enhance scientific communication ability can be seen as important, and it is necessary to first find out students' scientific communication skills.

This study compares and analyses the scientific communication skills of university students in Korea and Australia to find out the characteristics of university students' scientific communication skills. Eastern and Western communication has different communication styles depending on the context (Hong, 2021). Therefore, by examining and understanding the differences in scientific communication skills between Korean and Australian university students, we intend to provide an opportunity to broadly understand the characteristics of scientific communication skills.

Method

Subject of Research

The subjects of this study were 47 students from C University of Education in Korea and 39 students from Q and N universities in Australia. There are 18 Australian university students from University Q and 21 students from University N in the stud, with similar student levels at both universities. University students in both countries were in their first year of university and had not been taught any specific communication skills during their undergraduate studies. They all agreed to take a test of their scientific communication skills. Information on study subjects is shown in Table 1.

Table 1. Research Subject Information

		Korean university students (n=47)	Australian university students (n=39)
Gender	Male	23 (48.9%)	15 (38.5%)
	Female	24 (51.1%)	24 (61.5%)
Major	Humanities & social science	20 (42.6%)	26 (66.7%)
	Science	13 (27.7%)	11 (28.2%)
	Arts	14 (29.8%)	2 (5.1%)

Scientific Communication Skills

To compare the scientific communication skills of Korean and Australian university students, this study used the Scientific Communication Skills Test (SCST) developed by Jeon (2013). SCST can test the ability to communicate, exchange, and share scientific explanations and claims about facts, phenomena, and causes based on scientific knowledge and literacy in various forms. It consists of 16 multiple choice questions and 8 short-answer questions, and among scientific communication skills, written communication skills can be measured. The scientific communication skills test sheet has a reliability of .74 and has been borrowed from several studies (Kim & Lee, 2017; Kwon et al., 2017; Ha & Shin, 2017) that investigated changes in scientific communication skills. As shown in Figure 1, the scientific communication skill test sheet is divided into types according to the purpose of communication and expression forms used in communication. The types of scientific communication are largely divided into scientific explanation type and scientific claim type. Scientific explanation is divided into *description*, which corresponds to the description and description of facts, and *explanation*, which corresponds to the description of the cause and effect of events or phenomena (Jeon, 2013). Scientific claims are divided into *ground*, which corresponds to arguments using evidence to support the claim, and *justification*, which corresponds to arguments to justify evidence (Jeon, 2013). Expression forms used in communication are classified into letters, numbers, tables, and illustrations.

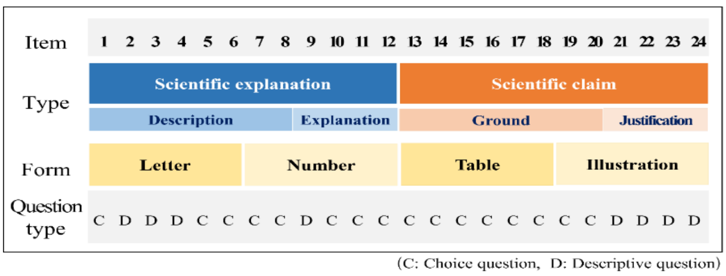

Figure 1. Item Construction of Scientific Communication Skill Test by Type and Form

The test papers provided to Australian university students were translated into English from the original Korean test papers and the research team firstly translated Korean version to English version and secondly confirmed the translation by native speakers in Australia. Thirdly, the translated content was presented to one Australian university student to confirm whether it matches the original content's intention and whether there were any problems in understanding the content. Table 2 presents the evaluation goals for each item of the scientific communication skills test tool. Based on the goal of each item, the types and forms of scientific communication skills were classified and analyzed.

Table 2. Evaluation Goal for each Item of the Scientific Communication Skills Test Tool

Item	Evaluation goal
1	Can describe using words appropriate to the characteristics of a given object.
2	Can explain given information by expressing it in appropriate numbers and symbols.
3	Characteristics of a given figure can be described in a table.
4	Can look at a given picture and explain it by expressing it with symbols appropriate to the characteristics of things.
5	Can express and explain conversations appropriate to a given situation in sentences.
6	Can explain a given situation by expressing the picture with the appropriate number.
7	Tables can be expressed graphically and explained appropriately for a given situation.
8	Can explain a given situation by expressing it with an appropriate picture.
9	Can identify a given event and explain the cause by expressing it in writing.
10	Can identify a given event and explain the cause by expressing it in writing.
11	Can explain by looking at the given table and expressing information appropriate to the table.
12	Is able to understand the given information and express it in an appropriate diagram and explain it.
13	Can make an argument by choosing the right word for a given situation.
14	Using the given information, can express ones’ argument in an equation.
15	Can make an argument by choosing a diagram that is appropriate for a given situation.
16	In a given situation, can choose an appropriate symbol and assert it.
17	Can express their argument in a sentence by synthesizing given numerical information.
18	By synthesizing the given information, can express the rationale for ones’ argument in numbers.
19	Evidence supporting a given claim can be expressed in an appropriate graph.
20	Using the given numerical information, can express ones’ argument as a picture.
21	Able to synthesize the given information and express ones’ arguments and counter-evidences in writing.
22	Can synthesize the given information and express ones’ argument in appropriate symbols.
23	Can express the given numerical information in a table appropriate to ones’ claim.
24	Can look at the given situation and express the table in an appropriate diagram.

Results

Scientific Communication Skills of Korean and Australian University Students

As a result of testing the scientific communication skills score according to gender and their study major of Korean and Australian students, the significance level is shown in Table 3, as not significant (p <.05). Korean and Australian university students did not differ in scientific communication skills according to gender and their major.

Table 3. Scientific Communication Skills' Score according to Gender and Major

		Statistic value (Pearson χ^2)	Significance probability (*p*)
Korean	Score according to gender	7.849	.853
	Score according to major	29.934	.270
Australian	Score according to gender	19.012	.213
	Score according to major	24.336	.757

*p <.05

Table 4 shows the results of comparing the scientific communication skills' scores of Korean and Australian university students. The scientific communication skills' test had a perfect score of 48, and university students in the two countries scored more than 77.44%. The average score of Korean university students was 38.72 points, and the average score of Australian university students was 36.69 points, showing a significantly higher difference (p <.05) for Korean university students than Australian university students.

Table 4. Scores of Scientific Communication Skills among University Students in Korea and Australia

Division	N	Total score		t	*p*
		M	S.D		
Korean	47	38.72	3.597	2.252*	.027
Australian	39	36.69	4.758		

* p <.05

Table 5 compares the scores for each item of the scientific communication skills test tool. In the results of the scientific communication ability test, the average score for Korean university students was higher than the average for Australian university students (see Table 4), but different patterns were shown depending on the items (see Table 5).

Significant differences were shown in the communication skills scores for university students from the two countries in seven questions (No. 1, No. 5, No. 9, No. 16, No. 20, No. 22, No. 23). Korean university students scored higher for items 1, 5, 16, and 20 and Australian university students scored higher for items 9, 22, and 23.

In order to analyse the characteristics of the scientific communication skills of Korean and Australian university students, the analysis contents according to the type and form of scientific communication are described in the following research results.

Table 5. Average Score of Korean/Australian University Students according to the each Scientific Communication Skills Test Question

Item	Division	Total score		t	*p*
		M	S.D		
1	Korean	1.32	.958	6.754***	.000
	Australian	.15	.540		
2	Korean	1.60	.798	-.265	.792
	Australian	1.64	.778		
3	Korean	1.02	1.011	.957	.341
	Australian	.82	.914		
4	Korean	1.91	.282	1.196	.235
	Australian	1.79	.615		
5	Korean	1.83	.564	4.647***	.000
	Australian	1.03	1.013		
6	Korean	1.49	.882	-.261	.795
	Australian	1.54	.854		
7	Korean	1.74	.675	-1.210	.230
	Australian	1.90	.447		
8	Korean	1.62	.795	1.503	.137
	Australian	1.33	.955		
9	Korean	1.34	.635	-5.432***	.000
	Australian	1.95	.320		
10	Korean	1.91	.408	1.082	.282
	Australian	1.79	.615		
11	Korean	1.74	.675	.345	.731
	Australian	1.69	.731		
12	Korean	1.66	.760	.696	.488
	Australian	1.54	.854		

Item	Division	Total score		t	*p*
		M	S.D		
13	Korean	1.49	.585	.449	.654
	Australian	1.44	.502		
14	Korean	1.87	.494	1.356	.179
	Australian	1.69	.731		
15	Korean	1.87	.494	-.831	.408
	Australian	1.95	.320		
16	Korean	1.87	.494	5.680***	.000
	Australian	.92	1.010		
17	Korean	1.79	.623	-.057	.955
	Australian	1.79	.615		
18	Korean	1.96	.292	1.609	.111
	Australian	1.79	.615		
19	Korean	1.87	.494	1.017	.312
	Australian	1.74	.677		
20	Korean	1.96	.292	2.872**	.005
	Australian	1.59	.818		
21	Korean	1.66	.635	-.855	.395
	Australian	1.77	.536		
22	Korean	1.30	.720	-4.044***	.000
	Australian	1.85	.489		
23	Korean	1.81	.576	-2.073*	.041
	Australian	2.00	.000		
24	Korean	1.90	.292	.749	.456
	Australian	1.96	.447		

***p <.001, **p <.01, *p <.05

Comparison of Scientific Communication Skills between Korean and Australian University Students

Table 6 shows the results of the comparative analysis by type of scientific communication skills between Korean and Australian university students. In the scientific explanatory type, the average score of Korean university students was 22.55 points and that of Australian university students was 20.21 points (p <.05). There was no significant difference in the scores between Korean and Australian university students in the scientific argument type.

Table 6. Average Score of Korean/Australian University Students by Type of Scientific Communication Skills

Type	Division	N	Total score		t	*p*
			M	S.D		
Scientific explanatory	Korean	47	22.55	2.709	3.493*	.001
	Australian	39	20.31	3.254		
Scientific argument	Korean	47	18.04	1.654	1.590	.115
	Australian	39	17.31	2.597		

*p <.01

Table 7 shows the results of comparing average scores for each subtypes of scientific communication skills. Statistically significant differences in scientific communication skills between Korean and Australian university students were found in the types of description, explanation, evidence, and justification.

In the description type, the average score for Korean university students was 12.53 points, and the average score for Australian university students was 10.21 points, and the score of Korean university students was higher with a significant difference ($p < .001$). These results mean that Korean university students have a higher level of description of facts and skills than Australian university students. However, in the explanation type, the average score of Korean university students was 6.66 points, and the average score of Australian university students was 6.97 points, indicating that Australian university students scored higher than Korean students. Australian university students scored high on causal descriptive items on an event or phenomenon. However, there was no statistically significant difference ($p < .315$).

The description type corresponding to the scientific explanatory type refers to the ability to express the characteristics and situations of things. Therefore, it is considered that Korean university students have a higher level of description and description of the characteristics and situations of objects than Australian university students. For the evidence type, the average score of Korean university students was 14.68 points, and the average score for Australian university students was 12.92 points, and the score for Korean university students was higher with a significant difference ($p < .001$). These results mean that Korean university students have a higher level of expressing evidence supporting their claims in the form of letters, numbers, tables, and pictures than Australian university students. However, in the justification type, the average score of Korean university students was 6.72 points, and the average score of Australian university students was 7.51 points. Although the level of expressing the evidence supporting the argument was high in Korean students, it was confirmed that the level of the Australian students was higher in expressing the evidence supporting the argument and even presenting the justification of the evidence.

Table 7. Average Score of Korean/Australian University Students according to Subtypes of Scientific Communication Skills

Type		Division	N	Total score		t	*p*
				M	S.D		
Scientific explanatory	Description	Korean	47	12.53	2.483	4.351**	.000
		Australian	39	10.21	2.451		
	Explanation	Korean	47	6.66	1.307	-1.011	.315
		Australian	39	6.97	1.581		
Scientific argument	Evidence	Korean	47	14.68	1.431	3.651**	.000
		Australian	39	12.92	2.905		
	Justification	Korena	47	6.72	1.362	-3.060*	.003
		Australian	39	7.51	.942		

$^{**}p <.001$, $^{*}p <.01$

Comparison of Scientific Communication Skills between Korean and Australian University Students

Table 8 shows the results of comparison between Korean and Australian university students by type of scientific communication skills. Statistically significant differences in scientific communication skills between Korean and Australian university students were found in representation of letters and visual images. In terms of letter expression, the average score for Korean university students was 9.43 points, and the average score for Australian university students was 8.13 points, indicating that Korean university students scored higher (p <.01). In addition, the average score for Korean university students was 10.98 points and the average score for Australian university students was 9.08 points in the representation of visual image, indicating that Korean university students scored higher (p <.001). These results mean that Korean university students have a higher skill to express the characteristics and situations of objects in representing letter and visual image than Australian university students. In the ability to express numbers and tables, Australian university students had higher scores than Korean university students, but there was no statistically significant difference.

Table 8. Average Score of Korean/Australian University Students by Type of Scientific Communication Skills

Form	Division	N	Total score		t	*p*
			M	S.D		
Letter	Korean	47	9.43	1.677	3.487*	.001
	Australian	39	8.13	1.764		
Number	Korean	47	10.13	1.765	-.422	.674
	Australian	39	10.31	2.190		

Form	Division	N	Total score		t	*p*
			M	S.D		
Table	Korean	47	10.06	1.451	-.123	.903
	Australian	39	10.10	1.465		
Visual image	Korean	47	10.98	1.053	5.665**	.000
	Australian	39	9.08	1.992		

$^{**}p<.001$, $^{*}p<.01$

Correlation between Types and Forms of Scientific Communication Skills among Korean and Australian University Students

Table 9 shows the results of analyzing the correlation between each variable in the type and form of scientific communication skills between Korean and Australian university students. In the case of Korean university students, significant correlations were shown in *description type - letter, number, table type, explanation type - letter, table type, evidence type – visual image type,* and *justification type - letter, number type*.

On the other hand, in the case of Australian university students, there was a significant correlation between all types and forms except for *explanation type-letter, visual image type* and *justification type-visual image type*.
The following are similar aspects in the correlation between the type and form of scientific communication skills of Korean and Australian university students. In the description type for the purpose of scientific explanation and the justification type for the purpose of scientific argument, both Korean and Australian university students had a lot of correlated expressions. Their scientific communication skills were characterized by descriptive type, letter expression (r_{Korean}=.451, $r_{Australian}$=.584), number expression (r_{Korean} =.589, $r_{Australian}$=.321), and table expression (r_{Korean}=.340, $r_{Australian}$=.346), showing a correlation with each. In addition, both university students in the two countries showed correlations in justification type, letter expression (r_{Korean}=.376, $r_{Australian}$=.355), and number expression (r_{Korean} =.440, $r_{Australian}$ =.508).

Differences in the relationship between the type and form of scientific communication skills of Korean and Australian university students are as follows. In descriptive type, Korean university students did not show a significant correlation with visual image expression, but Australian university students showed a correlation (r =.503) between descriptive type and visual image expression. This means that there is a correlation for Australian university students between their ability to describe and present facts and their ability to express themselves through visual images. In the explanatory type, Korean university students demonstrated a correlation with letter expression (r =.296), whereas Australian university students showed a correlation with number expression (r =.367). Therefore, it can be interpreted that Korean university students' ability to describe causality of events or phenomena have a correlation with writing ability, and Australian university students have a correlation with numerical expression ability. In the type of evidence, Australian university students showed correlations in letter expression (r =.664), number expression (r =.670), and tabular expression (r =.391), while Korean university students did not. It can be said that Australian university students' skills to present evidence in support of their argument is correlated with their skills to express letters, numbers, and tables. In justification type, Korean university students did not show a significant correlation with tabular expression, whereas Australian university students showed a correlation (r =.380) between justification type and tabular expression. This means that Australian university students' skills to present evidence and justification to support their argument correlates with their ability to express tables.

Table 9. Correlation between Types of Scientific Communication Skills and Form Factors

Division		Scientific explanatory		Scientific explanatory	
		Description	Explanation	Evidence	Justification
Korean	Letter	.451**	.296*	.239	.376**
	Number	.589***	.066	.034	.440**
	Table	.340*	.379**	.199	.262
	Visual image	.279	.263	.486**	-.080
Australian	Letter	.584***	.086	.664***	.355*
	Number	.321*	.367*	.670***	.508**
	Table	.346*	.546***	.391*	.380*
	Visual image	.503**	.093	.342*	.091

***p <.001, **p <.01, *p <.05

Discussion, Conclusion, and Implications

This study aimed to find out the characteristics of scientific communication skills by comparing and analyzing various aspects of scientific communication skills of Korean and Australian university students. The characteristics of scientific communication skills of Korean and Australian university students in this study are as follows. Firstly, in the overall aspect of scientific communication skills, Korean university students showed a higher level of scientific communication skills than Australian university students. However, there was a difference in the level of scientific communication between the university students from the two countries according to the type of scientific communication. In communication for the purpose of scientific explanation, Korean university students showed higher average scores than Australian university students. Looking at each subtype of scientific communication ability, Korean university students showed higher average scores than Australian university students in description type and evidence type. However, in the justification type, Australian university students showed higher average scores than Korean university students. Therefore, it can be said that Korean university students have a higher skill to describe the characteristics and situations of things and present evidence to support their arguments than Australian university students. It was confirmed that Australian university students had a high ability to express the evidence supporting the argument as well as present the justification of the evidence. According to Hofstede's (1984) cultural dimensions theory, Western culture has direct, analytical, and logical communication characteristics. Due to this difference, it is thought that Australian university students showed a higher level of justification skills than Korean university students.

Secondly, there was a difference in the level of scientific communication between university students in the two countries according to the type of scientific communication. Korean university students showed a higher level than Australian university students in describing letter and visual image skills. For the ability to express numbers and tables, Australian university students showed higher scores than Korean university students, however it was not statistically significant. These results can be explained in a context similar to the results of Hall's (1984) study comparing Eastern and Western communication cultures. Asian countries, which belong to a high context culture, do not have much information that is clearly visible on the outside in communication, whereas English-speaking countries, which belong to a low context culture, show a lot of direct verbal messages that are clearly expressed on the outside (Hall, 1984). In this context, it is judged that Australian university students scored higher in number and table expressions than Korean university students. However, since there was no statistically significant difference in the results of this study, it is necessary to qualitatively examine the characteristics of scientific communication based on the educational environment and cultural differences in the future.

Thirdly, in the correlation between the type and form of scientific communication skills, both Korean and Australian university students showed similarities in that there were many correlated expressions in the description type for the purpose of scientific explanation and the justification type for the purpose of scientific argument. Through this, it can be seen that the description and technical skills of both university students are closely related to the ability to express various forms such as letters, numbers, and tables. In addition, both university students in both countries were similar in the ability to present justification of evidence and the ability to express in letters and numbers. Therefore, it will help students to create scientific explanations by learning scientific language expression forms such as letters, numbers, and tables.

Fourthly, Australian university students have descriptive skills to describe and present facts, the skill to express in visual images, the ability to present justifications for evidence supporting arguments and the ability to express tables, the skill to present evidence to support arguments, and the ability to express letters, numbers, and tables abilities were correlated with each other. In the case of Korean university students, explanatory ability, which is a description of the cause and effect of an event or phenomenon, was related to writing ability, while for Australian university students it was closely related to numerical expression ability.

Through this study, Korean university students showed higher overall scientific communication skills than Australian university students, but there was a difference in the specific items in which the students of the two countries scored highly in. This study was conducted with a sample of university students at three specific universities, and there are limitations in generalizing the findings. However, by analyzing the types and forms of scientific communication, it was possible to identify the characteristics and differences in scientific communication ability of Korean and Australian university students, which will provide implications for the areas to be focused on to enhance scientific communication skills. For example, recommend training modules focusing on the development of specific skills where students showed lower performance, such as justification skills for

Korean students and descriptive skills for Australian students. There are complex differences in the education systems and cultural backgrounds of the two countries, and further research is needed to delve deeper into the underlying causes of these differences. However, this study provides information on the characteristics of scientific communication skills of university students of different cultures and languages, so it is meaningful as basic data to broadly understand the characteristics of scientific communication.

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