Science Education International
Vol. 24, Issue 3, 2013, 324-343

Risk communication about nuclear power in Korea: One-year descriptive analysis on Twitter

Minkee Kim[*†]

ABSTRACT: Over the last three decades, public understanding of science (PUS) has been one of the foremost research topics in the Korean society where numerous social scientific conflicts have taken place. As a lead channel of risk communication, Twitter has been studied in experimental research designs or among target user groups, leaving the measurement of overall PUS still unknown. Hence, this study aimed to examine every message collected during the one-year research period by a Twitter backup system installed on an online server, regarding the two key words: *nuclear power* and *nuclear power plants*. The results indicate that 20% of the entire posts contained promotional advertisements distributed by five state institutes related to nuclear power. Excluding these advertisements, there were 397,827 messages posted by 87,966 users forming a skewed distribution in the cumulative chart—a sled-shape model. Top 5% of the entire users posted half of the entire messages, while top 0.2% users entitled as active speakers posted 10% of the entire messages. As only 11% messages among the active users held balanced attitudes, it is likely that most of messages posted by the supporting state institutes and the opposing individuals would gain less credibility than they were intended, according to the theory of bidirectional risk communication.

KEY WORDS: public understanding of science, nuclear power, risk communication, social network service, Twitter, big data

INTRODUCTION

Enhancing public understanding of science (PUS) has been one of the foremost educational objectives among educators in science discipline over the last three decades (Min, 1994). According to the literature, the former president *Park Chung-hee* in the Republic of Korea claimed that the entire Korean citizens should be equipped with scientific minds in everyday life, and respects to and application of scientific knowledge. Since the president's statement in 1973, there emerged nation-wide movements for enhancing PUS through promoting out-of-school science activities and outstanding levels of welfare among scientists. Reviewing the historical campaign, Min addressed two challenges for promoting the

* Corresponding Author: physhero@gmail.com
† Korean Educational Development Institute, Korea

PUS in Korea. First, the latest scientific knowledge was not transmitted into publics due to the lack of lifelong education. Second, without the proper amount of PUS, publics' attitudes toward science and scientists could hardly become supportive or respectful. In his final remark on the PUS, he addressed potential of the continuing education taking place in secondary or higher educational institutes, quasi-public open universities, private cultural lectures, and non-profit organizations.

Recently, there has emerged the significance of studying PUS regarding nuclear power and nuclear power plants. In Japan, a tsunami took place in 2010 and its succeeding damages from leaking radioactive waste have caused a dramatic change in attitudes and recognition of nuclear power among the publics. According to the Korea Nuclear Energy Promotion Agency's (KONEPA) periodic report, 61% of survey participants opposed nuclear power after overlooking the Fukushima disaster (D. Kim, 2011). This change into negative attitudes was sensational, because 80% participants before the incident used to be supporting nuclear power as the national success in advanced science and technology, and its symbolic export to UAE. As there had not been any direct damage from the radioactive plant site in Fukushima and no precautious behavior was demanded in Korea, such dramatic change toward the negative attitudes warranted a closer examination on the public understanding of nuclear power (Kang, 2012). Another study concerning the Fukushima accident was carried out among 10^{th} graders from Korea, Japan, Taiwan, and Singapore (Lee & Park, 2012). Even though the chance of reoccurring such massive accidents is negligible, the Japanese students worried significantly more with their belief that another similar accident related to nuclear power would result in irreversible damages for decades in their society. Due to the accumulated historic experiences of nuclear accidents in Chernobyl and Fukushima, it would not be likely to alter the young citizens' attitudes.

In spite of its developed technology and related science, nuclear power are not always regarded as ethical in a sense that most of the electricity consumers are metropolitan citizens, whereas the power plant facilities are located in remote regions. This geological disparity causes other social-scientific conflicts such as building large pylons for transmitting high-voltage electricity and penetrating local farmlands (Song & Seo, 2013). Another recent study from the environmental philosophy addresses that nuclear-related technology first originated from the technology to build nuclear bombs and hydrogen fusion bombs (M.-J. Kim, 2012). She insists that the technology compatibility between the electricity generation and the massive arms should not be neglected.

> it is indeed needed for us to get more "ethical" energy than any other energy in this era. Thus, we urgently need to have the critical mind, the attitude, and the determination to revise downward the dependency of nuclear power by a gradual process. (p. 59)

Risk communication

One of the reasons why such social conflicts is seldom alleviated by educators and scientists' efforts could be inferred by Kang's (2012) explanation of the *risk communication*—a type of communication among interested parties about a present, emerging, or evolving risk. The related scientific knowledge on how the radioactive reaction functions and how radioactive materials influence human metabolism are hardly understandable for young citizens and publics. Once a government or experts who have adhered to the safety of nuclear power lose their credibility, publics with moderate or low scientific knowledge would not respect the official risk communication. But, they incline to non-governmental organizations opposing nuclear power. In this light, an official report submitted to the U.S. Department of Homeland Security categorizes such issues related to nuclear power into the *Lower familiarity/higher dread* type (Sheppard, Janoske, & Liu, 2012). Nuclear power issues are complex and hard for individuals and publics to interpret, respond to, and prepare for, as its dread effect could remain latent in the environment for years.

Twitter as a lead channel for risk communication in publics

Twitter has been the lead of social network services (SNS) with its microblogging features (Wright, 2010). That is, users can only express their opinion or share information within limited 140 characters. In terms of simplicity, it is similar to the mobile SMS that has been a platform of posting and receiving messages on Twitter with no or relatively lower cost. Contrast to the worries on its usefulness under the strict length limitation, Twitter has enabled rapid distribution of information and ubiquitous communication regardless of users' poor Internet accessibility. For example, when the 7-magnitude earthquake occurred in Haiti and the death toll reached over 100,000, Twitter enabled users to rapidly share rescue information and to participate in relief organizations and individuals (Smith, 2010). Comparing it with another popular SNS, the relief organizations posted more messages concerning "Updates on relief efforts in Haiti" on Twitter (61.6%) than they did on *Facebook* (44.9%). On Twitter, socially-recognized categorization using hash tags such as *#Haiti* and *#HaitiEarthquake* also facilitated connected communication in and out of the regions in need.

> Twitter's character-count limits and real-time updates render it a place for ongoing and immediate interaction. Post-update and categorization tools facilitate dialogue in ways blogs do not, making it a dynamic environment for practitioner–user interaction. (p. 330)

Institutes related to nuclear power in Korea

There are five major institutes related to the nuclear power plants and electricity generation in Korea. These state institutes pursue to communicate with the publics, to enhance understanding of nuclear power, and to achieve their confidence in Korea by means of events on sites or on social network services such as their website and Twitter.

Korea Atomic Energy Research Institute (KAERI, atom_kaeri on Twitter). Since its foundation in 1959, KAERI has been the foremost research institute for nuclear power generation. It has aimed to achieve the self-reliance of developing Korean Standard Nuclear Power Plants. The original design of the HANARO radioactive reactor devised in KAERI is the first export of the nuclear energy system to Jordan. Its mission is to meet the Korean government's agenda for sustainable development by means of lead research products (KAERI, 2013).

Korea Hydro and Nuclear Power Co., Ltd (KHNP, ikhnp on Twitter). Founded in 2001, it operates nuclear and hydroelectric plants accounting for 40% of electricity in Korea. Under its management, KHNP operates four nuclear power plant facilities. The company claims that nuclear power generation enables a quality supply of electricity with cost efficiency and environment friendliness (KHNP, 2013).

Korea Nuclear Energy Promotion Agency (KONEPA, anyatom on Twitter). Since its foundation in 1992, KONEPA has served for communicating to the public with accurate and objective information about nuclear energy. It claims that nuclear energy sustains the environment and the earth out of possible pollutions, while producing quality electricity. KONEPA has the four main projects: building-up public confidence, improving next-generation's understanding, sharing experiences of improvement of public understanding, and supporting technology exports of nuclear power plants (KONEPA, 2013).

Korea Radioactive Waste Agency (KORAD, yesKORAS on Twitter). Established in 2009, Ministry of Trade, Industry and Energy (MOTIE) has been responsible for managing this public organization. Its original name—Korea Radioactive Waste Management Corporation (KRMC)—has recently been changed in response to the local residents' petition. Its main functions and roles consist of transporting, storing, treating, and

disposing radioactive waste. KORAD has a vision statement to become "World's best eco-friendly radioactive waste management organization." (KORAD, 2013).

Nuclear Safety and Security Commission (NSSC, NSSCkorea on Twitter). NSSC was recently established in 2011 to meet the public's raised concern on nuclear power generation after the catastrophe at the Fukushima nuclear power plant. This institute is mainly responsible for safe and secure management of nuclear power to cultivate trust from the public and the world. Its functions include safety control of nuclear power plants, safety improvement plans, licensing of nuclear research products, and export and import control of critical materials or technology (NSSC, 2012).

METHOD

With the high expectation toward Twitter's capability, many studies in education have analyzed Twitter activities among focused groups: 49 target users from nonprofit or media organizations (Muralidharan, Rasmussen, Patterson, & Shin, 2011), 1400 focused messages with given themes (Smith, 2010), 140 university students on an experimental Twitter context (Park, 2013), and 494 messages among preservice teachers (Wright, 2010). In spite of their research contribution to the literature working on Twitter, there has not been much research that analyzes the big data over a longer period or examines PUS in non-experimental contexts. Hence, this study developed a Twitter backup system to explore every post among Korean-speaking users with the two given key words—*nuclear power* and *nuclear power plants*—between 1 October 2012 and 30 September 2013. In specific, three research questions are set as below:

(1) What are characteristics of the entire Twitter messages related to nuclear power among Korean-speaking users between October 2012 and September 2013?
(2) Who are featured users identified in the Twitter messages?
(3) What attitude do the featured users hold?

Twitter backup system

Every type of communication (personal opinions or statements, conversation with other users, and retweets) occurring on Twitter is subject to be accessible to anyone through the website: http://twitter.com. However, for technical reasons, this open search function can only collect posts within a limited period (approximately past 10 days). In order to collect and process these simultaneous posts in quantity, an online server

(Ubuntu 12.04.1 LTS) was installed on the Amazon Web Services (AWS) that operated 24 hours a day. On this system, a Perl script (a server programming language)—*TTYtter*—designed for searching and storing Twitter posts was implanted for automating the data collection (see more on http://www.floodgap.com/software/ttytter). This Twitter backup system has operated since September 2012 to perform four scheduled tasks: searching real-time posts with the two given key words, storing found results, processing them into a condensed textual database, and transferring them to an external backup storage.

Into this system, two key words were provided in the Korean alphabet: nuclear power (*won-ja-ryeok*) and nuclear power plant (*won-jeon*). As this language is mostly spoken in the Korean peninsula, this study presumes that Korean-speaking users on Twitter would regard socio-scientific issues of nuclear power facilities located in Korea. Between 1 October 2012 and 30 September, 746,825 posts were accumulated in a textual database. Filtering process was applied, as many irrelevant posts were collected due to phonetic similarity in the Korean alphabet. As a result, 249,676 posts containing similar-sound or spam words were removed from the database leaving 497,148 target messages (See Appendix 1). The database structure consists of three data fields: *time, user*, and *message*. One example is as shown below from the user *youngsamanim* who posted a news heading on 5 February 2013:

- TIME: 5 February 13
- USER: youngsamanim
- MESSAGE: [Kwangju] radioactive protective equipment provided for residents near the Youngkwang Nuclear Power Plants http://t.co/9nL49aLC

In order to process the big data sized 151 MB, Unix commands such as *ls* (listing files), *cat* (reading each file), *wc* (counting lines), *egrep* (searching input files with given key words), *printf* (placing output), and *awk* (scanning and matching lines) were used for examining the textual database (Bell Telephone Laboratories, 1979). The *Filter* (displaying data with given criteria) and *Pivot Table* (summarizing data in large quantity) functions in Microsoft Excel, and SPSS were employed for descriptive analysis such as frequency and histogram.

Terminology

For enhancing consistence and legibility in reporting the analysis, below terms were defined throughout this study:

- USER: An individual or institute as a user posts messages on Twitter.
- PROMOTIONAL ADVERTISEMENT: A certain amount of posts is automatically produced by web-based systems for advertising award-winning promotions and for disseminating positive images about nuclear power plants. These posts carry little arguable discussion or statement.
- MESSAGE: A Twitter message contains personal or institutional statements, headings of news articles, or retweets. The length of each message is limited within 140 characters.
- RETWEET: Users can forward (or retweet) others' messages demonstrating that they support the specific contents or statements. Larger retweets on a current or past message raise its significance and chance to be shown on the Twitter search.
- RETWEET RATIO: It indicates a frequency proportion of retweets out of entire messages that a user posts.
- TOTAL RANK: A user who has posted the most number of messages is ranked at the first (promotional advertisement excluded).
- ACTIVE SPEAKER: 10% of the entire tweet messages are posted by 0.2% of the entire users (promotional advertisement excluded). These 140 users are labeled as active speakers with their TOTAL RANK placed between 1st and 140th.
- ATTITUDE TYPE: Active speakers post messages with a consistent attitude type toward using nuclear power plants in Korea. These users along with their messages are mostly examined to be "supporting" or "opposing". If active speakers present both types, they are labeled as "neutral". Any other types are categorized into "irrelevant".
- AFFILIATION: Some of the active speakers represent a media corporation, non-profit organization, or state institution. During the one-year research period, this study identifies nine affiliations posted tweet messages: Asahi News Korea; Busan News; Green Peace Korea; Korea Hydro and Nuclear Power Co., Ltd (KHNP); Korea Nuclear Energy Promotion Agency (KONEPA); Kyodo News; Munhwa Broadcasting Corporation (MBC); Nuclear Safety and Security Commission (NSSC); and Seoul Metropolitan Government.

RESULTS

Between October 2012 and September 2013, the Twitter backup system collected 497,148 posts, which is averaged at 41,429 for a month (SD =

17,023). The frequency was counted smallest in January 2013 (22,913) and largest in August 2013 (88,380) as shown in Figure 1. Summarizing these big data, the succeeding sessions will report descriptive analysis answering the research questions.

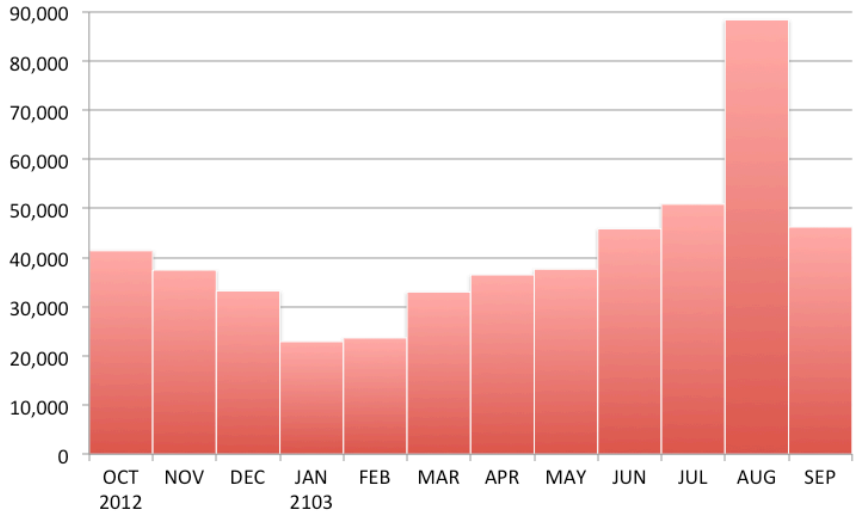

Figure 1. Number of Twitter posts with the key words "nuclear power" and "nuclear power plants" per month in Korea (N_{total} = 497,148)

Promotional advertisement from the 5 institutes

Examining each post, it was found that the database contained promotional advertisements posted by state institutes related to nuclear power plants in Korea. The 20% of the entire posts were written about promotional advertisements about quiz events held by state institutes related to electricity generation. For example, the below promotional advertisement was retweeted on 9 January 2013 by the user *ikhnp* that is the official Twitter account of Korea Hydro and Nuclear Power Co., Ltd (KHNP). The post advertised the newly launched website (http://atomstory.or.kr) that provides selected news articles and information supporting nuclear power. Its original advertisement had been posted by the user *anyatom* that is the official account of Korea Nuclear Energy Promotion Agency (KONEPA). This post is a piece of evidence that state institutes related to nuclear power retweet each other's advertisements so as to disseminate them widely and increase the chance to be shown in public.

- DATE: 9 January 2013
- USER: ikhnp

- MESSAGE: RT @anyatom: [JAN 9] Quiz Event! What is the name of hub website where all information related to nuclear power plus publics' discussion are taking place? HINT: The name has 5 Korean characters. http://t.co/HXrKBCJw

Two filter words *Quiz* and *Event* were used for discerning such advertisements from non-promotional messages as shown in Figure 2. The database contained 20% of posts identified by Quiz, Event, or their combination, leaving the other 397,827 normal messages. Most of the advertisements did not present an individual or institutional statement, but promoted events supporting nuclear power. As shown in Figure 3, most of these posts (n = 99,320) were related to the five state institutes of nuclear power (KRMC changed its name into KORAD) plus Korean Ministry of Education, Science and Technology (MEST). For example, below advertisement was retweeted 378 times by other users, as the advertisement asked to retweet it for winning an award. Although it was not always obvious whether or not the state institutes intended to occupy Twitter traffics for the promotional purpose, it was evident that none of the advertisements reflected public understanding of nuclear power. Retweeting such advertisements cannot be interpreted as a demonstration of a user's positive attitude toward nuclear power, because most of these advertisements involved award-winning competitions. Therefore, the upcoming descriptive analysis in the next sessions will exclude these 20% promotional advertisements leaving 397,827 normal messages.

- DATE: 22 February 2013
- USER: smefn
- MESSAGE: [TODAY'S AD] (FEB 22) RT Event. Korean Ministry of Education, Science and Technology supports research funds related national nuclear power policy and improving the policy. http://t.co/GqwYD35O5L
- RETWEET: 378 times

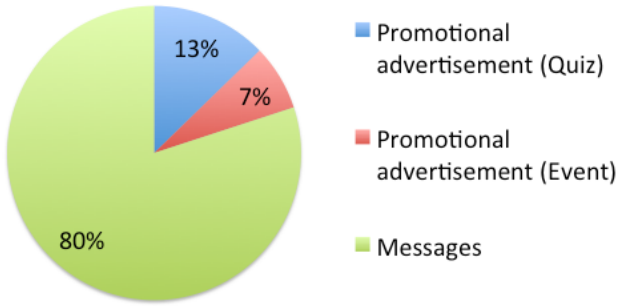

Figure 2. Proportion of promotional advertisement and messages (N_{total} = 497,148)

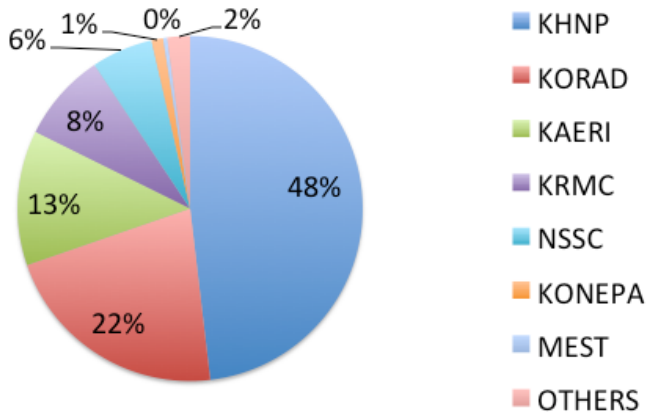

Figure 3. Affiliations shown in the promotional advertisements (n = 99,320); Korea Hydro and Nuclear Power Co., Ltd (KHNP); Korea radioactive Waste Agency (KORAD); Korea Atomic Energy Research Institute (KAERI); Korea Radioactive Waste Management Corporation (KRMC); Nuclear Safety and Security Commission (NSSC); Korea Nuclear Energy Promotion Agency (KONEPA); Ministry of Education (MEST)

Sled-shape model of user-message distribution (excluding the advertisements)

Having excluded the promotional advertisements, it was identified that 87,966 users posted messages related to nuclear power. As shown below, some users posted images or news articles and added their comments on them. First, the user *snanum* brought the cover image of the *Time* magazine issued on 10 August 1945. It was the week when an atomic bomb from US stroke Hiroshima prefecture in Japan. The user likened the historic attack in Hiroshima to the present accident in Fukushima, demonstrating his negative attitudes toward nuclear power. *kimchulhee* posted another opposing message. This message contains a more arguable approach citing a news article about the nuclear power technology written by a green-party agent. Lastly, *kuan6023* supporting nuclear power addressed that the electricity would cost much higher without nuclear power plants. Even though these three messages contain arguable discussion, none of them has received any retweet. The three users did not post more than a message.

- DATE: 5 August 13
- USER: snanum
- MESSAGE: On 6 August 1945, a nuclear bomb stroke Hiroshima resulting the 150,000 death toll. Fukushima is currently repeating

the disaster. The most dreadful fact is that we are forgetting the history. https://pbs.twimg.com/media/BQ36JfgCQAIZ0XN.jpg
- RETWEET: none

- DATE: 8 August 13
- USER: kimchulhee
- MESSAGE: I deeply agree with the author's insist that nuclear power technology is beyond human's capability. http://m.khan.co.kr/view.html?artid=201308072153165&code=990100
- RETWEET: none

- DATE: 7 December 12
- USER: kuan6023
- MESSAGE: Stopping nuclear power plants would raise the electricity cost by 50-100%. The public will suffer from the extra burden. http://t.co/zLF535Zu
- RETWEET: none

On average, a user posted 4.5 messages (N_u = 87,966; SD_m = 17.6). However, 55% user posted a single message, which means that much larger number of messages was posted by a limited number of users. In order to project this partial distribution, all users are ranked in order of their posted messages. The most active user *cozmicnomad* who was ranked at the first posted 2562 messages. Figure 4 presents a sled-shape model in the cumulative chart of messages per user. The top 0.2% users posted 10% of the entire messages, while the top 5% users did for the half of the entire messages. According to this skewed user-message distribution, there existed a featured group of users who actively posted extremely more messages than others. This study focuses on the top 0.2% users with their total ranks placed between the 1st and 140th, and entitles them as *active speakers*. These 140 users posted 283 messages on average resulting in an extremely more number of messages (t = + 15.8) compared to the sampled mean and standard deviation.

Attitudes types among the active speakers

The 140 active speakers posted 10% of the entire non-promotional messages that are mostly against nuclear power. Among them, 98 active speakers opposed nuclear power plants as shown in Appendix 2. Some of these users represent official Twitter accounts from media companies (Kyodo News, Asahi News Korea, Munhwa Broadcasting Corporation, and Busan News) and a non-governmental organization (Green Peace

Korea). Appendix 3 presents the other 20 users who posted messages with neutral or balanced attitudes toward nuclear power. Because each user posted widely different numbers of messages with a consistent attitude type, message frequencies from each user should be multiplied for a valid comparison of attitude types in quantity. Figure 5 shows the attitude types of messages categorized by *opposing*, *supporting*, *neutral*, and *irrelevant*. Among the active speaker, there are 72% messages opposing nuclear power.

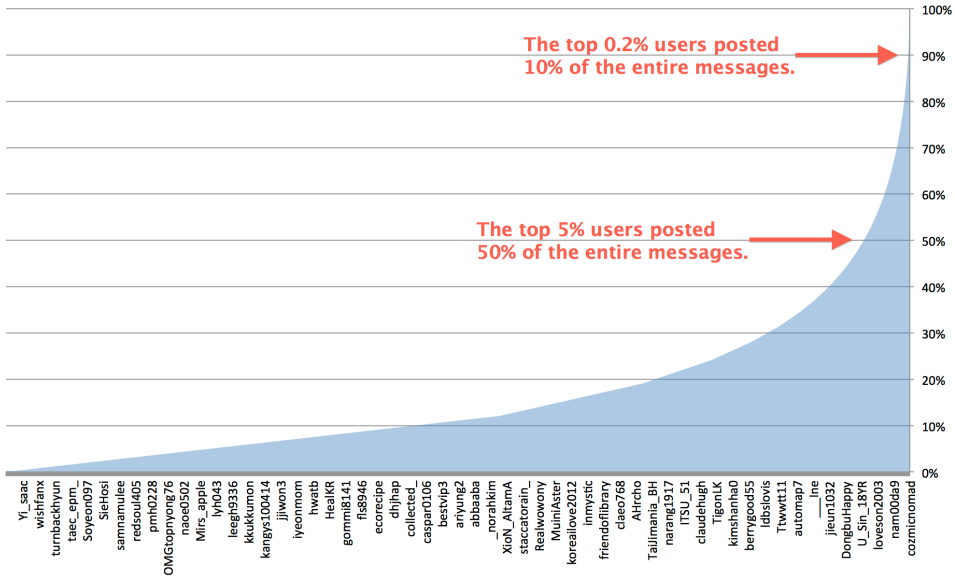

Figure 4. Sled-shape model of the cumulative chart of messages per user (N_u = 87,966; N_m = 397,827); the top 0.2% users (active speakers) posted 10% of the entire messages

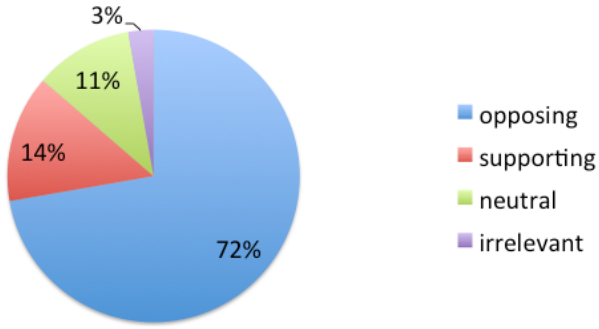

Figure 5. Attitude type of messages (n_m = 39,636) towards the nuclear power plants among the active speakers

The last finding in this series of descriptive analysis concerns the retweet ratio among the 17 active speakers who support nuclear power (see Table 1). As three users are representatives of state institutes (NSSC, KONEPA, and KHNP), it is apparent that all of their messages are supportive. In addition, the other 14 users as well mostly produced the retweets from these official messages posted by the institutes. The retweet ratio 100% of the user *bass0812* indicates that all the messages are exact duplicates without any of own comment or discussion. Under the user name, 8 messages are retweets about supporting news articles cited from a media company, and 589 are from NSSC, KONEPA, KHNP, or KORAD. Even for the user with a lower retweet ratio 72%, *youngsamanim*, most of its non-retweet messages were automatically posted by a media company, as the hash tag #MToday leads to the Twitter account of *Money Today*.

- DATE: 23 October 12
- USER: youngsamanim
- MESSAGE: President Lee Myung-bak addressed the safety of nuclear power should be well recognized among the public. #MToday http://t.co/JhjzosUa

Table 1. Active speakers supporting nuclear power and their retweet ratios

TOTAL RANK	USER	MESSAGE	RETWEET RATIO	NOTE
91	NSSCkorea	193	0%	Nuclear Safety and Security Commission (NSSC)
3	anyatom	943	10%	Korea Nuclear Energy Promotion Agency (KONEPA)
17	ikhnp	415	28%	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
38	youngsamanim	293	72%	Systematic retweets forwarded from NSSC, KONEPA, KHNP, or KORAD *
25	yang5060	348	98%	
41	ygchoi2	287	98%	
48	sonjaemin	273	99%	
5	bass0812	597	100%	
7	_9890198643872	575	100%	
47	loving9112	275	100%	
54	julia1206c	266	100%	
68	dongwha10	228	100%	
69	withme1212	228	100%	
97	leedoune	180	100%	
119	qldrnskfeh	165	100%	
132	songanea	158	100%	
135	harucareLee	155	100%	

* excluding 143 retweets related to other supporting news articles

LIMITATION

In advance of offering any conclusion from the series of descriptive analysis, a limitation should be carefully discussed. This study did not conduct content analysis on all 497,148 posts for comparing attitude types in supporting and opposing messages. Rather, the focus of content analysis was put on the top 0.2% users (140 active speakers) who posted 10% of the entire messages. The foremost reason of the diminishment is that it is beyond the author's capability to judge attitude types of each message from such amount of big textual data. The second reason is that it is not representative to make an overall conclusion on attitudes toward nuclear power in Korea, because the five state institutes and their duplicators who systematically retweeted the supporting messages occupied a massive amount of Twitter traffics (e.g., the 99,321 promotional advertisements). Nevertheless, the significance in this study of descriptive analysis is that it empirically examined entire messages with the aimed key words in a non-experimental design during the one-year research period, which enables a closer examination of the PUS in Korea.

CONCLUSION

In terms of PUS, a majority of users were indifferent to nuclear power or they did not expressed their attitude in more than two messages on Twitter for the one year; 55% of users posted a single message. Of note is that there were certain institutes and individuals who sought to occupy more portions of the Twitter messages intending to appeal their opinions and to influence the public understanding of nuclear power. Two pieces of evidence can be referred to. First, the sled-shape model was identified in the cumulative chart of messages per user. According to this skewed user-message distribution, only 5% of the users posted half of the entire messages collected in this study. The top 0.2% users posted an extremely more number of messages (t = + 15.8), accounting for 10% of the entire messages. Second, these 140 active speakers (the top 0.2% users) preserved very consistent attitude types toward nuclear power. The 17 supporting active speakers were representative Twitter accounts of the major state institutes and submissive duplicators who systematically forwarded the messages posted by these institutes.

This one-side persuasion organized by the supporting state institutes and opposing individuals would not be the most appropriate strategy to promote PUS related to nuclear power. An experimental study which examined the university students' attitudes toward nuclear power revealed that bidirectional messages with balanced attitudes were identified to be more credible than unidirectional, supposing or opposing discussion

(Park, 2013). In this study, there were only 11% messages among the active users who had such balanced neutral attitudes. In other words, it is highly likely that the other 89% of messages posted in Twitter among the active speakers would gain less credibility than they were intended. Many researchers on PUS address bidirectional communication related to macro-scope risks such as chemical, biological, radiological, and nuclear accidents (Kang, 2012).

FURTHER RESEARCH QUESTIONS

What will longitudinal studies demonstrate regarding socio-scientific issues such as nuclear power plants? As pointed out in the limitation section, this study could not examine every message (N_m = 397,827; excluding the promotional advertisements) posted by the entire users (N_u = 87,966) in terms of their attitude types, due to the massive amount of textual data. Other than the findings of this study—the sled-shape model and opposing active speakers, there should be more evidence to conclude influence of Twitter as a significant channel of risk communication. Methodological development would enable further research to estimate how much portion of the entire users support and oppose nuclear power in a longitudinal research design. A new methodology should be developed to identify the public's attitude types with validity and reliability, expanding the discussion from the focused active speakers.

How can related organizations communicate with the public in an efficient and ethical manner? Furthermore, how state institutes and individuals appeal their opinions to the public should be more studied to find the most efficient communication strategy. In school contexts with science teachers and students, Koballa (1992) categorized the types of persuasion strategies: *propaganda* for "communication techniques to spread doctrines", *coercion* for "reinforcement control to induce behaviour", *indoctrination for* "biased presentation of a debatable issue", and *brainwashing* for "an irresistible method of achieving total control over the human mind" (pp. 67–71). Beyond the current propaganda and indoctrination identified among the supporting and opposing active speakers, further research on how to communicate with the public through reasonable and debatable messages would contribute to the research area of risk communication.

REFERENCE

Bell Telephone Laboratories. (1979). *Unix TM Time-Sharing System : Unix Programmer ' S Manual* (7th ed., Vol. 1). New Jersey: Murray Hill.

KAERI. (2013). About KAERI: Greetings. Retrieved from http://www.kaeri.re.kr:8080/english/sub/sub01_01.jsp

Kang, Y. (2012). Nuclear accidents, risk communication, and politics of expertise : Centered on fukushima nuclear accident. *Journal of Engineering Education Research*, *15*(1), 35–44.

KHNP. (2013). KHNP is: Overview. Retrieved from http://cms.khnp.co.kr/eng/khnp-is-overview/http://cms.khnp.co.kr/eng/khnp-is-overview/

Kim, D. (2011). Highest anti-nuclear recognition in Korea after the Japanese disaster. *Happy Day Gochang*, *163*, 13.

Kim, M.-J. (2012). Is the nuclear energy indeed a solution in a time of crisis? *Environmental Philosophy*, *14*, 33–59.

Koballa, T. R. (1992). Persuasion and attitude change in science education. *Journal of Research in Science Teaching*, *29*(1), 63–80. Retrieved from http://dx.doi.org/10.1002/tea.3660290107

KONEPA. (2013). Activities. Retrieved from http://www.konepa.or.kr/eng/activities/activities.html

KORAD. (2013). About KORAD: General. Retrieved from http://www.korad.or.kr/krmc2011/eng/krmc/ke01_04.jsp

Lee, H. J., & Park, S. T. (2012). Comparison of perception differences about nuclear energy in 4 East Asian country students: Aiming at 10th grade students who participated in scientific camps, from four east asian countries: Korea, Japan, Taiwan, and Singapore. *Journal of the Korean Association for Research in Science Education*, *32*(4), 775–788.

Min, Y. (1994). Popularization of science through lifelong science education. *Journal of the Korean Association for Research in Science Education*, *14*(3), 393–398.

Muralidharan, S., Rasmussen, L., Patterson, D., & Shin, J.-H. (2011). Hope for Haiti: An analysis of Facebook and Twitter usage during the earthquake relief efforts. *Public Relations Review*, *37*(2), 175–177. doi:10.1016/j.pubrev.2011.01.010

NSSC. (2012). *NSSC Buils Up Safety and Security*. Seoul.

Park, W.-K. (2013). A study on message credibility regarding nuclear power plant issues on Twitter and Facebook accounts messages. *Speech and Communication*, *20*, 89–112.

Sheppard, B., Janoske, M., & Liu, B. (2012). *Understanding Risk Communication Theory: a Guide for Emergency Managers and Communicators*. College Park, MD.

Smith, B. G. (2010). Socially distributing public relations: Twitter, Haiti, and interactivity in social media. *Public Relations Review*, *36*(4), 329–335. doi:10.1016/j.pubrev.2010.08.005

Song, H., & Seo, Y. (2013). Living under power lines, more cases of cancer. *The Hankyoreh*.

Wright, N. (2010). Twittering in teacher education: Reflecting on practicum experiences. *Open Learning: The Journal of Open, Distance and e-Learning*, *25*(3), 259–265. doi:10.1080/02680513.2010.512102

APPENDICES

Appendix 1. Key words and filtered words

The two key words

Word	**Sound**	**Korean alphabet**
nuclear power plant	*won-jeon*	원전
nuclear power	*won-ja-ryeok*	원자력

Similar-sound words (filtered)

기원전, 수원전, 회원전, 강원전, 만원, 변역, 병원전체, 음원전곡, 응모, 응원전, 참여인원, 출원, 후원전

Spam words (filtered)

애린원, 온라인카지노, furin0620, Hibrain, Reiuzi_Utsuho_, DO7000, Mybet7

Appendix 2. Active speakers opposing nuclear power plants

TR	USER	M(R)	TR	USER	M(R)	TR	USER	M(R)
1	cozmicnomad	2562 (0.13)	46	saramimeonjeoda	277 (0.31)	92	lwt55dgcha1	192 (0.93)
2	akihirofromjap	1175 (0.36)	49	seomin_bot	272 (0)	93	jaesungtang	191 (1)
4	jonghee1	623 (0.04)	50	chamseon	270 (0.96)	94	samsara1294	186 (0.87)
6	kimyiha	579 (0.83)	51	dbehdgus1215	269 (1)	100	malidoeneun	179 (1)
8	tikhij_han	497 (0.05)	53	gkstjs57	268 (0)	104	miokjung0114	176 (0.99)
9	Progress_News	478 (0)	57	jnjfilm	265 (0.1)	105	jhannes37	175 (0.8)
10	coreacom	471 (0.99)	58	woodstock1000	260 (0.7)	106	islegreen	174 (0.05)
11	cdefghijklmnop	466 (0)	60	EnergyJustice	256 (0)	107	bhyk21291	173 (0.91)
12	124716	459 (0)	61	EuiQKIM	247 (0.93)	108	nogadean	173 (0.15)
13	KyodoNewsKorean	456 (0)	62	reemk13	247 (0.03)	110	k1071	171 (0.43)
14	csi1029	453 (0.99)	63	hyesan0	244 (0.84)	111	trashkiller2	171 (0.81)
15	timezen	451 (0.19)	64	dlteresa	235 (0.99)	112	ccha47	167 (0.84)
16	173951	434 (0.26)	65	foremoon	235 (0.74)	113	mbcnews	167 (0)
18	initd_bot	413 (0)	66	news_kor	234 (0)	114	salomark	167 (1)
19	114luck	406 (0.07)	67	seojuho	231 (0.26)	115	marysesa59	166 (0.93)
20	sockskurogohan	381 (0.06)	72	asahi_korean	224 (0)	116	bangyc	165 (0.56)
21	khani_bot	380 (0)	73	jchbae	222 (0.29)	120	hoodman55	164 (0.16)
22	JinJumong	373 (0.13)	74	baramnamuya	218 (0.96)	121	hwsearth	163 (0.96)
23	greenpeacekorea	361 (0.23)	75	troll8360	217 (0.58)	122	tang29593120	163 (0.98)
24	da3t7pay	351 (0.13)	76	smile7405	216 (1)	123	2badasok	162 (0.59)
26	NAMAENAKI_BOT1	340 (0)	77	20092901	212 (0.87)	124	djaak2002	162 (0.56)
27	KR_NewsWaver	334 (0)	78	zerocomo	212 (0)	126	unheim_neu	162 (0)
28	sookpoet	330 (0.88)	79	De_Renfort	208 (0.93)	127	seosan2012	161 (0.22)
29	handduck45	326 (0.48)	80	rhinoha	205 (0.9)	128	shadowemote	160 (0.77)
30	rubenruben2	317 (0.94)	81	yes4456	205 (0.07)	129	Hjs3452	159 (0.04)
31	dkdlel4500	309 (0.53)	82	threedaugher	204 (0.63)	130	cjkcsek	158 (0.52)
32	s17221	307 (0.9)	83	DTD_bot	202 (0)	131	janin2017	158 (0.99)
37	hushgom	295 (1)	84	wolgyesu	202 (1)	133	busantweet	157 (0.02)
39	some_to_be	292 (0.34)	85	koko6537	201 (0.01)	134	dolmen85	155 (0.9)
40	BeingSin	291 (0.92)	86	NAMAENAKI	201 (1)	136	StellaSoiree	155 (0.93)
42	korea_jiri_bot	285 (0)	88	Noel3679	200 (0.54)	139	finalvictory7	153 (0.69)
43	CineTrivia_Bot	280 (0)	89	sada69c59	196 (0.49)	140	surama8gi	153 (0)
45	rock1778	277 (0.94)	90	coolpuma0727	194 (0.88)			

* Note. TR: Total Rank; M(R): MESSAGE (RETWEET RATIO); 13: Kyodo News; 23: Green Peace Korea: 72: Asahi News Korea; 113: Munhwa Broadcasting Corporation (MBC); 133: Busan News

Appendix 3. Active speakers with neutral attitudes toward nuclear power plants

TR	USER	M(R)	TR	USER	M(R)	TR	USER	M(R)
33	skymanhan	305 (0.97)	70	aidoo43	226 (0)	103	mediadaum	176 (0)
34	Mfecane	300 (0.07)	87	news_bot102	201 (0)	117	flytonorth	165 (0)
35	sasang64	300 (0.99)	95	antkdyd03	185 (0)	118	kbsnewstweet	165 (0.02)
36	KR_NW_National	297 (0.01)	96	kzaanfever	181 (0.24)	125	ihanall	162 (0)
44	seoulgreenergy	279 (0.05)	98	News_Y	180 (0)	137	KR_NW_Business	154 (0)
52	YTN24	269 (0)	99	SBS8news	180 (0.13)	138	vkfehrkdtks37	154 (0.94)
59	airtosky88	256 (0.01)	101	MB_DIC	178 (0)			

* Note. TR: Total Rank; M(R): MESSAGE (RETWEET RATIO); 44: Seoul Municipality Office