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SCIENCE AND NON-SCIENCE UNDERGRADUATE STUDENTS' CRITICAL THINKING AND ARGUMENTATION PERFORMANCE IN READING A SCIENCE NEWS REPORT

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ABSTRACT. A scientifically literate person should be able to engage and critique science news reports about socioscientific issues from a variety of information sources. Such engagement involves critical thinking and argumentation skills to determine if claims made are justified by evidence and explained by reasonable explanations. This study explored university students' critical thinking performance when they read science news reports. Undergraduate science/applied science ($n = 52$) and non-science ($n = 52$) majors were asked to select a science news report from Internet sources and then to read, critique, and make comments about its contents. The science and non-science majors' comments and their quality were identified and assessed in terms of analyzing the argument elements—claims and warrants, counterclaims and warrants, rebuttals, qualifiers, and evidence. The results indicated there is significant difference in identifying and formulating evidence favoring science/applied science over non-science majors ($p < .01$). Quality of critical thinking associated with the strength of the arguments made indicated that science/applied science majors demonstrate significantly ($p < 0.05$) more advanced patterns than non-science majors. The results suggest that further studies into improving undergraduates' concepts of evidence in the context of reading and critiquing science news reports are needed.

KEY WORDS: argumentation skills, critical thinking, science news reports, university students

INTRODUCTION

Information communication technologies (ICT) have filled our lives with all kinds of reports that can be easily accessed from print and digital forms of newspapers, magazines, broadcast media (radio and television), and the Internet. ICT allow us to access information much more rapidly than ever before; however, most of these messages are abbreviated texts with distinctive, unfamiliar genres that may lack peer review and be difficult to understand. Regardless of the content, including science, these news reports are criticized as having bias, faults, exaggerations, and false or weak evidence for the claims (McClune & Jarman, 2012). Therefore, it is necessary to be careful, deliberate, and critical readers of these news reports in order to reduce the likelihood of being misinformed or misled

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about the science ideas contained, ascribing greater certainty to the claims than intended or justified, and assuming rapid applications of the reported claims (Norris & Phillips, 2012; Yore, Bisanz & Hand, 2003).

Two decades of research indicated that high-performing high school and university science students have difficulty determining the certainty of claims and confirming or disconfirming evidence for the stated claims in science news reports (Norris & Phillips, 2012). Norris & Phillips (2003) claimed that science literacy involves fundamental literacy in constructing and making sense of scientific discourses such as science news reports. Norris, Phillips, Smith, Gilbert, Stange, Baker & Weber (2008) emphasized the importance of enhancing students' citizenship ability to analyze and critique arguments regarding the controversy of social applications of science and technology in news media because these arguments usually present one interest group's perspective without a balanced counterperspective, which might inappropriately influence a person's decision on problems in democratic society. Therefore, it is necessary for engaged citizens to demonstrate critical thinking while reading news reports in order to avoid being misled and to making unsupported decisions. Furthermore, critique is an essential social aspect of science (Ford, 2008) and a critical science and engineering practice (United States National Research Council [NRC], 2012). These abilities are also essential for scientifically literate citizens to deal with the content of science media reports.

This study explored future citizens' ability to apply critical thinking while reading science new reports. Consequently, university students were asked to locate an Internet science news report of interest, to read it, to critique the report, and to represent the critical elements of an argument regarding its contents. Differences between the responses of science/ applied science majors (hereafter called science majors) and non-science majors were analyzed as the central focus of this study. The results will help science educators develop science curriculum and instruction that integrates news reports of contemporary science and technology to improve scientific literacy at the postsecondary education level.

Background

Science literacy for all is the central goal of many international science education reforms focused on general citizenship. Unfortunately, science literacy does not have a universal, shared definition. Recently, an increased number of science education researchers involved in language and literacy within science have suggested that science literacy involves three clusters: fundamental literacy in science (metacognition, critical thinking, habits of mind, language, and ICT), understanding of the big ideas (core ideas, crosscutting concepts, nature of science, scientific inquiry, technological design, etc.), and fuller participation in the public debate about socioscientific issues resulting in informed decisions and sustainable actions (Yore, 2011, 2012; Yore, Pimm & Tuan, 2007). This contemporary vision presents these interacting clusters of knowledge, abilities, and dispositions as symbiotic relationships within and between the three components where improvement in one component will influence performance in the other components within that cluster and in the other two clusters. This study explored the relationships within the fundamental literacy cluster amongst critical thinking, reading science news reports, and empirical argumentation. Cottrell (2005) suggested that an application of critical thinking is to examine and evaluate the text contents or arguments in a mass media science report; in addition, the USA's new framework for science education identified critique and argument as essential evaluative practices in science and engineering (NRC, 2012).

Characteristics of Science News Reports

Composing science news reports involves selecting the main ideas and supportive detail from a scientific report or interview and constructing a report using what we refer to as the "journalist version report" (JVR) genre. Science journalists need to retain the central message of the scientists (experimental findings, potential applications, etc.) while addressing a diverse, non-expert audience. Due to limited number of words and space available, a science news report is usually a brief, incomplete description of the research with omission of some details, such as evidence, plausible reasoning, or the research process. The science JVR produced is remarkably different from scientific research documents or journal papers that consist of complete methodology, results, discussion, conclusions, and suggestions. In other words, science JVRs have a unique genre that is distinct from other forms of science writing (Jarman & McClune, 2007). The JVR contents lack peer review and quality control common to the knowledge production cycle in scientific communities; unexpected demands as well on space or time at press schedules can result in the loss of important text, frequently at the end of the news report. This places critical demands on the reader to infer or supply the missing structures, reasoning, and argument elements and to avoid overestimating the validity of the authors' claims and strength of the argument.

Previous studies have examined students' evaluation of claims and arguments in science news reports. Norris & Phillips (1994) and Phillips & Norris (1999) found that university students were inclined to accept the claims in the report. Korpan, Bisanz & Bisanz (1997) found that university students often focused on methodological problems in science news reports, such as how the study was conducted and why the results occurred. Ratcliffe (1999) found that most of students could recall facts from uncertain arguments and performed limited reasoning in recognizing the problems of external validity from insufficient evidence. Kolsto, Bungum, Arnesen, Isnes, Kristensen, Mathiassen, Ulvik et al. (2006) found that university students used 13 criteria applied to critically examine texts and that the quality of the application of these criteria varied with individuals. However, few studies explored how undergraduate science and non-science major students perform critical thinking when they encounter science news reports on the Internet, especially in terms of examining their argumentation skills.

Critical Thinking and Science News Reports

The Program for International Student Assessment project reported that many students search scientific information websites and construct scientific knowledge through the Internet (Organization for Economic Co-operation and Development, 2006). Gomez-Zwiep (2008) suggested that some students' misconceptions about science originate from science news media. Therefore, students have to deliberately adopt a critical stance and attitude when reading information on the Internet in order to avoid being misled or constructing incorrect knowledge. Critical thinking can be considered the deliberate process of determining what to believe or do about a worthy challenge (Ford & Yore, 2012). This means that readers need to evaluate the evidence behind a claim, belief, or action that will allow them to determine the validity, reliability, and authenticity of the information and how well it supports the claim.

The Discovery Channel television program *Mythbuster* is a popular example of interrogating knowledge claims and popular myths. This program sets out to confirm or rebut rumored ideas disseminated by the Internet or other media through designing and conducting scientific experiments to test the claims and to search for evidence to support or refute the claims. In addition to entertaining audiences, *Mythbuster* demonstrates that testing ideas with evidence and adopting a critical attitude is important to everyone as scientific-literate citizens; however, it is not practical to do many of the scientific experiments used on the program to verify media claims. Therefore, most people must use a different approach involving information sources, a critical stance, and a skeptical attitude when engaging science news reports in media sources.

The critical thinking literature was reasonably consistent that identifying and assessing claims and critiquing arguments were essential when deciding what to believe or do (Finocchiaro, 2005). Ennis (1996) claimed that critical thinkers could evaluate the accuracy and reliability of various arguments. Cottrell (2005) also agreed that evaluation was an essential part of critical thinking, which involves a series of cognitive processes aimed at recognizing a problem, choosing a solution plan, and evaluating the solution. That is to say, a critical thinker can understand others' expressions, hold a healthy level of skepticism, and use appropriate criteria to evaluate an argument. Norris & Phillips (1994) believed that these attributes were central to critical reading. Therefore, these critical thinking abilities are indispensable to students as they engage in reading and responding to various kinds of news reports, including Internet science-related news.

Critical Thinking, Argumentation, and Their Quality

The relationship between critical thinking and argumentation has been recognized for over two decades. Moon (2008) argued that constructing an argument is the core process of critical thinking. Therefore, generating or evaluating arguments about issues can be an important tool for developing and assessing students' critical thinking ability (Lubben, Sadeck, Scholtz & Braund, 2010). Students who are able to examine and assess an argument for and against a claim—identify and evaluate an argument, degree of supporting evidence, and possible counterclaims—are regarded to be performing crucial parts of critical thinking (O'Rourke, 2005). Nussbaum (2008) said that effective argumentation skills are core components of critical thinking, which includes the ability to construct one's own arguments for agreeing or disagreeing with the claims or standpoints behind any science news report. Therefore, students have to justify their arguments with supporting evidence or to rebut the report's argument with supported counterclaims, contrary examples, or non-supportive facts. If students could transfer these critical practices and abilities to examine media information, it would indicate a high likelihood that they could apply their critical thinking and argumentation skills to other knowledge sources (Kuhn & Udell, 2007; Nussbaum & Edwards, 2011).

Critical thinking is an essential kind of evaluative thinking that involves assessing the quality of an argument presented in support of a belief or an assertion (Fisher, 2001). Toulmin's (1958) model of the structural components of a sound argument includes data, backings, warrants, evidence, claim, rebuttal, and qualifiers. This model has been the basis of evaluating the quality of an argument in terms of the presence or absence of these structural components. Some researchers have suggested that a simple checklist of argumentative elements does not accurately reflect the persuasive quality of an argument; rather, an evaluation framework must consider the combination of elements. Kuhn (2010) suggested that the use of rebuttals represents better quality arguments and demonstrates the capacity for higher-level argumentation. Zeidler, Osborne, Erduran, Simon & Monk (2003) categorized the argument quality into five levels. The first level, lowest quality, is an argument composed of a claim; the second level is composed of a claim with at least one warrant or evidence; the third level is composed of claims or counterclaims with warrants, evidence, or a weak rebuttal; the fourth level is composed of claims with warrants, evidence, and rebuttals; the fifth level, highest quality, is composed of warrants, evidence, and more than one rebuttal.

Scholtz, Braund, Hodges, Koopman & Lubben (2008) pointed out that the use of a qualifier in students' arguments limits the applicability of a claim and thus makes it more precise. Yu & Yore (2012) reported that, when students simultaneously used elaborated warrants that establish data as evidence to justify their claims and rebut counterclaims, they construct better quality of arguments. Nussbaum & Schraw (2007) suggested that if students can make counterarguments to their own or others' arguments, integrate rebuttals into their justifications, or integrate their arguments, counterarguments, and rebuttals into a supportive network for a final position, then it would be indicative of generating more compelling argumentation. They further suggested that effective argumentation first involves students considering arguments and counterarguments simultaneously, then elaborating, evaluating, and organizing the arguments, counterarguments, and rebuttals into an overall final position.

Content Knowledge, Critical Thinking, and Argumentation

Both critical thinking and argumentation are context-dependent (Cavagnetto, 2010). It is impossible for students to demonstrate critical thinking or make an argument without engaging an interesting and worthwhile challenge (Ford & Yore, 2012). Consequently, students' content knowledge about the issue influences their performance on critical thinking or argumentation in the context of the issue (e.g., Sadler & Fowler, 2006; Willingham, 2007). Sadler & Fowler (2006) found that students with more knowledge about genetics outperformed students with less knowledge about genetics when making justifications about genetic engineering. Bråten, Strømsø & Salmerón (2011) also found that students with higher topic knowledge perceived differences existing in texts and used deeper criteria to justify their arguments when being asked to evaluate the scientific information about climate change.

Furthermore, Kuhn (1991) suggested that the quality of students' higher-order thinking skills, which include critical thinking and argumentation, was determined by their complex knowledge base. However, content knowledge about the issue is merely one part of this complex knowledge base; thus, prior content knowledge is not the only factor influencing students' performance on critical thinking or argumentation. Mercier & Sperber (2011) suggested that students familiar with argumentative knowledge would generate better argumentation or critical thinking. Argumentative knowledge consists of what argument and argument elements are and how to make a good argument or argumentation sequence (Weinberger & Fischer, 2006). Understanding this knowledge covers understanding and utility of evidence that is beneficial to students when they use evidence to support their own arguments or rebut others' arguments (Schalk van der Schee & Boersma, 2013). Tytler, Duggan & Gott (2001) found that scientists, compared with students, were more familiar with (a) the nature of evidence and the process to get the evidence and (b) constructing evidence to support their arguments. Tytler & Peterson (2004) found that the students who had fewer ideas about evidence had difficulty in generating evidence-based arguments. Moreover, if students lack understanding of what makes a good argument, they often fail to provide evidence for claims.

In summary, inadequate knowledge about evidence limited students' argumentation quality, especially when students have to use evidence to evaluate knowledge claims and justify their arguments. Therefore, this study explored the quality of undergraduate students' critical thinking in terms of analyzing the elements appearing in their written arguments about science news reports. The unrestricted choice of a contemporary science news report based on personal interest provided an authentic context for critical reading, critique, and argumentation about a personally valued issue.

Methods

This study used mixed methods to collect and interpret data that documented the argument elements reported by university students reading Internet science news reports. These procedures, based on the assumption that critical thinking and argumentation were closely related, were used to understand whether or not differences in critical thinking existed between science majors and non-science majors when they read, critiqued, and responded to self-selected science news reports. Two research questions guided this study:

1. Is there any significant difference in use of argument elements between science and non-science majors?
2. Is there any significant difference in quality level of critical thinking between science and non-science majors in terms of analyzing argument elements?

Participants

The researcher recruited students at Taiwanese universities as participants by posting an invitation letter on the Internet. The invitation included statements about the purpose of this study, the participant's qualifications, the task to be completed, the deadline to finish the task and return email their response, and the reward for completion (a book of coupons valued at 200 NT dollars) for their comments judged as clear and valid. Included in the invitation was a letter of consent to be signed by each participant that documented their voluntary willingness to join the study, a requirement of the university's research ethics board.

One hundred thirty students returned the letter of consent and stated their intention to participate. The description of the required tasks, responses, and reply deadline were emailed to these potential participants. Their completed email replies included their name, major, gender, and mail address for the book coupons and their responses to participation tasks, which specified the science news report, a respondent-generated summary of the report (JVR), and their response to a critical thinking/ argument task. Comparing the students' description of the science news report's purpose with the contents of the actual report, the author screened out 26 participants for invalid and unclear comments. For example, the science report only focused on the discussions of disadvantages of using nuclear power in Taiwan, but the student's summary involved the statements about the advantages of it, which did not appear in the science report. The remaining 104 undergraduate volunteers consisting of 52 science and applied science majors (30 males and 22 females) and 52 non-science majors (24 males and 28 females) were identified as valid participants in the study. All participants were first-semester seniors in their university program. The science majors were in science (39, 75.0 %), medicine (5, 9.6 %), engineering (2, 3.8 %), and agriculture (5, 9.6 %); the non-science majors were in liberal arts (30, 57.7 %), law (2, 3.8 %), education (17, 32.7 %), and business and management (3, 5.8 %).

Procedures

All participants were asked to choose, identify, and submit a science news report, which consisted of between 500 and 1,000 Chinese characters, from an Internet source that matched their reading interest, aptitude, and understanding. Several trustworthy Chinese websites about science news were suggested for the participants to look for the news reports (e.g., The Development of Science, PanScience, The Scientists, etc.), but the use of these websites was not required. The advantage of providing free choice was that the students' critical thinking would not be hindered because of their lack of interest in or total lack of scientific knowledge about the scientific idea(s) in the report. After reading the news report, they had to write their comments about its contents as specified in the following tasks:

1. Please write down the purpose of the article in 200 Chinese characters or less.
2. Do you agree or disagree with the author's claim (i.e., conclusion) in the science news report? Please write down your reasons for your agreement/disagreement in detail.

The brief summary task helped the researcher to determine whether or not the participant (a) actually engaged the science news report and (b) identified its main idea and intent. The second task required the participants to take and justify a position—essential components in critical thinking (Ford & Yore, 2012). Preliminary assessment of the summaries and critiques were used to eliminate inappropriate responses. Participants who did not carefully read their news report or who selected an editorial were excluded from the sample and further analysis. Analysis of the valid responses investigated their stance on the claim and was further analyzed for source evidence and quality of argument in their justification of support or rebuttal. The students had to complete the tasks within 2 weeks of their acceptance as participants. Completion involved the summary, analysis, and digital copy of the selected science news report via return email.

Data Analysis

The process of data analysis included three phases. First, the researcher and a research assistant, who has a master's degree in science education, collaborated to examine and judge (a) whether the students selected science news reports (not editorials) and (b) if the students provided summaries (JVRs) that matched the purpose of the article selected and an expert summary provided by a science educator with expertise in reading comprehension. If the participants selected an editorial or if the summary was not aligned with the expert's summary, we regarded the written argument as invalid and excluded it from the sample. Phase 1 eliminated 26 of the original 130 participants; 52 science (S, including applied sciences) and 52 non-science (NS) majors remained. Preliminary consideration of the science news reports chosen related to a range of different issues, including 18 reports on global warming (9 S, 9 NS), 17 on energy utility and choice (10 S, 7 NS), 14 on the impact of biotechnology (6 S, 8 NS), 12 on environmental protection and ecological conservation (6 S, 6 NS), 14 on the effectiveness of drugs (5 S, 9 NS), 11 on the risk of radiation (6 S, 5 NS), 9 on the health effects of food (6 S, 3 NS), and 9 on the problem of new products (4 S, 5 NS). Inspection of the topics and news reports chosen by S and NS participants did not reveal any obvious differences. Most of the science reports were related to socioscientific issues as would be expected based on media popularity and availability of science, technology, society, and environment articles.

Second, the researcher and the research assistant individually identified which structural elements of an argument appeared in students' analytical comments. The following operational definitions and examples from a student's comments for each argument element illustrate this process.

In this study, a *claim* was taken to be an assertion that a student constructed to express his/her position to the argument of the science news report. For example, one student selected a science news report about "genetically modified organisms (GMO)" and his claim was "I agree the development of GMO". *Evidence* was taken to include facts, concrete examples, or descriptive or numerical data derived from surveys, observations, or scientific experiments (Inch & Warnick, 2010). This student based his support for the claim he made on a statement: "The news report said 25 % of GMO have been used in solving famine problems in the world". A *warrant* was taken to be a reasoned justification of why the data were evidence and, therefore, related to the claim. This student stated: "GMO can help humans solve the problem of famine". A *qualifier* was taken to be a premise that indicates the rational strength of a claim and delineates the limited applicability of a claim. This student stated: "Not all famine problems can be solved by GMO, but to some degree it really helps". A *rebuttal* was taken to be a rejection of a counterclaim, warrant, or evidence that is against a counterargument, which is opposed to the central argument, or an exception to the claim. A counterargument to the GMO report could be: "I disagree with the production of the GMO, because it might be harmful to human health". The rebuttal could be: "So far, there is no scientific research to suggest that eating GMO would be harmful to human health". A *backing* in an argument serves as an established foundation for a warrant that links data and evidence. Due to lack of clarity between an integral nature of warrants and backings, this study regarded combined backings and warrants (Zeidler et al., 2003).

The scoring rubric in Phase 2 of the data analysis was based on established guidelines to address the concern about frequently used checklists for argumentative elements (Author, 2010). Table 1 provides combinations of elements that improve on previous checklists, illustrations drawn from participant' responses, and related scoring values. Claims did not receive any points unless they were connected to another element. Each valid example of a warrant (backing), qualifier, or evidence received a score of one point; each valid rebuttal received a score of two points. The individual scores of each element category and the sum of each score for all element categories were recorded for the S and NS participants and organized for further statistical comparison of the two groups.

Third, the researcher developed an analytic framework that documented the level of critical thinking demonstrated by the participants' written responses in Phase 2 based on those used in other studies (Osborne, Erduran & Simon, 2004; Sadler & Donnelly, 2006; Scholtz et al., 2008; Yu & Yore, 2012). This framework assessed the quality of the participant's critical position and its justification of what to believe or do based on reading and evaluating the science news report. The earlier analysis revealed that all comments contained some argument or counterargument, but it did not fully consider qualifiers for an argument or paired arguments–counterarguments in terms of what to believe or do amongst a set of alternative claims within explicit limits. After identifying different argument elements that appeared in the comments (Phase 2), the researcher categorized participants' plausible

TABLE 1

Scoring framework for the analysis of argument elements

Argument element	*Example*	*Scoring*
Claim with warrants	NS29: I do not support the development of robots [a claim] because robots would result in the loss of jobs for many people [a warrant].	1+1 For a claim and a warrant
Counterclaim with warrants	S12: I disagree with the application of stem cells [a claim] because the stem cells come from human embryo. Using it not only violates the ethical principles, [warrant 1 for the claim] but also breaks the law [warrant 2 for the claim]. However, it is a hope for the people who get genetic diseases [a counterclaim]. It is said that embryonic stem cells can help those who suffer from a neurodegenerative disorder that can cause tremors [a warrant for a counterclaim].	1+1 For a counterclaim and a warrant
Qualifier	NS48: Under an emergency situation, I absolutely [qualifier 1] agree we can eat the kind of unapproved medicine and get a better [qualifier 2] chance to survive.	2 For two qualifiers
Rebuttal	S31: I agree with the application of gene therapy [a claim]. However, most of us ignore the price we pay for it. Especially, many volunteers for human tests sacrifice themselves to make it work. This point is the key for me to opposing the gene therapy [counterclaim]. However, it is worth the sacrifices of the volunteers to help us further understand what gene therapy is [rebuttal 1] and how it works to cure the disease [rebuttal 2].	2+2 For two rebuttals
Evidence	NS16: I disagree to inject the flu vaccine [a claim]. So far, the news has reported that there four cases have existed that have shown side effects after they had been injected the flu vaccine [evidence].	1 For one piece of evidence

S science major, *NS* non-science major

reasoning performance and critical justification indicated in their comments into five ordinal categories with similar levels of critique and evaluation. The five ordinal categories were considered and verified by two science educators specializing in studies of students' higher-order thinking skills.

- Level 1, the lowest level, indicates students could generate only a simple argument (a claim with warrants) OR a counterargument (a counterclaim with warrants) in their comments.

- Level 2 indicates students could generate both an argument and a counterargument OR an argument or counterargument with evidence or a qualifier.
- Level 3 indicates students could construct both an argument and a counterargument with evidence or with at least a qualifier OR an argument or counterargument with both evidence and at least a qualifier.
- Level 4 indicates students could construct both an argument and a counterargument with evidence and at least one qualifier OR with evidence and at least one rebuttal.
- Level 5, the highest level, indicates students could construct a sound argument consisting of an argument, counterargument, evidence, and at least one qualifier and one rebuttal.

For example, an S major claimed he supported stem cells research for growing organs. The warrant was that it might solve the problem about the lack of donated organs. Then he constructed comments about the success rate of stem cells applications as evidence to support his claim. He also generated a counterargument that, if the stem cells came from human embryos, he would disagree with this kind of application since it violated the survival rights of embryos and was a form of murder. There was one qualifier (might be) in his comment. In short, his comments entailed an argument, counterargument, evidence, and one qualifier. Therefore, the quality of critical thinking (critique and evaluation) was judged as Level 4.

The researcher and research assistant examined the summaries (Phase 1) and independently identified the argument elements included in comments (Phase 2). Both raters subsequently scored each comment and judged the quality of the students' critical thinking. A constant-comparison approach and discussions were applied to confirm the agreement between the two raters; the agreement rate reached 87 % (90/104). When disagreement occurred, a third rater (a science education professor with expertise in science learning) was consulted to provide a reliability check on the raters' judgments or to help resolve the discrepant ratings. Descriptive statistics (means and standard deviations) were calculated and summarized for S and NS majors' use of argument elements and the quality of critical thinking. Phase 1 scores were compared through a series of independent *t* tests (Research Question #1). Subsequently, a Chi-square (χ^2) was conducted to examine the percentage differences in the quality of critical thinking across the five ordinal levels for the S and NS groups of students (Research Question #2).

Results

The results that follow describe the general performance and the differences in performance for critique and critical thinking that existed between undergraduate S and NS majors from several Taiwanese universities when reading a self-selected science news report.

Research Question #1. Is There Any Significant Difference in Use of Argument Elements Between Science and Non-science Majors?

The descriptive results of the scoring rubric (see Table 1) for argument elements contained in the participants' comments were reported for S and NS majors to allow easy comparison across the groups. Table 2 shows that NS majors achieved slightly higher average scores in making arguments, counterarguments, and qualifiers than S majors ($4.44 > 4.35$, $1.63 > 1.44$, $1.06 > 0.85$); however, S majors had higher average scores in constructing evidence and rebuttals than NS majors ($2.56 > 1.54$, $1.08 > 0.46$). These results were explored using independent *t*tests for the individual categories and total score. The *t*test analyses revealed nonsignificant difference for arguments, counterarguments, qualifiers, and rebuttals as well as total scores. However, the *t*test of the difference in using evidence revealed a significantly higher average score for S majors compared with the NS majors ($t = -3.23$, $p < 0.01$).

The difference in the scores for formulating evidence encouraged the researchers to further examine the type of evidence students constructed in their comments. Inspection of these results revealed that 15 students (11 NS, 4 S) did not construct any evidence for their arguments, while the

TABLE 2

Descriptive statistics and *t*test results for argument elements and total score by non-science and science majors

Critical thinking skill category	*Non-science majors (n = 52)* Score (SD)	*Science majors (n = 52)* Score (SD)	*t value* (p value)
Claim+warrant	4.44 (2.46)	4.35 (1.71)	0.23 (0.82)
Counterclaim+warrant	1.63 (1.89)	1.44 (1.72)	0.54 (0.59)
Qualifier	1.06 (1.27)	0.85 (0.94)	0.96 (0.34)
Evidence	1.54 (1.70)	2.56 (1.51)	−3.23 (<0.01)
Rebuttal	0.46 (1.02)	1.08 (2.48)	−1.65 (0.10)
Total score	9.13 (4.06)	10.27 (3.84)	−1.46 (0.15)

other 89 students (41 NS, 48 S) constructed some evidence for their arguments. The interesting result was when the students who constructed evidence were considered 61.6 % of the NS ($n = 32$) and 38.5 % of the S majors ($n = 20$) only used the descriptive evidence to support arguments or to rebut counterarguments. Descriptive evidence includes instances, facts, and common or personal experiences. For example, one NS major agreed to discontinue all nuclear power plants in Taiwan; his warrants were: "The safety of nuclear utilities remains doubtful [and] the hazardous nature of nuclear wastes is an unsolved problem". The evidence he provided was that the "recent nuclear disaster that happened in Japan reminds us that we should not rely on nuclear power at all," which was an example of descriptive evidence. However, 17.3 % of NS ($n = 9$) and 53.8 % of S majors ($n = 28$) provided evidence with statistical data to support arguments or rebut counterarguments. For example, one S major agreed with research on stem cells for growing organs. To support her claim, she wrote as evidence: "30 % to 40 % of all approved cases showed the application of stem cells for alleviating the symptoms of Parkinson's disease have been confirmed. One of my friends is the volunteer case of human experimentation". The pattern of evidence use was explored using a χ^2 test to examine the different types of evidence used by the S and NS majors; it revealed a statistically significant difference ($\chi^2 = 15.79$, $p < 0.01$), indicating that NS majors tend to use descriptive evidence more frequently when compared with S majors.

Research Question #2. Is There Any Significant Difference in Quality Level of Critical Thinking Between Science and Non-science Majors in Terms of Analyzing Argument Elements?

The quality of critical thinking for the S and NS majors was determined by their adoption of combinations of argument elements in their comments. The descriptive percentage distributions of the quality levels of critical thinking are summarized in Table 3. Inspection of these results indicates differences in the percentages and skewed distributions of S majors toward the higher levels and NS majors toward the lower levels. The largest proportion (42.3 %) of S majors was in Level 4, while the largest proportion of NS majors (34.6 %) was in Level 3. The difference in distribution patterns was examined using a χ^2; the results revealed that there were significant differences ($\chi^2 = 10.74$, $p < 0.05$) between NS and S majors' critical thinking performance. This result favored S over NS majors in that the majority of S majors demonstrated higher levels of critical thinking—they were in Levels 3, 4, and 5, while the majority of

TABLE 3

Quality level of critical thinking of non-science and science majors and percentage and number of students

Quality level of critical thinking	*Non-science majors (n = 52), % (n)*	*Science majors (n = 52), % (n)*
1	5.8 % (3)	7.7 % (4)
2	30.8 % (16)	17.3 % (9)
3	34.6 % (18)	26.9 % (14)
4	15.4 % (8)	42.3 % (22)
5	13.4 % (7)	5.8 % (3)

NS majors demonstrated lower levels of critical thinking—they were in Levels 1, 2, and 3. The biggest difference (26.9 %) was at Level 4 where students adopted five argument elements in their comments, which must include evidence.

For example, one S major student said:
If my house was located far from the power lines, I probably would agree that the effect of radiation from power lines on human health is harmless. [Q + CA] However, previous research told us that for people staying in the environment with low frequency electromagnetic radiation for a longer time, 40 % of them felt tired and uncomfortable. [E] I believe it is true. So, I do not accept this report that said radiation from power lines is harmless to human health. [A]

The student's comment included an argument, a counterargument, a qualifier, and statistical evidence. The quality of critical thinking was categorized as Level 4. Another example, one NS major student wrote:

I think that using mobile phones is harmless to our health, because so far I have not yet heard about who gets hurt when they use it. [A] However, this report said that the negative health effects of incessant mobile phone usage, such as brain damage and irregular sleep patterns appeared in pre-teens. [E] About this point, I just wonder how long we can define "incessant"? Ten minutes, one hour or much longer? [R]

This response contained an argument, descriptive evidence, and a rebuttal. Therefore, the quality of critical thinking was categorized as Level 3.

Discussion and Implications

This study revealed that there were significant differences between S and NS majors in their performance of critical thinking skills in the context of reading science news reports of their choice. The differences were most noticeable in use of evidence that supported their arguments or rebutted the arguments in the reports. Further exploration of the type of evidence (descriptive or statistical) revealed that S majors used significantly more statistical evidential comments than did the NS majors.

These results may indicate that these two groups of students have different argumentative knowledge—particularly the knowledge about empirical evidence, which is the hallmark of the natural sciences tradition. The more knowledge about evidence the students have, the more likely they are able to use evidence in their comments (Schalk et al., 2013). Therefore, this finding is not only comforting, but it is reasonable to assume that awareness and use of evidence were an implicit or explicit part of these senior students' university science programs. Furthermore, it is refreshing to find this disposition toward and proficiency with empirical evidence since most of these S majors will become scientists or other science-oriented professionals in the near future. They not only experience more experimental courses in science stressing numeric and empirical evidence but also have more chances to construct empirical arguments, analyze scientific data to warrant these data as evidence, and to make evidence-based claims. Hence, the S majors significantly outperformed the NS majors in using argument elements—evidence—in critical thinking and critiques. Relatively, fewer NS majors formulated or used evidence as well as S majors under the unprompted task conditions. It is possible that NS majors had fewer experiences in their university programs to use statistical evidence in making evidence-based arguments but might do so if prompted. However, the NS majors performed similar to the S majors in some argumentation elements (i.e., argument, counterargument, qualifier, and rebuttal), which likely reflects the argument traditions and their experiences in the arts, humanities, and social sciences. Likewise, students' domain-specific argumentation traditions might explain another significant difference in which more S majors could integrate more argument elements into their justifications, which must include evidence, than NS majors did in their justifications. Level 4 of critical thinking quality represents students and critiques that justified, verified, or conditioned their claims and counterclaims with qualifiers and rebuttals. Most importantly, they were able to use evidence in support of their own arguments or in opposition to arguments that appeared in the reports.

The students' content knowledge about the focus topic in the science news reports may have partly contributed to the performance differences between the S and NS majors. Free-choice science news reports were used in this study to minimize the content knowledge influence on critique, evaluation, and critical thinking performance. It was assumed that all participants would select a science news report that they were interested in and had some background knowledge about. Sadler & Fowler (2006) found that S majors outperformed NS majors in argumentation quality about socioscientific context dealing with genetic engineering because S majors had more background knowledge about the target ideas, which is regarded as a necessary condition for someone to evaluate critically the content of texts (McClune & Jarman, 2012). Bråten et al. (2011) indicated that undergraduate students with more knowledge about climate change could use more and deeper criteria to critically evaluate the scientific information. We believed that most students participating in this study were equipped with some knowledge about the target ideas and that they tended to choose an article they were interested in and could understand the contents in order to analyze the reporter's claim and provide a detailed rationale for their decision. The NS majors, compared with the S majors, may have had a relatively insufficient knowledge base about the target idea in the news report, which to some extent negatively influenced their critique in their JVR.

Implications for Postsecondary Science Education Programs

Critiquing and evaluating the veracity of the arguments, claims, warrants, evidence, counterclaims, and rebuttals in a science news report are fundamental expectations of scientifically literate citizens in today's world (Yore, 2012). All of the students in this study demonstrated their scientific literacy to some degree, especially their critical thinking proficiency in terms of argumentation skills when reading self-selected, science-related news. However, significant differences existed in formulating evidence and the proportion in levels of critical thinking between the two groups. Moreover, 15 students (11 NS, 4 S) did not use or formulate any evidence to support their arguments or rebut the arguments in the news reports. This result seems to show that some students had weak ability to integrate more argument elements so as to make relatively sound, evidence-based arguments while critically reading text about socioscientific issues. Many socioscientific issues that citizens must consider are composed of an integrated mixture of sociopolitical, socioeconomic, and socioscientific dimensions involving science, technology, society, and environment factors. Therefore, it would be useful for the general–liberal component of postsecondary education to engage a broad range of argument traditions from the arts, humanities, and sciences. Particularly through the design of interdisciplinary courses, teachers can lead students to explicitly practice argumentation and critical thinking skills in the context of reading science news. It will be beneficial for equipping students with abilities to address a variety of socioscientific issues.

Barker & Julien (2012) stated, "The culture of science expects members to use peer-reviewed published work whether it be electronic or print scientific journals. The peer-review process provides a quality control that verifies research methodologies, results, and conclusions, and the use of findings as evidence" (p. 19). However, this level of quality assurance is not afforded in media reports about science, and students do not use the same peer-reviewed sources as their information for building understanding and writing reports. They continued:

> Here is an example of students accepting knowledge without question because of unconditional trust in textbooks, in the teachers, or in both. (p. 23) … Reading as a task is unlikely to develop critical thinking skills and a science inquiry approach using content analysis [, such as required in this study,] helps students really differentiate between facts, myths, and values and thus read for evidence. (p. 37)

Therefore, explicit critical reading instruction and tasks should be part of any general–liberal education. Moreover, it is important to enhance university students' understandings of the nature of science and the concept of evidence in order to improve the quality of their critical thinking and argumentation. The modern evaluativist naïve realist view of science places inquiry, argument, and evidence as central in doing and understanding the scientific enterprise (Yore, Hand & Florence, 2004). The concept of evidence is complex and entails a wide range of related concepts, which include reliability and validity of data, experimental design and data collection, interpretation and representation of evidence, and evaluation criteria for evidence (Inch & Warnick, 2010). The science practices and knowledge about evidence, argument, and critique not only need to be embedded in authentic contexts to learn but also need explicit instruction on a just-in-time basis as students encounter difficulties and need to know as a central part of the foundational courses in a postsecondary science program (NRC, 2012).

Limitations of the Study and Future Research

Several limitations of this study need to be addressed. First, the extent of the students' prior knowledge about the science news report of their choice and their argumentative knowledge leading them to make evidenced-arguments were not ascertained in this study. Previous studies have confirmed that both types of knowledge influence students' performance on critical thinking or argumentation. Especially if students are more familiar with the nature and utility of evidence, they could generate better evidence-based arguments (Schalk et al., 2013; Tytler & Peterson, 2004). Therefore, two unexplored questions arise:

1. What do undergraduate students with different majors understand about the nature of evidence?
2. How do they make use of evidence to support or rebut arguments?

Few studies have explored the extent of university students' understanding of the concept of evidence, where they may have acquired such understanding, and how they could be equipped to construct empirical evidence and compelling arguments and counterarguments. There is need for further studies into improving university students' critical thinking and argumentation in terms of helping them address argumentation bias, constructing more precise knowledge about evidence, and formulating persuasive, empirically based arguments.

Second, taking the voluntary willingness of participants into consideration, this study asked the participants to choose only one science news report to read and then to make comments in order to keep the time and effort demands reasonable. This might have limited their performance on critical thinking and argumentation and the reliability of documenting these qualities. Hence, follow-up studies may engage students in more science news reports, which include their own and researcher selections. Comparing the differences in university students' ability to critically read self-selected and common texts or genre will help to gain deeper understanding of their critical thinking ability to deal with scientific or socioscientific information.

Third, the study explored undergraduate students' critical thinking ability, especially focusing on evaluating arguments that appeared in self-selected texts from Internet sources. This is of particular importance when someone searches for information on the Internet (Brand-Gruwel & Stadtler, 2011). However, the ability to evaluate information involves several aspects: being able to define the problem, search and select reliable sources and information, interpret the target information, and integrate information into a comprehensible, consistent, and usable body of knowledge (Brand-Gruwel & Stadtler, 2011). This ever-increasing task and complex process need further exploration to document the dynamic relationship amongst these abilities or to survey students' weaknesses in order to find ways to improve their critical reading of science news reports.

Finally, increased reliance on ICT and digital information sources requires that users are both scientifically literate and critical readers. Unfortunately, little is known about how people locate, assess, and use different information sources about science (Barker & Julien, 2012). Contemporary media reports about science and socioscientific issues are high-interest, authentic contexts for engaging students critically with challenges about what to believe or do (Ford & Yore, 2012; McClune & Jarman, 2012). Reading, analyzing, and critiquing science news reports can provide relevant setting and opportunities for teachers to scaffold students' declarative and procedural knowledge about evidence and further develop their evaluation criteria of evidence and practice formulating evidence. However, research is needed to determine how people read for evidence and make sense of the JVR genre and construct understanding and justification of what to believe or do about the target ideas (Norris, 2012).

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