Journal of Geography

ISSN: 0022-1341 (Print) 1752-6868 (Online) Journal homepage: www.tandfonline.com/journals/rjog20

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To cite this article: Xiaowei Xuan, Qingna Jin, Injeong Jo, Yushan Duan & Mijung Kim (2019) The Potential Contribution of Geography Curriculum to Scientific Literacy, Journal of Geography, 118:5, 185-196, DOI: 10.1080/00221341.2019.1611906

To link to this article: https://doi.org/10.1080/00221341.2019.1611906

Published online: 23 May 2019.

The Potential Contribution of Geography Curriculum to Scientific Literacy

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Abstract

Few studies, if any, have systematically investigated the connection or relationship between geography curriculum and scientific literacy. With this realization, in this article, we examined the potential contribution of geography curriculum to developing students' scientific literacy, with China's middle-school geography curriculum as an example. Through content analysis and semi-structured interviews, we found that geography curriculum holds significant potential to develop scientific literacy, especially regarding interpreting data in various formats, scientific reasoning, and interrelationships among science, technology, society, and environment. This study could provide insights for educators to design interdisciplinary programs to develop students' scientific literacy.

Key Words: *geography curriculum, scientific literacy, middle-school level*

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Introduction

Geography connects students to world events, problems, and decisions throughout their lives and, "when taught well, makes a fundamental contribution to the education of all children and young people, promoting the development of citizenship" (IGU-CGE 2015, 1). Through geography education, students "learn how to use geographic thinking and information to make well-reasoned decisions and to solve personal and community problems" (Heffron 2012, 44). However, in many regions around the world, geography, as a school subject, has had insufficient attention paid to it (Bednarz, Heffron, and Solem 2014; Brysch 2014; Lambert and Hopkin 2014; Solem and Tani 2017). For example, in the United States, "geography remains a named core academic subject with no dedicated federal funding stream" (Brysch 2014, vi). In England, geography was placed in the national curriculum; however, this place has been constantly contested (Lambert and Hopkin 2014). In other countries, such as India, formal geography education is generally neglected in schools (Solem and Tani 2017). Similarly, in China, geography is deemed a school subject with a lower status in the curriculum hierarchy.

Some scholars (e.g., Brysch 2014; Oldakowski and Johnson 2018) have argued that the decade-plus emphasis on science, technology, engineering, and math (STEM) might explain the inhibited teaching and learning of geography. In schools, subjects like geography that are not explicitly related to STEM need to compete for classroom time and attention as an independent school subject. Because much curriculum content in geography and STEM subjects, especially science, overlaps (Gillette 2015), it might be beneficial for those wishing to improve geographic education in schools to examine the possibilities of an interdisciplinary approach rather than pursuing science and geography as separate school subjects (IGU-CGE 2015; Oldakowski and Johnson 2018; Oyana et al. 2015). Many empirical studies implementing an interdisciplinary curriculum of geography and science have shown positive results in regard to students' learning (e.g., Eidietis and Rutherford 2009; Florentina and Barbu 2015; Grubbs and Grubbs 2015; Oldakowski and Johnson 2018). Usually, these studies reported improvement in students' learning around certain topics (e.g., climate change and sea-level rise) when interdisciplinary approaches were adopted in classroom teaching and learning. Few studies, if any, have specifically and systematically examined the connections between geography curriculum and science or other STEM subjects. Evaluating to what extent and on what aspects (e.g., knowledge of physical geography, skills in map reading, and spatial thinking) there is a connection between geography curriculum and other subjects would yield valuable information. This could be used to help design appropriate interdisciplinary programs to facilitate students' learning, as well as to define the orientation of geography in education, especially at the K–12 level (e.g., whether or not integrating geographical knowledge, skills, and perspectives with STEM subjects is feasible or meaningful for the further development of the subject).

Recognizing the importance of investigating connections between geography curriculum and the broader STEM education, in this study, we examined the relationship between geography and science, a critical component of STEM. We decided to closely examine the geography curriculum through the lens of scientific literacy, which is the desired general outcome of learning science (Holbrook and Rannikmae 2009; McEneaney 2003; UNESCO 1994) and one of the goals of STEM education (NRC 2011). Our research objective was to explore the potential contribution of geography to developing and enhancing students' scientific literacy.

To conduct the specific analysis, we chose China's middle-school (grade 7 to 9) geography curriculum. In the elementary grades (1 to 6) in China, geography is integrated with science and social studies (the title of this course is sometimes translated into Morality and Society) instead of being a stand-alone subject. At the middle-school level, geography is studied as an individual subject and is mandatory for all students. China makes a good example because this positioning of geography in school curricula is quite common around the world, including in Sweden, Finland, the Netherlands, some states in Germany, and the United States (Bednarz, Heffron, and Solem 2014; Solem and Tani 2017). Moreover, even if we acknowledge that political, cultural, social, and philosophical traditions shape geography education significantly (Butt and Lambert 2014; Solem and Tani 2017), geography as a discipline is concerned with a body of knowledge and skills that are common around the globe (Butt and Lambert 2014). Therefore, even though we specifically examined China's geography curriculum, the insights gained through our analysis have potential significance in other jurisdictions as well.

Our research purpose in this study was to explore the potential contribution of China's middle-school geography curriculum to developing students' scientific literacy. In this article, we begin by describing the framework of scientific literacy, followed by the research methodology and methods in this study. After then discussing our findings, we draw conclusions, noting some limitations and the application of the study.

Research Design

A content analysis of the geography curriculum, plus interviews conducted with geography and/or science educators, were used as data sources. First, we developed a definition framework of scientific literacy that was then used as the coding scheme for our content analysis and then conducted interviews to gather additional information.

Analysis Through the Lens of Scientific Literacy

UNESCO suggested that scientific literacy is "a universal requirement if people are not to be alienated in some degree from the society in which they live, if they are not to be overwhelmed and demoralized by change" (UNESCO 1994, 9). Scientific literacy has become the general goal of both science education and the broader STEM education. Since the term was proposed in the 1950s, it has encompassed many different concepts and interpretations (Laugksch 2000; DeBoer 2000; Boujaoude 2002; McEneaney 2003; Dillon 2009; Holbrook and Rannikmae 2009). Therefore, it is impossible to form a framework of scientific literacy on which all researchers agree.

A definition framework of scientific literacy was developed by integrating the framework found in early literature, including both the seminal works (e.g., AAAS 1993; Chiappetta, Fillman, and Sethna 1991; Chiappetta, Sethna, and Fillman 1993; NRC 1996; Yager 2000; Boujaoude 2002) and more recent attempts (e.g., Bybee and McCrae 2011; OECD 2017). The definitional framework of scientific literacy in this study includes four domains: (1) knowledge, (2) inquiry process, (3) application and connection, and (4) values and attitudes, covering elements shared among various definitions and frameworks of scientific literacy. The knowledge domain refers to facts, concepts, principles, laws, hypotheses, theories, and models of science necessary for a scientifically literate individual (AAAS 1993; Chiappetta et al. 1993; NRC 1996; Boujaoude 2002; OECD 2017). The second domain, inquiry process, was generated through combining "the investigative nature of science" and "science as a way of knowing," which were proposed by Chiappetta et al (1991, 1993) and further developed by Boujaoude (2002); it refers to not only the skills and methods involved in scientific inquiry (e.g., observing, measuring, classifying, and experimenting) (AAAS 1993; NRC 1996; Yager 2000) but also the abilities to analyze and evaluate data in a variety of representations, draw appropriate scientific conclusions, and to evaluate and design scientific inquiry (OECD 2017). Application and connection, as the third domain, refers to both the interaction of science, technology, society, and environment (e.g., Chiappetta et al 1991, 1993; NRC 1996; Yager 2000) and the personal use of science (Yager 2000; OECD 2017).The fourth and final domain, values and attitudes, includes all the aspects related to world view, emotion, motivation, personal interest, and moral and ethical issues (e.g., Chiappetta et al 1991, 1993; Yager 2000; Boujaoude 2002; Bybee and McCrae 2011).

We utilized this framework to perform the content analysis, that in turn helped us to further revise and finalize the framework (Table 1). In particular, during the analysis, we found it necessary to distinguish different subcomponents of the process of scientific inquiry because much curriculum content was related to the

Table 1. The finalized framework of scientific literacy.

Domains	Components	Subcomponents (if applicable)
Knowledge	A. Scientific concepts, principles, laws, hypotheses, theories, and models of science	
Inquiry process	B. The exploring and discovering process of science inquiry	B-1. Observing, classifying, hypothesizing, and experimenting, etc. B-2. Recording and interpreting data in various formats (e.g., texts, graphs, tables, and charts) B-3. Scientific reasoning B-4. Evaluating scientific inquiry
Application & connection	C. Interrelationships among science, technology, society, and environment (STSE)	
	D. Personal use of science to make everyday decisions, solve everyday problems, and improve one's life	
Values & attitudes	E. Science-related moral and ethical issues	
	F. Interest in science and technology	

scientific inquiry process yet focused on specific subcomponents of it, such as scientific reasoning and hands-on experimentation. With this framework, we attempted to represent the general goals of science education as well as some of the goals of STEM education.

Content Analysis

Content analysis is a qualitative research technique widely used in the social sciences and humanities (Hsieh and Shannon 2005), especially for analyzing textual data (Cavanagh 1997). In this study, we adopted this method to analyze the geography curriculum standard.

In China, curriculum standards are the most important and direct guidelines for teaching and learning all school subjects; they stipulate the curriculum ideas, goals, content, implementation procedures, and evaluation methods (Chen and Lin 2012). All textbooks and other curriculum resources are also developed according to these standards. Schools might have different class hours and use different textbooks and teachers might adopt varied teaching approaches, but every classroom follows the same national curriculum standard. In this study, therefore, as a written representation of geography education in China, the National Geography Curriculum Standard for Middle School (Ministry of Education of People's Republic of China 2011) was the main research material analyzed from the perspective of scientific literacy.

According to the curriculum standard, middle-school geography includes the following four units: The Earth and Maps, World Geography, Chinese Geography, and Local Geography. Each unit also has several topics (Table 2) with specific learning objectives (LOs) explaining the cognitive and knowledge outcomes that students are supposed to attain through learning this topic. Since these LOs "reflect and present the general geography curriculum" (Chen and Lin 2012, 75), they were coded with the previously discussed scientific literacy framework.

Coding Process and Interrater Reliability

The first two authors coded the LOs with the scientific literacy framework developed in this study. Each LO that related to one or more aspects of scientific literacy was assigned the corresponding code(s). For example, LO #24: *With a certain region as an example, through reading maps and analyzing other data, explain the impact of climate on the industrial production and people's lives.* The two coders agreed that this LO involved *recording and interpreting data in various formats* (B-2) because students were required to read maps and analyze other kinds of data, *scientific reasoning* (B-3) because students were asked to explain the (causal) relations among geographical elements, and *interrelationships among STSE* (C) because both environmental (i.e., the climate) and social aspects (i.e., industrial production and people's lives) were involved. Thus, this single LO was coded as B-2, B-3, and C. The majority of the LOs were assigned two or more codes because most LOs indicated both *what* (e.g., component A, C, D, and E in the scientific literacy framework) and *how* (e.g., component B-1, B-2, and B-3 in the scientific literacy framework) students were supposed to learn in the geography classes. During the analysis, we also found that some LOs (6 out of 100 LOs) were incapable of reflecting any component of scientific literacy. We coded these ones as Null.

To establish the reliability and validity of the coding process, the first two authors independently coded a sample of randomly chosen LOs (20%) and then compared their coding results and discussed their initial coding strategies. This process allowed them to share coding strategies in order to code the remaining LOs separately. Both the percentage agreement (81.6%; 60% for coding the random samples) and the kappa value (0.777; calculated with SPSS 23.0), which were calculated before the

Table 2. Middle school geography curriculum content in China (grade 7 to 9).

Unit	Topic	Number of learning objectives (100 in total)
The earth and maps	The earth & globe	6
	Maps	5
World geography	Oceans & land	4
	Climate	9
	Residents	8
	Differences in regional development	3
	Selected focus regions	19
Chinese geography	Territory & population	6
	Natural environment & natural resources	9
	Economy & culture	6
	Regional differences	3
	Selected focus regions	16
Local geography	——	6

final consensus was reached, suggested the coding results were reliable and could be used in this study.

After the reliability was confirmed, the coding discrepancy between the two coders was discussed to ensure that the final coding was consistent according to the coding schemes and coding strategies. Most of the disagreements were from deciding whether a LO should be coded as B-2 or/and B-3. According to its broad definition, scientific reasoning "includes the thinking skills involved in inquiry, experimentation, evidence evaluation, inference and argumentation that are done in the service of conceptual change or scientific understanding" and these skills support the formation and modification of concepts and theories about the natural and social worlds (Zimmerman 2005, 1). In other words, according to scholars in the field of scientific reasoning (e.g., Duschl and Osborne 2002; Sandoval and Reiser 2004; Zembal-Saul 2009), students' scientific reasoning usually involves, but is not limited to, interpreting data to generate evidence and then make some cause–effect arguments or statements. Thus, seen from this perspective, interpreting data could be seen as a part of scientific reasoning. However, during the coding process, we found that many LOs particularly focused on the demand for students to interpret data (e.g., LO #25: Describe and summarize the characteristics of world population growth and distribution through reading maps and other materials), while others required students to further explain the reasons for certain phenomena after interpreting data (e.g., LO #37: Take a certain continent for example, through reading maps and analyzing other data, describe and summarize the characteristics of its landform, climate, and water resource distribution, and then explain their interrelationships). To distinguish these LOs, after intense discussion, we decided to take *data interpretation* out of *scientific reasoning* as a separate subcomponent. Thus, *scientific reasoning* in our framework (as shown in Table 1) mainly refers to generating or constructing causal explanations. With this criterion, the aforementioned two examples (LO #25 and #37) were coded as B-2 and B-2 and B-3, respectively, in terms of *how* students were supposed to learn. After consensus was achieved on the coding results, we statistically analyzed these results to present our findings, that is, to assess the contribution of geography curriculum to facilitating students' scientific literacy (Table 3).

Interviews with Geography and/or Science Educators

Analyzing the curriculum standard, the written representation of the intended curriculum, provided valuable information. However, with the objective being to gain a more comprehensive understanding of the relations between geography curriculum and scientific literacy, it was also necessary to learn how the written curriculum was implemented in classrooms. Thus, besides the content analysis, we also adopted interviews as another method to gather supplementary data. Purposeful sampling was employed for the interviewee inclusion in this study (Merriam 1998). To be specific, snowball sampling was adopted (Morse 2004), which is a technique "for gathering research subjects through the identification of an initial subject who is used to provide the names of other actors" (Atkinson and Flint 2004, 2). We interviewed five geography teachers and one science teacher teaching in middle schools (grade 7 to 9). These six teachers (five female and one male) had various teaching experience ranging from 3 to 25 years. Besides these teachers, we also interviewed six professors working in the fields of science and/or geography education (one in science education, two in science and geography education, and three in geography education) and two geography-teaching instructors. Taking into account the small sample size of the interviewees, we acknowledge that it

Table 3. Results of the content analysis: The number of relevant LOs for each component and subcomponent of scientific literacy.

	B							
A	**B-1**	**B-2**	**B-3**	**B-4**	**C**	**D**	**E**	**F**
54	3	53	34	0	12	2	2	0

Note: The total number of the LOs in the curriculum standard is 100, so the number of the relevant LOs for each component and subcomponent of scientific literacy shown in this table is also its percentage.

was not justifiable or appropriate to generalize the interpretation of these interviews into a broader context. Data from these interviews were supplementary data aimed at enriching the findings from the content analysis.

For consistency, all the interviewees were interviewed individually by the first author. Each interview started with a "getting-to-know-you" part (Ellis 2006, 119), which aimed to gain basic and background information about the educators, for example, educational and pedagogical beliefs, thoughts about geography and geography education, as well as ideas about science, development of science and STEM education. Information gained from this part was helpful for the authors to interpret what interviewees shared more holistically (Ellis 2006). The interviewees were then invited to share what and how they thought regarding the potential contribution of learning geography to the development of scientific literacy in terms of the six components (A through F) of scientific literacy evaluated in this study. Thus, the scientific literacy framework we developed in this study, as well as the results of the aforementioned coding process, were shared with the interviewees. We acknowledged that showing them the framework, as well as our coding results, would cause certain bias. This was one of the limitations of this study that we acknowledge and discuss at the end of this article. To minimize the bias caused by our framework (Kvale 1996), the interviewees, especially the school teachers, had been reassured that they should not feel compelled to agree with the framework. The interviewer, when she showed the interviewees these pieces of our work, especially the scientific literacy framework, paid great attention to the language she used to avoid them thinking that the framework was "the" definition of scientific literacy, as she introduced the coexistence of various definitions and interpretations of scientific literacy in the academic literature (McEneaney 2003). Interviewees' ideas about the framework were also asked, such as anything they thought as critical to scientific literacy yet missing in the framework. Moreover, the interviewer also explicitly explained to the interviewees that their experiences and ideas were what we appreciated in this study. During the interviews, middle-school teachers were also invited to share related experiences in their teaching practice, such as the attempts they had tried to facilitate any aspect of scientific literacy through geography teaching and any challenge they had met. Each interview lasted 1 to 2 hours and was conducted entirely in Mandarin Chinese. All the interviews were audiotaped and then transcribed verbatim and coded by theme.

Research Findings

Through the content analysis of the curriculum standard and the interviews, we found that the Chinese middle-school geography curriculum had significant potential to develop students' scientific literacy, especially in terms of scientific inquiry (component B). In what follows, we present the results of our content analysis (see Table 3), followed by the findings regarding each component and subcomponent of scientific literacy.

Through the content analysis, among the 100 LOs in the curriculum standard, 94 were assigned one or more codes (A to E); no LOs were coded F, and 6 were considered not relevant to any of the four domains of scientific literacy. With the 94 coded LOs, we had 160 coding results in total.

Knowledge in Scientific Literacy

A: Scientific concepts, principles, laws, hypotheses, theories, and models of science

Our content analysis of China's middle-school geography curriculum showed the *knowledge* domain of scientific literacy received 54 coding results. In other words, 54 LOs contained knowledge that could be coded as *scientific concepts, principles, laws, hypotheses, theories, and models of science* (component A). As discussed previously, almost every LO would indicate specific demands for students regarding both knowledge and cognition (Lee et al. 2016), that is, *what* and *how* students need to learn. This domain of scientific literacy was about the *what* aspect specifically. Around half of the knowledge that students were supposed to learn in their geography classes was coded as belonging to the knowledge domain and pertained to Earth science and physical geography. The rest was knowledge of, for example, human geography or cultural geography.

Inquiry Process in Scientific Literacy

Different from the *knowledge* domain (component A), the second domain *inquiry process* (component B), was about *how* students are supposed to learn. During our coding process, we divided component B into four specific subcomponents that often occur sequentially: *observing, classifying, hypothesizing, and experimenting, etc.* (B1); *recording and interpreting data in various formats* (B2); *scientific reasoning* (B3); and *evaluating science inquiry* (B4).

B-1: Observing, classifying, hypothesizing, and experimenting

Only 3 LOs involved *observing, classifying, hypothesizing, and experimenting* (B-1). This was not surprising given that geography, compared with other science subjects such as chemistry or physics, offers relatively fewer chances for students to do hands-on experiments. Nevertheless, during the interviews, one of the geography-teacher educators mentioned that students might have more opportunities to participate in hands-on activities than what our content analysis suggested, because "school geography teachers are encouraged to design activities to engage students in the inquiry process, even though this is not required in the curriculum document." This was confirmed during the interviews with middle-school geography teachers. When they were invited to share something that they thought was interesting and related to any aspect of scientific literacy during their geography teaching, they mentioned some experience about students' hands-on activities that were not required or stated in the curriculum document and were therefore not represented in our percentages. For example, one teacher shared with us that, to achieve LO #16: be able to distinguish weather from climate and use these terms appropriately, which we had coded only as A, she would encourage her students to observe and record the temperature, precipitation, and wind (both the direction and strength) for a certain time period. Therefore, the geography curriculum might have more influence on this aspect (B-1) in practice, even though the percentage derived from the content analysis was very low.

B-2: Recording and interpreting data in various formats

Among all the subcomponents of scientific inquiry, *recording and interpreting data in various formats* (B-2) had the highest percentage: 53% of the LOs involved this aspect, especially *data interpretation*. In other words, around half of the curriculum objectives indicated that students would learn geographical knowledge (either physical, human, or cultural geography or Earth science) by interpreting and analyzing various kinds of data. Our further examination revealed that these LOs targeted students' abilities of data interpretation mainly through map reading. By providing students opportunities to read and use maps, geography curriculum therefore has the potential to facilitate their ability to interpret data (Chen and Lin 2012), which is a key component of scientific literacy. Almost all the interviewees acknowledged the positive influence of map reading on students' data interpretation abilities and thus their scientific literacy. What follows is a representative episode in which a geography teacher shared how he thought about map reading:

> … the ability to read and use maps is essential for citizens who live in both the current and the future society. This ability will help people make informed decisions, including science-related ones. Maps are an important way to represent data in geography, and students' ability to interpret and understand the data shown in maps is a goal and responsibility of the geography education in school … exposing students to the practice of reading and using maps, which is frequent in school geography teaching and learning, benefits their ability to interpret data …. Using maps as tools could be one of the advantages of geography in facilitating students' scientific literacy.

Nevertheless, some concerns around map reading in geography teaching and learning were also raised, such as the lack of an appropriate evaluation system and a disconnect between map reading in the classroom and in everyday life. As a professor in geography education mentioned, "in map teaching and learning, a hierarchical evaluation system is necessary which could be used to appropriately evaluate students' abilities of reading and using maps. It would be helpful to make the map teaching and learning more effective." Moreover, geography teachers also expressed some struggles, such as "what we need to teach [in class] is mainly reading the paper-based or printed maps, because that is how the map reading is assessed [in some significant examinations] … however, in real life, few people would read a printed map …." The lack of the connection with the everyday life would make both teachers and students less motivated to learn and practice reading and using maps, which is a significant part of geography education.

B-3: Scientific reasoning

We coded 34 LOs as *scientific reasoning* (B-3), indicating that students need to learn geography through scientific reasoning. As discussed previously, these LOs mainly focused on the demand for students to identify causal relationships or interrelationships and construct explanations with examples as evidence, not only for natural but also social phenomena. Most of the LOs involving scientific reasoning were under the topic of Selected Focus Regions in both World Geography and Chinese Geography (see Table 2). After students learned, for example, the characteristics of the landforms and climate of certain regions, as well as the distribution of population, water, and other resources in these regions, they would be able to analyze and explore the causal relationships among these geographical elements and explain certain phenomena. For example, LO #53, which was next to the last in the fifth topic within Chinese Geography (i.e., Selected Focus Regions), required students to be able to explain with examples how the natural environment (such as climate and landforms) impacts the local customs in certain regions. With this specific LO, students were supposed to construct an explanation of geographical facts related to cause and effect (Claval 2015); therefore, scientific reasoning was involved. Interviews with the geography educators confirmed both the existence and importance of scientific reasoning in geography learning, as the following interview transcript excerpts demonstrate:

> Geography is a subject about 'place.'… Sometimes, the location and features of a place could influence … how people in this place interact with the environment and other places … Students are usually required and encouraged to explore this kind of causal relationship during their geography learning … human being's activities significantly influence the environment in return … this is the other part of the causal relationship. Human being and the place or the environment are more like interacting as both cause and effect. That reciprocal causal relationship is the core of geography education.

> It [scientific reasoning involving causal relationships] helps students understand the interactions of geographic elements in analyzing geographic causes …. Compared to science subjects [such as physics, biology], cause and effect relationships are more complicated in geography, because there usually are multiple variables that need to be considered.

However, regarding the development of scientific reasoning based on the topics of Selected Focus Regions, which contains examples of causal relationship, interviewees also expressed concerns. For example, one professor in geography education emphasized the significance of the transferability of students' ability in scientific reasoning from the selected focus regions to other regions. He mentioned that the ultimate goal of the geography curriculum in this regard is:

> to achieve the transferability of students' abilities of scientific reasoning or analyzing the causal relationship from these certain examples to other areas, such as the places where students live … however, in actual pedagogical practice, the transferability, which should be the emphasis, is always neglected …

This concern was about scientific reasoning as well as the connection to students' personal and everyday lives, which is discussed in detail later in this article.

B-4: Evaluating science inquiry

Regarding the aspect of *evaluating science inquiry* (B-4), no relevant LO was identified in the written geography curriculum. Interviews with the teachers also indicated that they seldom engaged their students in this kind of process. Teacher interviewees mentioned their reasons for and struggles with this, such as "class time is so limited and … lots of content needs to be covered," "to be honest, I am not quite clear and confident about evaluating science inquiry … " and "if there were some materials for the teachers, such as detailed evaluation rubrics for evaluating this ability, that would be very helpful for our pedagogical practice related to this."

Application and connection in scientific literacy

C: Interrelationships among science, technology, society, and environment (STSE)

We coded 12 LOs as relevant to component C: *interrelationships among science, technology, society, and environment (STSE)*, which is also about the *what* aspect instead of the *how*. Among all these 12 LOs, nine were also coded as B-3 at the same time, with the other three coded as B-2. In other words, according to the curriculum standard, students are usually supposed to learn or understand the interrelationships among STSEs through the practice of scientific reasoning. Even though this component took a small portion (12 out of 100 LOs), interviewees in this study emphasized its importance in geography education. One teacher shared with us that "focusing on the interaction or interrelationship between various geography elements is the core of geography teaching and learning." Geography is a subject exploring both the physical properties of Earth's surface and the human societies spread across it. The goals of the geography curriculum include developing students' understanding of places and the relationships between people and their environments. These features of geography as both a subject and the geography education practice in schools could explain why teachers thought this was significant. However, during the interviews, some educators also expressed their concerns regarding the potential of the geography curriculum to develop students' understanding of the interrelations among STSEs. In particular, they mentioned and emphasized that how much the geography curriculum could contribute to STSE depended on the teachers' teaching methods:

> The interrelations among these elements are abstract, so students cannot observe them directly in most cases. If teachers

> teach these abstract interactions at a theoretical level without using examples students are familiar with, it is almost impossible for students to really understand these complicated interrelations. On the contrary, if teachers utilize daily geographical phenomena as teaching and learning resources, students will not only get a better understanding of the place where they live but will also comprehend these interrelations more easily. For example, teachers in the mountainous areas of southern China could encourage their students to explore topics like "Why does a lot of bamboo grow in our hometown, instead of wood forests?"

D: Personal use of science to make everyday decisions, solve everyday problems, and improve one's life

At the beginning of the curriculum standard, five main characteristics of China's middle school geography curriculum were clearly stated. One of them was the connection with everyday life: "The content of the mandatory middle school geography curriculum is closely connected with students' everyday lives; geographical phenomena and problems that student might come across in their daily lives are included and explored" (Ministry of Education of People's Republic of China 2011, 2). Therefore, it was surprising to find a very low percentage of this aspect (2%). Only two LOs were about the place where students and teachers lived. Therefore, even though the local context was emphasized in the curriculum document, for example, in the statement of the main characteristics and goals of the curriculum, it was not well-represented in the specific LOs. Moreover, during the interviews, some geography teachers expressed that they had limited access to the curriculum resources that supported teaching and learning the geography of their own locality.

> Materials that we can use to teach the local geography are limited in the curriculum resources provided alongside the textbooks. Many provinces are using the same textbooks. … It is impossible for the textbook publisher to develop various versions of curriculum materials suitable for different places. … It is also hard to search online for the relevant curriculum resources specifically about the locality. … This is the most challenging aspect I found for teaching this part, I mean … you need to develop the resources all by yourself.

Values and Attitudes in Scientific Literacy

The *values and attitudes* domain in scientific literacy was only slightly represented in China's middle-school geography curriculum. Its two specific components (E and F) had two and zero relevant LOs respectively.

E: Science-related moral and ethical issues

Environmental ethics is the extension of human ethics to the natural environment, and it regulates the relationship between humans and nature (Zeng 2004; Ma 2007). Research on environmental ethics mainly focuses on the moral relationships between humans and the environment and the influence of the environment on humans and nonhumans (Stuckelberger 2009). Defining the main issues of environmental ethics is one important research theme in the field of environmental ethics (Yang 2013), and environmental ethics is part of science-related ethics (Chen 2014). Thus, LOs about the issues involved in environmental ethics were coded as component E, which represented 2% of the LOs. Even though the percentage was low, the educators we interviewed were positive about the potential contribution of geography curriculum to developing students' scientific literacy in terms of this particular aspect.

> Geography education has regarded cultivating students' correct environmental views as one of the great missions. Through geography learning, students should and are supposed to realize that we, human beings, are co-habiting on Earth with other creatures both living and nonliving. We are responsible to respect their existence and regulate and adjust our behaviors for the sake of sustainable development. Those views are more easily accessible to individuals who have been educated geographically.

F: Interest in science and technology

Our content analysis showed that no LO particularly addressed component F: *interest in science and technology*. In other words, students' interest was seldom represented in the curriculum document. Nevertheless, the interviewees in our study, especially the geography teachers and geography-teacher educators, thought there were increasing possibilities that students would become interested in science and technology through geography learning, "especially students' interest and passion of technology through learning and using geospatial technologies." As geospatial technologies (e.g., GPS, GIS) become more widely used in today's society, they are increasingly emphasized in geography education (Bednarz, Acheson, and Bednarz 2006), as this interviewee mentioned:

> The learning and using of these geospatial technologies might positively influence students' interest. However, whether and to what extent the positive influence takes place depends largely on how teachers organize and support students' learning.

Conclusion and Discussion

In this study, we examined China's middle-school geography curriculum standards through the lens of scientific literacy to investigate whether, to what extent, and on what aspects the geography curriculum had the potential to contribute to facilitating students' scientific literacy. In addition, we also interviewed science and geography educators to learn their experiences and thoughts regarding the connections between geography and science or the broader STEM education.

Geography Curriculum Has Potential to Contribute to Scientific Literacy

In our analysis of both the curriculum document and the interviews, we found that the geography curriculum, besides containing some scientific knowledge (i.e., knowledge about physical geography and Earth science), had potential to contribute to developing students' scientific literacy, especially in terms of *interpreting data in various formats, scientific reasoning*, and the *interrelationships among science, technology, society, and environment (STSE).* Through further examination, we realized that these positive potentials mainly result from the interdisciplinary nature of scientific literacy and the unique features of geography as a school subject.

In spite of arguments that scientific literacy is the main goal of science education, educators often emphasize its interdisciplinary nature and eagerly integrate science with other school subjects, such as mathematics and literacy, to achieve this goal. In other words, the interdisciplinary nature of scientific literacy requires many subjects to be integrated in schooling for students to become scientifically literate citizens, thereby opening space for other subjects, such as geography, to contribute to achieving this goal.

Moreover, features of geography also determine that the geography curriculum has the potential to contribute to developing scientific literacy, especially on these aforementioned aspects. Geography is a subject exploring the physical properties of Earth's surface, the human societies spread across it, and the ongoing human–environment interrelations. The interrelations and interdependences among these geographical elements, which include the *interrelationships among STSEs*, are at the core of geography learning. To explore these interrelations, students are encouraged to engage in processes of *scientific reasoning*, even if the particular term "scientific reasoning" is not mentioned frequently in the geography curriculum. These reasoning practices, based on the evidence generated through data interpretation, are mostly dedicated to identifying the best or most reasonable explanation for a geographical phenomenon or the best solution to a geographical problem. Our analysis in this study revealed that these reasoning processes are not only well represented in the curriculum document but also widely employed in geography teaching and learning practice. To aid these reasoning processes, students are usually provided with multiple data sources, including maps, texts, and graphs. This is evident in both the intended curriculum as represented by the written LOs and the enacted curriculum in classrooms as shared by our interviewees. Therefore, during geography learning, students have significant opportunities to develop their capabilities of *interpreting data in various formats*.

Discerning these connections between the geography curriculum and scientific literacy could provide some insights for educators to design fruitful interdisciplinary programs by integrating geography with science or other STEM subjects in classroom educational practice.

Connection with Everyday Life Is not Evident in the Current Geography Curriculum

With our analysis of China's middle-school geography curriculum, it was particularly surprising to learn that LOs involving connections between geography learning and everyday life were limited. Component D, personal use of science to make everyday decisions, solve everyday problems, and improve one's life, represented only 2% of the LOs. The majority of the geography curriculum focused on introducing students to aspects of other students' lives, the physical, human, and economic geography of their own and other countries, alongside an overview of the world (Catling 2011), leaving the geography of students' own locality as a minor part. Lacking a connection to the local is not a problem limited to China's geography curriculum; the problem is also found in other jurisdictions. According to Catling (2011), the challenge facing geography education in the United Kingdom, as in many other countries, lies in developing ways to engage students and teachers in everyday geography to enhance students' geographical learning. Everyday geography provides the contexts "for exploring much in geography that is central to the subject as well as being vital in understanding the world as it is evolving" (Catling 2011, 26).

Besides the written intended curriculum, the absence or limited connection between geography learning and students' everyday lives was also reported by some interviewees when they talked about how the curriculum was implemented in classrooms. Some interviewees believed that the use of materials closely related to the local context could assist students to understand phenomena in their everyday lives by using what they learned in the classrooms. Nevertheless, teachers' limited access to curriculum resources for teaching and learning about their students' locality and difficulties in creating teaching resources could be major obstacles to their use of locality-focused materials in classrooms. Revealing this challenge could be useful for curriculum-resource developers or teacher-education providers to support teachers, not limited to geography teachers, in exploring local contexts and issues with their students.

Limitations of this Study

We acknowledge certain limitations of this study. First, as we discussed previously, the framework of scientific literacy developed in this study cannot include all the intended goals of science education or be consistent with everyone's perception of scientific literacy. In this study, we focused on some aspects of scientific literacy (as shown in Table 1) and reported our research findings around these aspects only. Second, through content analysis and interviews, we gained some significant information, as discussed above. However, we acknowledge that it is difficult to account for the development of students' scientific literacy through geography learning in this study. Furthermore, with the interviews, especially the ones with geography teachers, we hoped to gain insights about how the intended (written) curriculum was enacted in their classrooms. But taking into account the small sample size and without close observation in classrooms, we cannot know what the classroom teaching and learning actually looked like. Moreover, during the interviews, as we discussed previously, we offered the framework developed in this study to the interviewees. Even if we tried to minimize the bias potentially caused by this methodological decision, we acknowledged this as another limitation of this study.

Nevertheless, the findings in this study reveal that, to some extent, geography can be integrated into interdisciplinary projects (e.g., some STEM learning projects) to facilitate students' scientific literacy. Thus, the findings gained from this analysis might contribute to teachers' or educators' design of integrated activities to facilitate students' interdisciplinary learning.

Application of the Results

In spite of the limitations identified, the findings in this study reveal that, to some extent, geography can be integrated into interdisciplinary projects (e.g., some STEM learning projects) to facilitate the development of students' scientific literacy. Thus, the findings gained from this analysis might contribute to teachers' or educators' design of integrated activities to facilitate students' interdisciplinary learning. Because geography is a discipline with globally common knowledge and skill components, these findings can also have application beyond the Chinese context. The results of this study show that geography curriculum can make a meaningful contribution to the development of scientific literacy and should therefore be given a higher priority.

Acknowledgments

I would like to thank Prof. Changwen Chen, Prof. Shengqing Chen, and Prof. Zhifang Xia for their suggestions on earlier drafts of this article.

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