Conceptualizing Community Scientific Literacy: Results from a Systematic Literature Review and a Delphi Method Survey of Experts

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Declarations

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Abstract

The predominant conceptualization of scientific literacy occurs on the micro scale of an individual person. However, scientific literacy can also be exhibited at the meso scale by groups of people in communities of place, practice, or interest. What comprises this community level scientific literacy (CSL) is both understudied and undertheorized. In this paper, we utilized a systematic literature review to describe how CSL is characterized in the extant literature and a Delphi survey of experts to elicit more current thought. Guided by Cultural-Historical Activity Theory, inductive and deductive analyses produced seven elements of CSL and their constituent characteristics: 1) resources, 2) attributes of those resources, 3) actors, 4) interactions between actors, 5) contexts, 6) topics, and 7) purposes. The typology created through this process is meant to be generative, serving as a starting point for continuing refinement within science education and other fields related to science learning and knowing.

Keywords: scientific literacy, community, sociocultural, cultural historical activity theory

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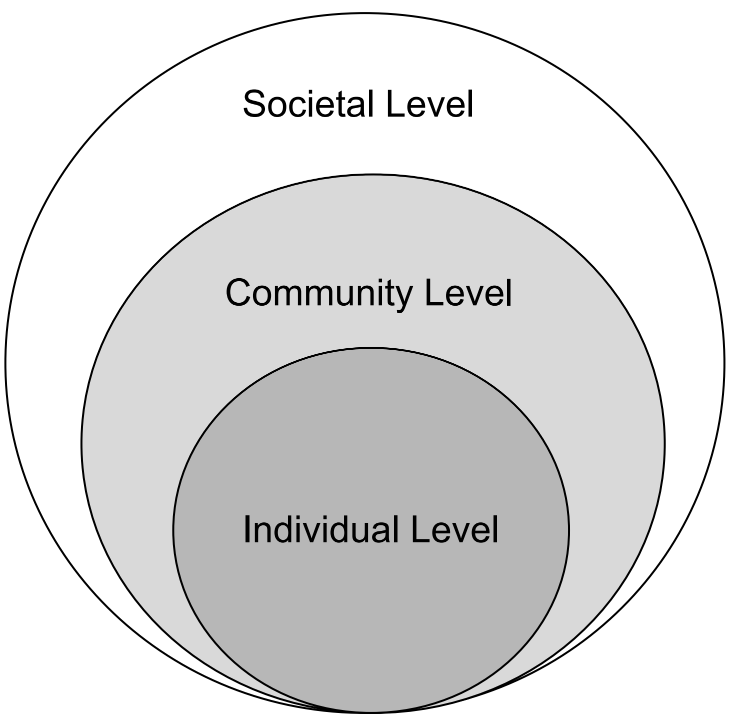
Scientific literacy has been widely held as a desired outcome of science learning within formal and informal settings (DeBoer, 2000). However, scientific literacy is generally not considered the ultimate outcome in and of itself. Instead, scientific literacy can be considered an important means for individuals to achieve societal goals—be they economic, democratic, or cultural (Osborne, 2000). We argue that this causal chain is incomplete because it neglects the intermediary step of individuals acting together—in communities of practice, place, or interest—to achieve those collective goals. The central premise for the present research is that community level scientific literacy (at the meso scale) serves as an important bridge between individual level scientific literacy (at the micro scale) and societal level goals (at the macro scale) (see Figure 1).

Figure 1

Scientific literacy at different scales of social organization



Currently, a group's scientific literacy is conceptualized as the aggregate of its constituent individuals' scientific literacy. However, scientific literacy at the community level is likely more than the sum or average of its individual parts. It is likely something different altogether and, hence we argue, requires its own set of constructs. There is not a consensus in the extant research as to what the underlying constructs are for community scientific literacy (CSL), and it is an area of research that is both undertheorized and understudied (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016).

In this paper, we present research that begins to address this lacuna. As such, the research questions are: *What constitutes community level science literacy? How can we define it? What are its constituent components or constructs?* To answer these research questions, this study employed a systematic literature review (to describe how this concept has been discussed in the extant literature base) and a Delphi method survey of experts (to elicit current thinking on this topic). The typology created through this process is meant to be generative, serving as a starting point for continuing refinement and conversation within science education and other fields related to science learning and knowing.

Conceptual Background

Scientific Literacy at the Individual Level

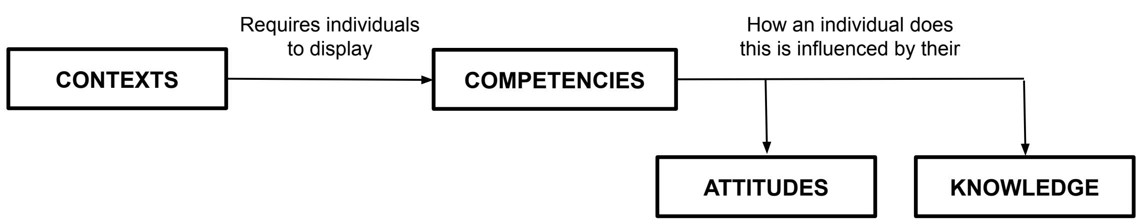
Paul Hurd is credited for the inception of the term *scientific literacy* in an article calling for reforms in science education emphasizing the role of science in citizenship (Hurd, 1958). He stated, "The American people, sparked by a Sputnik, and almost as a single voice, have inquired whether their children are receiving the kind of education that will enable them to cope with a society of expanding scientific and technological developments" (Hurd, 1958, p. 13-14). In addition to science content, Hurd described needing to understand "the meaning of science" (Hurd, 1958, p. 14) which included aspects of how scientific research is done in which students act as a "scientist for a day" in classroom laboratory experiences (Hurd, 1958, p. 16).

Since then, scientific literacy has been at the forefront of other charges for science education reform within the U.S. (Rudolph, 2019). While its use and seeming importance have grown, its meaning has also become increasingly diffuse (DeBoer, 2000). For example, it has been defined as: conceptual knowledge; epistemic knowledge and understanding of the Nature of Science; knowledge needed to participate in science-based social issues; and wonder, appreciation, and curiosity about science (for comprehensive reviews of the history and conceptual development of science literacy, please see: DeBoer, 2000; Laugksch, 2000; NASEM, 2016; Norris & Phillips, 2003; Roberts & Bybee, 2014). Across the literature, Roberts (2007) identified two broad and competing visions of science literacy. Vision I involves canonical science, including an individual's knowledge of science content and scientific processes. In contrast, Vision II involves the knowledge and skills needed by individuals to navigate everyday issues that have a connection to science. Feinstein (2010) aligned these two visions with the idea of usefulness—to whom and how is science useful? He concluded that while Vision I supports the development of science insiders who gain a deep understanding of science content, Vision II supports the development of competent outsiders who see the relevance and meaningfulness of science in their everyday lives. With Vision I scientific literacy as a driving perspective, science education reform efforts are aimed at producing scientists and engineers through the development of the Science, Technology, Engineering, and Mathematics (STEM) "pipeline." While the Vision II orientation encourages science education reform, such as *Science for All Americans* (American Association for the Advancement of Science, 1989), geared towards promoting science understanding for participation in civic life (Aikenhead, 2006).

Despite the breadth of definitions and orientations, one aspect holds across them all: scientific literacy has largely been conceived at an *individual* level (NASEM, 2016). For instance, the Programme for International Student Assessment (PISA) defines scientific literacy as "an *individual's* [emphasis added] scientific knowledge and use of that knowledge" (Organisation for Economic Co-operation and Development [OECD], 2016, p. 24) in which an individual's competencies are related to their knowledge, attitudes, and contexts (see Figure 2). PISA has identified three competencies for individuals: to be able to explain scientific phenomena, to be able to evaluate and design scientific inquiries, and to interpret scientific data and evidence. These competencies are influenced by an individual's knowledge and attitudes. The PISA definition takes an expansive view of knowledge; in addition to content (factual) knowledge, it includes both procedural (common science methods and processes) and epistemic (process for knowledge-building in science) knowledge. Attitudes include a positive view toward science and its value to society. The personal, local, and global context of an individual will also affect their need to enact competencies (OECD, 2016). While the PISA definition acknowledges the importance of context and other definitions note the importance of scientific literacy for society, these conceptualizations are primarily construed at the individual level.

Figure 2

Conceptual model for individual level scientific literacy (remade from OECD, 2016, p. 25)



Scientific Literacy at a Community Level

Generally, a *group's* scientific literacy is conceptualized and operationalized as the aggregate of its individual's knowledge, attitudes, and competencies (NASEM, 2016). For instance, the U.S. National Science Board assesses the adult public's science knowledge and attitudes via large-scale surveys. The public's science knowledge—measured through a series of true-false factual questions—has remained low (62%) for decades (Besley & Hill, 2020). Understanding of scientific processes, such as experiments and inquiry, has also remained low (64% and lower) over time (Besley & Hill, 2020). Despite lower levels of scientific knowledge, a preponderance of U.S. Americans see value in science; nearly 90% agree that science and technology offer more opportunities for future generations (Besley & Hill, 2020). These aggregated results are used as a proxy for "public science literacy" and drive societal-level science directives and policies, such as funding initiatives via the U.S. National Science Foundation.

However, this conceptualization may be insufficient for CSL. Rather than an aggregate approach, Roth and Barton (2004) posit that scientific literacy:

> must be understood as a community practice, undergirded by a collective responsibility and a social consciousness with respect to the issues that threaten our planet. We need to treat scientific literacy as a recognizable feature and analyzable feature that emerges from the (improvised) choreography of human interaction, which is always a collectively achieved, indeterminate process. (p. 3)

Qualitative case study research, particularly in the field of public health, suggests that scientific literacy can be expressed in a collective manner "when the knowledge and skills possessed by particular individuals are leveraged alongside the knowledge and skills of others in a given community" (NASEM, 2016, p. 84). In this way, science literacy at a community level does not rely on all individuals reaching a certain level of knowledge, skills, and/or competencies, and therefore, extends beyond the aggregate of individual level scientific literacy.

In environmental education research, work has begun to conceptualize community level environmental literacy. Ardoin and colleagues (2023) identify the need for *collective* environmental literacy as a means to meet the challenges of large-scale environmental sustainability. Through a systematic review of literature, they developed a list of related constructs and theories, which they synthesized into four key elements: dynamic, synergistic, shared, and multi-scalar. They concluded that collective environmental literacy is "a dynamic, synergistic process that occurs as group members develop and leverage shared resources to undertake individual and aggregate actions over time to address sustainability issues within the multi-scalar context of a socio-environmental system" (Ardoin et al., 2023, p. 35). In parallel, Gibson and colleagues (2022) held an interdisciplinary convening to discuss the conceptualization and measurement of community level environmental literacy (CLEL). Rather than a singular definition of CLEL, the discussion resulted in a set of guiding questions and spectra, highlighting tensions and diversity of thought. For instance, researchers may consider how they are defining "community," on a spectrum from passive association (i.e., people living in the same town) to intentional association (i.e., a community of interest or practice). Additional questions center on definitions of environment (from natural systems to human systems) and literacy (from latent to enabled). Similarly, considerations for measurement involve the identification of outcomes (from aggregate to collective) and its focus (from process to product).

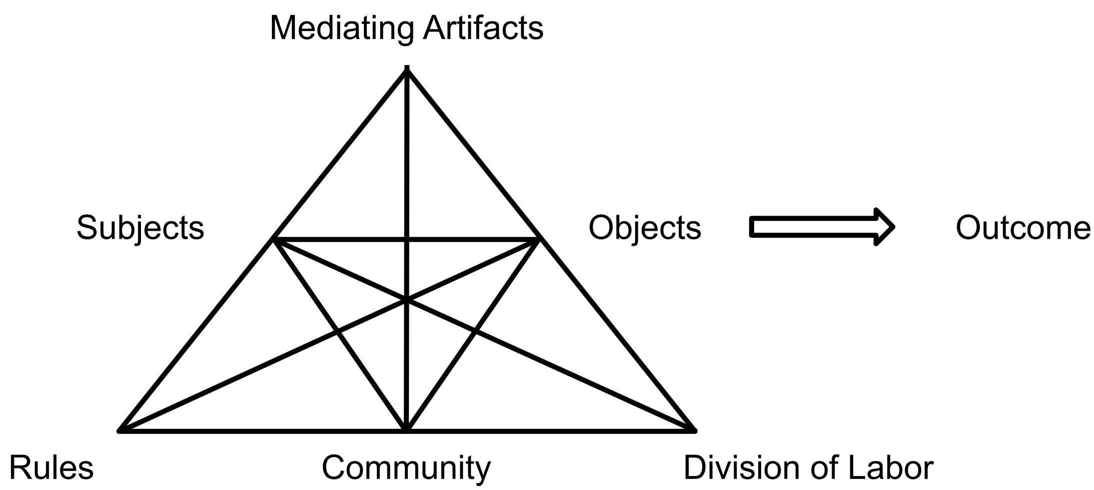
Given the limited empirical work on CSL, especially in comparison to that at the individual level, there is a need to "pursue expanding conceptions of science literacy" and measurement in "ways that go beyond aggregating the science literacy of the individuals" (NASEM, 2016, p. 9). While the NASEM report argued for the importance of CSL and offered qualitative case study evidence of its appearance in environmental and health case studies, it did not provide a clear definition. In order to operationalize CSL, its constituent constructs must be clearly articulated. Therefore, the aim of this paper is to clarify the constructs that comprise CSL, such that they serve as a foundation for further research, and to support the development of new methods of measurement.

Theoretical Framework

This study is informed by second generation Cultural-Historical Activity Theory (CHAT), a socio-psychological theory that centers on collective human activity situated and embedded within complex social contexts (Engeström, 1987). Use of this theory allows a researcher to study an activity system through the investigation of different components of that system. (However, it must be noted that these components are not separate from each other, but rather they exist in relation to each other.) The constituent components of CHAT include: the outcomes, the object, the subject, the community, the rules, the means, and the division of labor (see Figure 3). *Outcomes* refers to the motivation or intended purpose of the activity. *Object* refers to the focal entity. *Subject* refers to an actor in the system. *Community* refers to the group of subjects with a shared interest in the outcome, and *rules* include how the community of subjects interact to achieve the outcome. The *means* are the material or conceptual tools and resources used to reach the outcome, and the *division of labor* includes how the subjects divide work or resources to achieve the outcome.

Figure 3

Cultural Historical Activity Theory (remade from Engström, 1987)



CHAT is a useful framework for conceptualization of CSL, particularly because it extends the unit of analysis from the individual to the collective. Vygotsky developed first generation activity theory to rectify a psychological focus on an individual isolated from a context and to be more consistent with sociocultural theories of learning (Roth & Lee, 2007). In short, CHAT supports the view that learning and doing is relational, whereby individuals are constantly shaped by their context (Wertsch, 1991). CHAT can be fruitful to study scientific literacy in everyday activity, outside of formalized school settings and in more accordance with the Vision II orientation emphasizing civic utility. For example, Roth (2003) conducted discourse analysis between residents and scientific experts engaging with one another at a public meeting to discuss the town's ongoing issue with water quality. He described the "choreography of scientific literacy," (p. 5) becoming a recognizable phenomenon through the lens of activity theory. He noted how the different —scientific, historical, and local—knowledges shared among participants in the meeting created a collective understanding of the problem that would not have otherwise been possible. Drawing on the same case study, van Eijck & Roth (2010) proposed that collective scientific literacy is situated, distributed, and dynamic. As such, sociocultural and cultural-historical activity theories are best matched to understand scientific literacy as it emerges "in the wild" (van Eijck & Roth, 2010).

Taken together, the components of CHAT were used to guide analysis and interpretation of the data in this study. In particular, we used the CHAT definition for *community*: the group of people comprising a community may be bound together by geographic place, by profession or practice, by topic of interest, and/or by identity. In accordance with CHAT, subjects in this community are engaged in activity to achieve a mutual outcome, utilizing their shared means, by dividing their labor, and through adherence to agreed-upon (either tacitly or explicitly) rules of interaction. CHAT was also used as a guiding framework during data analysis and creation of codes, described in more detail in the Methods section.

Methods

The research questions guiding this study were: *What constitutes community level science literacy? How can we define it? What are its constituent components or constructs?* To capture both past and current conceptualizations, our research design incorporated the use of a systematic literature review and a Delphi methods survey.

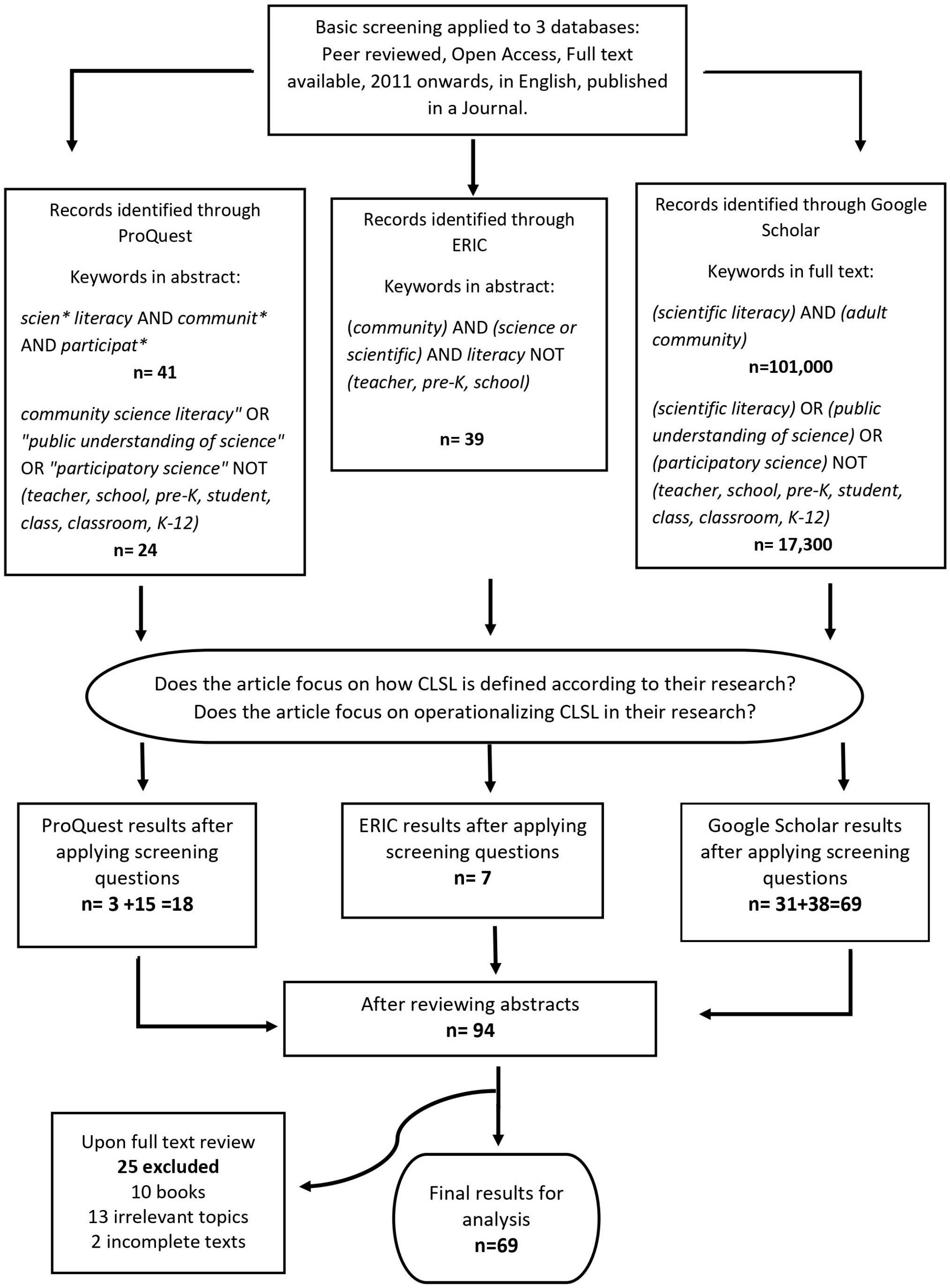
Systematic Literature Review

Data Collection

In this study, we used a systematic literature review (SLR) to search for relevant literature since it follows specific steps for replicability. We also adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to search for articles (Page et al., 2021) (see Figure 4). We informed our selection of keywords for the final searches through pilot systematic searches carried

Figure 4

Decision tree to determine inclusion/exclusion in systematic literature review



out in all the databases. We searched the ProQuest database with a keyword combination of (scien* literacy AND communit*AND participat*) and (community science literacy OR public understanding of science OR participatory science). The Educational Resources Information Center (ERIC) database was searched using keywords (community AND science or scientific AND literacy). Google Scholar was searched using the keywords (scientific literacy AND adult community) and ("scientific literacy" OR "public understanding of science" OR "participatory science"). Google Scholar searches yielded more than ten thousand articles, presented in decreasing order of relevance. Therefore, to narrow down the results, only the first 100 articles from each search were considered as the resultant sample for this SLR.

Search results were restricted to those published in English, between 2000 to 2021, were peer-reviewed, and had full text available online. This search yielded 304 articles whose abstracts were further screened, using the research questions. Abstract screening yielded 94 articles which were read in their entirety for inclusion. At this stage, we excluded 10 results which were books or book chapters, and 2 for missing parts of the entire article. An additional 13 articles were excluded during this process due to duplication or belonging to a different discipline like physics and engineering. Through this process, a final sample of 69 articles was identified after which each article was read again in its entirety for analysis. All articles are cited in the references section, with an * to denote their inclusion in the data corpus.

Data Analysis

The data were coded in Microsoft Excel and displayed using a matrix format to allow for a systematic and trustworthy analysis (Miles et al., 2014). The authors and a research assistant coded together using a collaborative process. Each article was discussed to understand how the authors had conceptualized or discussed CSL. Our team of three coders initially analyzed six articles together, to establish an inter-coder agreement. The articles were then divided between the three coders. Following the constant comparative method (Charmaz, 2006; Glaser, 1965), the research team held regular review sessions to discuss the sub-categories and check for consistency.

The codebook was developed through both inductive and deductive means. The final 69 articles were analyzed with codes to describe the following: location, article type, theoretical framework, study setting, educational setting, geographical settings, participants, knowledge type, literacy type, type of community, and level of CSL (see Table 1). The conceptualization of CSL was coded inductively, in combination with the Delphi analysis (described in a subsequent section).

Description of Literature Sample

This study reviewed 69 articles, with almost half of them (41%) published in the United States, followed by European countries (19%), the UK (13%), Canada (12%), and Australia (9%) (see Table 1). The most common types of articles were position papers (43%) and empirical studies (41%). Articles in this review belonged to six broad disciplines: public understanding of science, science education, citizen/community science, public health, science communication, and information technology. Of the articles which mentioned their study settings, 17% were based in the urban context, 9% were rural-based, and 2 % focused on suburban, urban, and rural areas together. Of the empirical studies that mentioned geographical characteristics of their study sites, the most common included coastal regions (6%) and watershed communities (4%). The majority of studies (67%) were conducted in informal education settings such as museums and online public forums, while some were within formal settings such as universities or K-12 classrooms. The majority of articles addressed or held interventions with adults (49%), followed by children/youth (23%) and young adults (9%). Researchers most frequently described the acquisition of Western knowledge/science (91%), with some articles highlighting the importance of indigenous knowledge (16%). Scientific literacy was the most frequently mentioned literacy type (42%), followed by other discipline-specific literacies such as health, environment, and marine literacy, among others. A little more than half of the articles (55%) in this review had identified theoretical frameworks as a basis of their study, of which, Communities of Practice was the most used theoretical framework (7%). We also analyzed the articles to understand which type of communities studied. Articles mentioned communities of place (19%), related to either a geographical region like a watershed or related to a town or neighborhood. Other communities were described based on virtual locations/online (12%), of interest 6%), and related to practice (6%).

Table 1

Description of SLR Sample Article Characteristics

Characteristic	Category	Frequency	%
Location	USA	28	41%
	EU countries	13	19%
	UK	9	13%
	Canada	8	12%
	Australia	6	9%
	Estonia	1	1%
	Singapore	1	1%
	Argentina	1	1%
	South Africa	1	1%
	Mexico	1	1%
Article Type	Position	30	43%
	Empirical	29	42%
	Review	8	12%
	Editorial	1	1%
	Practitioner article	1	1%
Theoretical Frameworks	No theory mentioned	31	45%
	'Other' theories	19	26%
	Community of Practice	5	7%
	Activity theory	4	6%
	Deficit model	4	6%
	Collective participation/ Collective impact theory	3	6%
	Constructivist theory	3	4%
Study Setting	Not applicable	49	71%
	Urban	12	17%
	Rural	6	9%
	Urban & Rural	1	1%
	Suburban	1	1%
Educational Setting	Informal	46	67%
	Formal	16	23%
	Not identified	4	6%
	Formal & Informal	3	4%
Geographical Setting	Not applicable	59	86%
	Coastal	4	6%
	Watershed	3	4%
	Plains	2	3%
	Mediterranean region	1	1%

Delphi Method Surveys

To gather a more current and collective opinion about what constitutes CSL, we also used the

Delphi method in this study. The Delphi method is particularly useful for identifying areas of agreement, as well as areas for which there is no agreement, and for complex topics (Landeta, 2006). The Delphi method has four key characteristics: (1) it is composed of a panel of experts, in which participants are chosen based on purposeful selection criteria; (2) the process ensures anonymity and confidentiality, in which participants are not known to each other and therefore do not directly influence each other's responses; (3) the participants receive controlled feedback, to understand the group's perspectives; and (4) there are multiple survey iterations, in which participants are provided several opportunities to express and revise their opinion (Giannarou & Zervas, 2014).

Expert Panel Selection

The process of selecting an expert panel is an important part of the Delphi method process (Gordon, 1994). An initial list of 122 possible panelists was created through a literature search to gather those researchers who have repeatedly published on topics such as scientific literacy and public understanding of science. In addition, snowball sampling was used, based on the recommendations of other invited participants. From this list, we made a concerted effort to select a diversity of experts, including but not limited to diversity in area of expertise, gender, race/ethnicity, professional role/work setting, and geographic location. Through a personalized email, we invited 75 experts to participate in the Delphi study. Thirty-five experts (47% response rate) agreed to participate (see Table 2 for a description of the participants, as provided through self-report in survey #1). This sample size was congruent with recommendations for 30 participants to ensure representativeness of a Delphi panel (Shariff, 2015), while allowing for some attrition between survey iterations. Survey #2 included 33 of the 35 participants (6% attrition).

Data Collection and Analysis

The Delphi method uses a series of iterative rounds of surveys to elicit responses from experts. The iterations move from open-ended, qualitative data collection to gather ideas to closed-ended, quantitative data collection to evaluate and refine those ideas (Shariff, 2015). The sequence of surveys used in this study is described below (and the full text of the surveys is included in the Supplemental

Table 2

Description of Delphi Study Expert Panel Participants

Characteristic	Category	Frequency	%
Gender	Female	15	43%
	Male	19	54%
	Prefer not to say	1	3%
Race/Ethnicity	American Indian or Alaska Native	1	3%
	Asian	4	11%
	Black or African American	2	6%
	White or Caucasian	22	63%
	Other	3	9%
	Prefer not to say	3	9%
Geographic Location	Israel	1	3%
	United States	31	89%
	United Kingdom	3	9%
Work Setting	Formal (e.g., K-12, Higher education)	18	51%
	In/non-formal (e.g., museums, NGOs)	12	34%
	Other (mixed)	5	14%
Years of Experience	1 to 10 years	1	3%
	11 to 20 years	13	37%
	21 to 30 years	11	31%
	More than 31 years	10	29%
Area of Expertise (self-selected; more than 1 area could be selected)	Citizen science	2	6%
	Environmental activism, advocacy	3	9%
	Environmental justice	4	11%
	Environmental science	4	11%
	Formal science education	13	37%
	In/non-formal science education	13	37%
	Public understanding of science	12	34%
	Science and technology	4	11%
	Science communication	10	29%
	Social networks	2	6%
	Other	2	6%

Note: Total percentages may not add to 100 due to rounding.

Materials). Initially, three surveys were planned, however, results indicated that two were sufficient to achieve the research purpose, which is to provide an expansive framework for CSL rather than to force participants to false consensus, a known criticism of this research method (Landeta, 2006).

Survey #1. The goal of survey #1 was to generate and collect a wide range of ideas about the characteristics of what it means for a community to be scientifically literate. After describing the purpose of the study, attaining participant consent, and a series of demographic questions, we asked: In your opinion, what constitutes community level science literacy? How can we define it? What are its constituent components or constructs? Participants were provided with the sentence prompt "Community level scientific literacy is…" to complete with their own words. This prompt was listed ten times for each participant, to simulate brainstorming and encourage exhaustive responses. Together, the 35 participants contributed 210 different responses to this prompt.

A team of three researchers used an open-coding, inductive process to analyze the responses, using the constant comparative method (Charmaz, 2006; Glaser, 1965). All researchers coded all data, and discrepancies were discussed until agreement was reached. These codes were then grouped into categories guided by the CHAT theoretical framework (Engström, 1987). For instance, through open-coding of Delphi panelist responses, we developed a code that referred to the different types of *actors* who are involved in CSL. CHAT refers to these individuals as *subjects*. Another example is that the Delphi panelists mentioned aspects of *interactions among actors*; whereas CHAT refers to these as *rules*. Because some code groups did not align one-to-one and because some of the descriptions slightly differ from CHAT, we decided to create original code names that more closely aligned to the data and to our research purpose. Through this iterative process, we created seven thematic "elements" of CSL and their characteristics as seen across the data set: 1) resources, 2) attributes of those resources, 3) actors, 4) interactions between actors, 5) contexts, 6) topics, and 7) purposes (see Table 3).

Survey #2. In survey #2, we presented the results from survey #1 to all participants, prompting evaluation of and feedback about the elements. Each element was presented separately. We provided the category name, a short definition, and examples taken from participant responses. Then, we asked two Likert scale questions. First, we asked how *satisfied* they were with the description of the element, with a response scale of: extremely satisfied, somewhat satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied, and extremely dissatisfied. Second, we asked how *important* they found the element as a part of a complete conceptualization of CSL. The response scale was: extremely important, very important,

Table 3

Codebook of CSL elements for analysis of Delphi survey responses and SLR article content

Code / Element of CSL	Definition of Code	Subcode	Definition of Subcode
Resources	Describes the material or conceptual assets and tools that exist within a community of people	Science Knowledge	General as well as specialized scientific content knowledge and scientific expertise, understanding of the Nature of Science
		Attitudes towards Science	Positive attitudes towards science, value of science, interest in science, trust, and appreciation
		Science Skills	Ability to evaluate misinformation, to recognize pseudoscience, to understand science news/media, and to discuss scientific topics
		Multiple Forms of Knowledge	Knowledge of the community–such as the history, practices, identity, norms, and values–as well as ways of indigenous or non-Western ways of knowing and cultural epistemologies
		Social Power and Capacity	Social and cultural resources, social power, social capital
Attributes of Resources	Serves as a corollary to the resources component, to describe the different types and nature of resources within a community	Diverse	Resources are non-uniform, different, variable, heterogeneous, interdependent
		Distributed	Resources are shared, distributed and redistributed within a community
		Accessible	Resources are not latent, rather they are activated, used, leveraged, mobilized, and exchanged
		Dynamic	Resources are changeable, depending on drivers such as socio-political events, community needs
Actors	Identifies the entities that constitute the community	Bounded	Actors are a bounded group, delimited in some way, such as geographical place, or a shared affinity, interest, or practice
		Positioned in a Variety of Roles	Actors serve within a variety of roles within the community, representing diverse perspectives, related to areas of expertise, as well as to professional experience, social relationships, and power
		Multi-generational	Actors will be multi-generational, representing diverse ages from youth to adult
		Multi-scalar	Actors include community and cultural groups, such as social institutions, political organizations, and governmental entities and structures
Interactions among Actors	Serves as a corollary to the actors within a	Level of Collaboration	Degree to which actors engage or have opportunities to engage with each other

	community, to describe rules for mutual engagement	Level of Trust	Degree to which actors exhibit trust in one another, particularly between experts and non-experts
		Level of Appreciation	Degree to which actors show appreciation for each other's possession of varied resources such as knowledge and skills
		Level of Respect	Degree to which actors exhibit respect for one another, particularly between experts and non-experts
Contexts	Describes the situatedness of CSL within the different places and public spheres of communities	Physical Contexts	Aspects of the place in which the community is located, including geographical location, as well as spaces such as in-person or virtual gatherings
		Socio-cultural-historical Contexts	Aspects of the community related to its people, including identity, language, and history
		Coupled Contexts	Refers to the interdependence of physical and socio-cultural-historical contexts, how they are nested and coupled
Topics	Defines the underlying features of issues in which CSL may be exhibited	High Science Salience	Topics have a scientific component, involving science knowledge, attitudes, and skills
		High Social Salience	Topics have a social component, involving politics, economics, community knowledge
		Salient across the Community	Topics involve common concerns and shared futures, have relevance to the community
Purposes	Identifies the goals or outcomes of communities who exhibit CSL	Defined by the Community	Purposes are based on the community's goals and needs, are community-identified, and community-driven
		Solutions and Action Oriented	Goals are useful and beneficial for the community, geared towards solutions and action
		Socially Just	Purposes lead to impactful and positive change, community transformation, community well-being/thriving/flourishing

moderately important, slightly important, and not at all important. Lastly, we asked an open-ended question to elicit anything *missing* from the description of the element.

For the quantitative closed-response questions about satisfaction and importance (1 and 2 above), we counted the frequency of responses and assigned numbers to the responses on a range of 5 (highest) to 1 (lowest) to calculate the average and standard deviation. For the open-ended question about what might be missing (3 above), we compiled those comments in abbreviated form and made a list of suggested changes and additions to the original element descriptions.

Integration of SLR and Delphi Data Analyses

After creating the codebook of CSL elements from the Delphi data (see Table 3), we returned to the SLR analysis, applying the codes iteratively to each of the articles. These codes were used to characterize the conceptualization of CSL as presented in the article text.

Methodological Limitations

There are limitations in this research, particularly due to the methodologies chosen. The SLR search process included only those articles published in peer-reviewed literature and in English. This would have eliminated studies published in languages other than English, which also would have limited the geographic locations of the studies examined. This SLR also did not use gray literature, such as doctoral dissertations, since it can make replication difficult. However, gray literature can often include cutting-edge, new research that was not captured. Furthermore, the systematic search process—keyword selection, database selection, and the inclusion/exclusion criteria—likely omits relevant literature. We did pilot many different combinations of search terms and databases to maximize the catchment and inclusion of related research. Additionally, searching for databases across a wider variety of disciplines would also have obtained different results. The Delphi method does have limitations, as well. In particular, choice of the expert panel influences the results. Although care was taken to invite participants from a diversity of countries, expertise, and identities, there is a greater proportion of panelists from the U.S. and who identify as White. These limitations should be taken into account when interpreting the results.

Results

While the Delphi surveys explicitly asked participants for their conceptualization of scientific literacy at the community level, we investigated how articles included in the literature review conceived of collective-ness. Articles were categorized based on the unit of analysis used in the articles to describe the process of science learning occurring—as an aggregate of individuals or as a community.

When considering the collective, most articles described scientific literacy at the individual level (54%) and as an aggregate characteristic of individuals (29%). Articles discussed elements of scientific literacy, such as the use or possession of scientific knowledge that occurs among individuals in a common space. Dietrich and Schibeci (2003) described groups within the community with shared characteristics such as similar education levels, geographic locations, or jobs. Others discussed students' scientific literacy in the shared space of a classroom (Sadler, 2007; Tang, 2015; Ziedler, 2007). Other articles discussed the *public's* understanding of science, risk appraisal, and science communication (Jansen et al., 2020; Lewis et al., 2017; Spoel et al., 2009), treating the public as a singular entity comprising the aggregate of its individuals.

Less common, a whole group was used as the unit of analysis in only 14% of the articles. For example, Špiranec and Kos (2013) studied civic engagement in a group setting and concluded that college students tended to use colleagues as sources of information while acting for the common interests of the group. Scientific literacy and knowledge were considered as a collective property developed by and belonging to community members living in a watershed region according to research (Roth & Désautels 2004; Roth & Lee 2002, 2004). Another study mentioned the need for a broader understanding of science among the public, and the authors (Zimmerman et al., 2001) made a passing mention of the need for CSL:

> Scientific literacy is typically assessed by measuring individuals' knowledge about scientific facts and methods. No widespread, concerted effort has been made to teach or assess the broad range of knowledge necessary to understand science as a communal activity. (p.54)

In what follows, we attempt to address the latter—what truly differentiates *community* level SL from individual aggregate perspectives. Here, we present the results of both the systematic literature review and the Delphi study thematically. The themes are arranged via the categorical codes created through the data analysis process and informed by CHAT's constituent components: resources, attributes of those resources, actors, interactions between actors, contexts, topics, and purposes (refer to Table 3 for an overview).

Resources

Resources are defined as material or conceptual assets and tools that exist within a community of people. Within the SLR, resources such as science knowledge, science attitudes, and science skills were predominant. While Delphi participants also mentioned these resources, they added emphasis on the value of different ways of knowing and other forms of knowledge, as well as social power and capacity.

Science Knowledge as a Resource

In the SLR, the most frequently considered type of resource was content knowledge. Indeed, almost all articles mentioned possessing knowledge of science explicitly, either as a discipline or in general. Science literacy has been considered as the publics' possession of knowledge, but sometimes also the lack thereof. Predominantly, this conceptualization includes canonical knowledge as defined by Western science and by specific disciplines such as zoology, botany, chemistry, and the health sciences. Examples of science knowledge and understanding within the SLR articles included topics such as climate science (Ledley et al., 2014), ocean science (Halverson & Tran, 2010), radon pollution (Henrikson & Frøyland, 2000), avian fauna (Evans et al., 2005), and genetic engineering (Dietrich & Schibeci, 2003). Some articles also considered understanding new scientific and technological advances as a necessary part of being scientifically literate. For example, Marino & Hayes (2012) posited that it is the responsibility of educators "to advance an understanding and practice related to video games and science knowledge that enhances the potential for active engaged citizenship" (p. 952).

According to Delphi panelists, knowledge is considered as a possession of individuals, in which there is "an acknowledgment of the depth of knowledge of any one individual." They also explicitly and frequently mentioned "scientific knowledge" and "science expertise" as important when conceptualizing CSL. One participant stated, "the main thing that frames this for me is the notion of intellectual dependence. We are all dependent on expertise." Similar to the SLR, panelists described this knowledge as "defined largely [with respect to] [W]estern scientific knowledge and institutions" but also that this knowledge is "more profound than what a [W]estern scientist learns in [W]estern institutions."

In addition to science content knowledge, an understanding of the Nature of Science (NOS) was also mentioned in the SLR and among the Delphi panel. Within the research community, there is not a single conceptualization of NOS. However, in science education, it generally refers to characteristics of scientific knowledge such as tentativeness, reliance on evidence and observation, subjectivity, and its social and cultural embeddedness (Lederman & Lederman, 2014). A few articles in the SLR focused on the public understanding of the NOS. For instance, Marino & Hayes (2012) asserted the importance of video games for learning because it led to "students' enhanced use of the scientific method" (p. 950). Authors also emphasized the need for students to understand the process and limitations of science (Kolstø 2001), contending that "teaching models suffer from lack of discussion and inclusion of knowledge concerning the nature of science and scientific knowledge" (p. 292), and that such knowledge is needed to make decisions about socio-scientific issues. A few authors emphasized the importance of students and the public knowing about research practices and how science research is done (Nicholas, 2017; Pickersgill, 2011). For example, Pickersgill (2011) argued the need for participants in medical trials to be informed of "realities (including scope and limits) of scientific practice" (p. 4).

Similarly, Delphi participants mentioned that CSL would involve knowledge of the NOS and an understanding of science as a human endeavor. This included an understanding of the processes of science, as "a collective understanding of how science is conducted" and "an understanding of the scientific process/method." It also included the epistemological commitments of scientists, such as the "essential role of consensus (among relevant experts)" as well as a reliance on "evidence-based thinking." Furthermore, CSL would involve "appreciating [the] affordances and limitations of science."

Attitudes towards Science as a Resource

Possessing positive attitudes towards science was widely considered an important aspect of CSL among both the SLR articles and the Delphi panelists. Scientific attitudes, such as valuing science

(Halverson & Tran, 2010; Holbrook & Rannikmae, 2009; Kolstø, 2001), having an interest in science (Bauer 2009; Miller, 2001), supporting science (Laugksch, 2000), appreciating science (Evans et al., 2005), and scientific knowledge (Field & Powell, 2001), and possessing prior attitudes and beliefs in scientific claims and texts (Britt et al., 2014; Kreimer, 2015; Morosoli et al., 2019) were considered necessary resources.

Delphi panelists highlighted the need for communities to value science in order to be considered as scientifically literate. For example, one participant stated that CSL involves “a community culture that includes interest in science and that values science.” This culture may be “seen in how a community places value in scientific institutions and practices (are they funded, in what ways, with what perceived benefit).” The value of science is ultimately derived from its usefulness in “addressing communal and global challenges.”

Science Skills as Resource

Skills related to science were considered a resource for CSL. Often, this skill set centered on aspects of fundamental science literacy, which involves “reading and writing when the content is science” (Norris & Phillips, 2003, p. 224). The examples of science skills included the ability to evaluate misinformation, recognize pseudoscience, understand science news and media, and discuss scientific topics.

SLR article authors mentioned various skills which are acquired in the process of learning different types of science knowledge. These included scientific writing and research skills (Ilett, 2019) and understanding technology when using media for scientific information (Wagner et al., 2002). Zimmerman et al. (2001) noted the importance of having the skills to determine the authentic nature and source of scientific information and “where the research was published” (p. 47). Britt et al. (2014) defined scientific literacy as “the ability of people to understand and critically evaluate scientific content in order to achieve their goals” (p. 105), and while they considered this ability to be goal-directed based on people’s needs, it solely focused on a lay individual’s ability to read, understand, and interpret scientific information.

One Delphi participant stated it is “less about knowledge in a ‘storehouse/bank of information’ or ‘elaborated schemata’ sense than it is about the skills/resources to accomplish socially valued outcomes.” Similar to the SLR, Delphi panelists discussed the need for skills specifically related to interpretation of science text. One panelist identified that CSL requires “skills for assessing integrity and credibility of scientific claims in public media.” This concern focuses on the prevalence of science-related misinformation in these public spaces. Therefore, communities need the skills to understand the “limits and boundaries of knowledge claims” and to “acknowledge the role of empirical evidence to resolve disputes of ‘fact’.” However, one panelist problematized this focus on fundamental literacy:

> That calling something ‘literacy’ connects it unwittingly to print and language. Our knowing is so much broader than that in science, just as our senses are broader than sight and sound. I rarely actually use this term ‘science literacy,’ both because it too easily positions people as consumers of science, but also centers language so strongly.

These three resources—science knowledge, attitudes, and skills—are not new to the field of science education. They comprise the main elements of individual level science literacy as it has been conceptualized in the literature (DeBoer, 2000) and in international science assessments such as the Programme for International Student Assessment (OECD, 2016). However, the following two resources were considered as more novel, and perhaps more pertinent, for a robust conceptualization of scientific literacy at the community level.

Multiple Forms of Knowledge as a Resource

Science is one of many forms of knowledge and ways of knowing (Aikenhead, 1996). Both the SLR and the Delphi panel acknowledged the importance of considering multiple forms of collective knowledge. This included knowledge of the community—such as the history, practices, identity, norms, and values—as well as ways of indigenous or non-Western ways of knowing and cultural epistemologies.

Within the SLR articles, authors noted the importance of acknowledging and valuing multiple forms of knowledge and ways of knowing. Aikenhead (2007) asserted how “indigenous cultures worldwide … have developed ways of describing and explaining nature based on empirical and rational means, but much differently than Eurocentric science" (p. 68). Related to issues of fracking, Williams and colleagues (2017) noted the need for "willingness of governing institutions to recognize, encounter, and accommodate diverse and polyvalent public views" (p. 99). Similarly, noting the importance of sociocultural contexts, authors discussed the importance of acknowledging and using the health and medical knowledge of the community while developing community health solutions (Hughes et al., 2019). Authors also highlighted the importance of traditional wisdom held by community elders and its critical role in community-based conservation, as well as environmental and science education (Ferreira et al., 2021; Roth & Désautels, 2004; Roth & Lee, 2002, 2004).

To highlight the importance of multiple forms of knowledge, Roth and Lee (2004) argued for a non-traditional position on scientific literacy, because "... in a democratic society, all forms of knowledge that contribute to a controversial or urgent issue are to be valued; science is but one of these different forms of knowledge" (p. 284). Roth and Désautels (2004) clarified that "ordinary citizens can be involved in questioning scientists and science" and participate in a way such that "*various forms of knowledge* [emphasis added] contribute to the solution of real problems" (p. 8). Roth (2003) argued, "what constitutes 'knowledge' at a given moment or across a range of situations is a matter of analysis, which has to take account of the *motivations, interests, relations of power, goals and contingencies that shape the activity* [emphasis added]" (p. 17). Conversely, Miller (2001) considered the possession of scientific knowledge as most important, noting the differences in knowledge between scientists and the public:

> Government and industry pay out large sums of money to scientific researchers. If there is not a gap between what scientists and members of the general public know about science, then something is very wrong. We do not want a public understanding of science political correctness in which the very idea that scientists are more knowledgeable than ordinary citizens is taboo. (p. 118)

Delphi panelists described how community knowledge is complementary to science knowledge. As one panelist stated, CSL:

> values epistemic heterogeneity, where epistemic authority is shared. While scientific knowledge

> and practice is valued as a part of community level science literacy requires more than this. It requires a critical understanding of communities (People and Place) and how scientific K[nowlege]+P[ractice] understandings intersected with science in meaningful ways. It involves how people in communities appropriate these K[nowlege]+P[ractice] in ways that are salient to their communities and work in conjunction with other relevant forms of knowledge and practices.

In this way, community knowledge is not separate from science knowledge, instead as stated by another panelist, it is “embedded in my community’s cultural epistemologies—it encompasses our lived science.” One panelist expanded on this idea of embeddedness within their own native indigenous community, writing that CSL is:

> Dependent on the community’s core values. It can be found in art, textiles, cooking, environmental observation...it does not have to be situated in academic literacy. We need to be more open to worldviews. In this case, my whole community is literate in Native science!

Social Power and Capacity as a Resource

At the community level, social and cultural resources, existing in conjunction with the knowledge, attitudes, and skills of individuals, serve as valuable assets. These resources were described as “social capital” and “social power” that support a community’s capacity. In the SLR, Adams et al. (2011) described, “community members demonstrated a *capacity* [emphasis added] to understand and grapple with the scientific complexity and uncertainty associated with the results of the HES (Household Exposure Study)” (p. 185). Delphi panelists, in particular, mentioned “community science capacity” as important for conceptualizing CSL. A Delphi participant emphasized that community-level capacity is “a capability not possible for a single person or group to undertake on its own.” This aligns with Valladares (2021) who noted that often the objective of equal science participation of all social groups to gain scientific literacy is hindered because of “unequal distributions of resources, power, and privilege among social groups” and therefore diverse people have diverse “perceptions, experiences” of science (p. 575).

Overall, we acknowledge that all these resources can exist as individual-level characteristics. For instance, we could describe a person’s scientific and community knowledge, science attitudes and skills, and social power and capacity. Thus, the next section—attributes of resources—is particularly important to move towards a *community* level perspective of scientific literacy.

Attributes of Resources

Attributes serve as a corollary to the resources component, to describe the *collective* nature of resources within a community. Resources were described as diverse, distributed, accessible, and dynamic. As such, CSL would mean that resources are diverse, and spread across the community, in such a way that they are accessible to others and are changeable.

Resources are Diverse

The SLR results highlighted resources as diverse both in terms of their multiple forms as well as their levels across a collective. A few articles from the SLR mentioned the heterogeneous and interdependent nature of the resources, with diversity across community members (Aikenhead, 2007; Roth & Lee, 2004; Valladares, 2021). Roth and Lee (2004) observed, "not all individuals have to know a basic stock of scientific facts or concepts—we do drive without knowing anything about car mechanics and we do eat bread without knowing how to bake" (p. 18). Similarly, Liu (2009) suggested:

> Although their [lay people] informal knowledge and experiences may not be totally compatible with the commonly accepted scientific views, they are 'functional' in everyday contexts because they seem to explain various phenomena to their own satisfaction. (p. 305)

Likewise, Pouliot (2015) argued that the "theoretical divide between specialists and lay people" (p. 462) has lost its relevance due to the current advancements and unexpected effects of science-technology advancements. The author supported the notion of resources being non-uniform, stating the need for "a strong recognition of *forms of knowledge other than scientific knowledge* [emphasis added]" and that "lay knowledge enriches, on an equal footing, the common understanding of problematic techno-scientific situations" (Callon, 1999; as cited in Pouliot, 2015, p. 462). In the same way, Aikenhead (2007) urged the acknowledgment of the pluralistic nature of scientific literacy, and the articulation of several sciences which include diverse perspectives including "(1) relevant neo-indigenous sciences; (2) Eurocentric sciences (plural) found in the everyday working world of professional science and science-related occupations (not simply academic science); and (3) where applicable, Indigenous sciences" (p. 68).

Delphi panelists also considered resources as diverse, in that they are "interdependent," "intersecting," "synergistic," and "complementary." One Delphi participant stated that CSL is "a heterogeneous mix of breadth and depth of science literacy across the community such that all members are needed to support community goals." Another described how this heterogeneity leads to "a synergistic relationship between science and a community's ways of understanding and finding solutions for the good of the community." Similar to Roth and Lee (2002), one panelist noted this diversity is a help rather than a hindrance to how a community can function, such as was exemplified during the AIDS crisis:

> Not everyone needs to have the same level of science knowledge; the key is that the community can collectively make sense and use information, similar to how the gay community worked together to address AIDS/HIV per the relevant research in this area.

Resources are Distributed

A community could have "diverse expertise" among its actors, in which one person's science knowledge may be "in relationship with other forms of community knowledge." However, knowledge must be "shared" because "everyone in the community is not [at] the same (level of knowledge)." Thus, being able to successfully share resources, like knowledge, depends on how those diverse resources are distributed across the community.

In many of the articles, several types of resources were described as being shared, distributed, and redistributed within a community. For example, Adams (2011) described participants' shared experiences and re-distribution of prevention knowledge to limit exposure to household endocrine-disrupting compounds. Similarly, Halverson & Tran (2010) highlighted how knowledge and tools should be considered as "assets to be shared that can be built on and revised by the community" (p. 277). The community here referred to a scientist-educator partnership between marine scientists and informal science educators. These authors also encouraged ownership of these resources among all the members of the community, noting that "the boundary crossing" experienced by scientists "allowed them to cultivate a network of contacts and resources within the education community of practice, focused on the practical application of ocean sciences research and content" whereas the informal educators were "introduced to some of the knowledge, rules, and norms of the scientific community, while also being given the opportunity to reflect on and change their typical practice within their own community" (Halverson & Tran, 2010, p. 275).

Delphi panelists often described resources—in particular, knowledge and expertise—as being "shared" in the community. One panelist noted that CSL is more than the aggregation of knowledge, rather it is "a collective level of scientific understanding that arises from an integration of acquired expertise that has been shared among community members in a way that makes the whole greater than the sum of its parts." In addition to knowledge, one Delphi panelist emphasized that power also needed to be shared. They wrote that CSL:

> Involves redistributing power across people and places, e.g., Positions people as insiders to science and to place because of who they are and what they know about their communities (I like how the youth in my work have talked about being community science experts. Even while they use this label for themselves, as individual people, it has a collective notion that we are in this work together with and for our communities).

Overall, as noted by one panelist, the sharing of resources is a function of the "diversification and distribution of knowledge, coupled with integration." In particular, how those diverse resources are organized across the community will either help or hinder sharing: "shared resources [are] distributed and organized so that no individual member of the community needs to attain a particular threshold of knowledge, skills, and abilities."

Resources are Accessible

While resources could be diverse and distributed across a community, for CSL, they would also need to be accessible. Accessible resources are not latent, rather they are activated, used, leveraged, mobilized, and exchanged. Some articles mentioned how knowledge is not always accessible to the community members, such as the lack of public access to complex knowledge related to GM foods

(Shaw, 2002) and lack of public access and understanding of bioethical research (Pickersgill, 2011). For example, Field & Powell (2001) identified the importance of presenting current research developments to the public because of the profound impact science has on personal decisions and policy issues. Other articles indicated when this knowledge is accessible for the community (Britt et al., 2014; Pouliot, 2015; Roth, 2003) and how this may activate or mobilize the community to address issues that are important or unique to them (Britt et al., 2014). Roth and Lee (2002) argued, "individuals do well without knowing science because, as an integral part of social life, they have access to different levels of expertise whenever they need it" (p. 34).

Delphi panelists described how resources were accessible within a community, especially in terms of their activation. For example, they noted that CSL is evident when a "community is positioned [to] collectively mobilize scientific knowledge and resources to advance their needs/goals." Mobilization of resources was a result of knowledge distribution across the community as well as connections among and between community members. A panelist observed that CSL is "knowing who in the community, with relevant expertise related to science, to talk to." Additionally, it requires "as a community, know[ing] where to look to find resources to address scientific issues." Accessibility is also about connecting with those resources. CSL was posited as a function of "your network and the people you have access to" as well as "in part an expression of scientific communities' capacity to connect with communities."

Resources are Dynamic

Resources were also described as being dynamic. A community's knowledge, attitudes, skills, or capacity are not always fixed at a certain level, rather these resources are changeable, depending on drivers such as socio-political events, community needs, or advances in scientific knowledge. These resources are also contested and ultimately change or transform, depending on the social situations.

Resources are often dynamic because of evolving scientific knowledge, new technologies, and discoveries. These advances may alter information disseminated to the public, thus restructuring knowledge and opinions of laypersons. In the SLR, articles described the dynamic nature of resources—

people's knowledge, attitudes, or skills—as they are negotiated. Wagner et al. (2002) studied how the knowledge and attitudes of the European public about genetically modified organisms (GMOs) was highly driven by the information presented to them in mass media. They suggested, "the process by which individuals come to render new technologies or scientific achievements intelligible is driven by *inter-individual* [emphasis added] and mass-media communication, and results in milieu-specific imaginations that then allow an acceptable level of understanding" (p. 323). Similarly, Zimmerman et al. (2001) stressed the importance of citizens being able to critically evaluate the "frontier science that is preliminary or tentative in nature" (p. 37) as reported in popular media.

Articles related to citizen science offered another form of the dynamic nature of resources. These articles noted the change in knowledge, attitudes, and skills of citizen scientists, such that it fostered scientific literacy holistically. Evans et al. (2005) commented on how their neighborhood Nestwatch program increased participants' content knowledge and sense of place and attachment to their local natural environment. The authors defined science literacy "as both an understanding of scientific content and ways of thinking such that citizens can make better sense of our increasingly technical and scientific world" (Evans et al., 2005, p. 589). Likewise, Liu (2009) defined scientific literacy more "as a life-long process with practical, useful consequences to both individuals and societies" rather than a goal to be attained (p. 306).

Delphi panelists also defined CSL as dynamic, in that it is "a socio-cultural process, not an end-point; one that at any one moment in time defines the collective capacity of a community to address issues in the community that have high scientific salience." As a process rather than a product, CSL "responds to both people coming/going and learning within the community." Some Delphi participants emphasized that the dynamic nature of CSL means that communities can grow their resources by "building knowledge and practice—a core activity of science. Science literacy for me means people are contributors to that, from different socio-ecological locations." This conceptualization portrays communities as builders of science literacy "characterized by participation in science" rather than just consumers.

Actors

When describing community scientific literacy, it is important to identify the entities that constitute the *community*. One Delphi panelist remarked, “a first question might be—how do you define a community? Once you have answered the first question, how are the populations within the community defined?” To this end, we searched the literature and the Delphi panelist responses for “who” was mentioned and grouped them into descriptive categories. Descriptors of community actors included: bounded in some definable way; serving in a variety of roles, multigenerational, and existing at different scales beyond the individual to include informal groups as well as societal or community organizations.

Community Actors are Bounded

Community actors are a bounded group, delimited in some way. It is common for communities to be bounded by a common geographical place, such as a town or country. However, they may also be bounded by a shared affinity, interest, or practice. These boundaries can be evident and created by the community, such as a gated community, but they may not always be so, such as a virtual community of amateur astronomers (Aristeidou & Herodotou, 2020).

Articles in the SLR mentioned communities as distinctly bounded entities. For instance, middle school students and teachers were bound together because they shared a common physical (school) and geographic (coastal town) location and participated in water quality research along with science researchers (Roth & Lee, 2004). However, there were also communities engaged in other spaces based on shared interest. For instance, members of an online community—the Climate Literacy and Energy Awareness Network (CLEAN)— are bound together by the common interest they share in promoting climate literacy through climate and energy education (Ledley et al., 2014).

Similarly, Delphi participants noted that communities are groups “defined” in numerous ways. While communities are sometimes bounded by place, they can also be defined by “non-place-centered communities of practice or identity.” For example, communities can be a “multi-racial, multi-species group linked by its interdependence and by history and possible common futures.” However, the use of the phrase “community member” was problematized, since actors are “not necessarily self-aware; people can help constitute CSL without knowing they are part of a system.” Furthermore, communities may be "self-identified" rather than prescriptively bounded by others (such as researchers) or automatically by co-location in a specific place.

Community Actors are Positioned in a Variety of Roles

Community actors serve in a variety of roles within the community, representing diverse perspectives. Roles included those attributed to areas of expertise, as well as to professional experience, social relationships, and power. One common role was that of the "expert"—those individuals in the community who were identified as having some expertise beyond that of the general public.

Science experts included scientists as well as museum curators, medical doctors, and healthcare providers. The SLR articles indicated a consistent and clear delineation between subject experts (scientists, doctors) and the general public (students, parents, families, and community members) but noted that these groups were brought together based on common interests or issues such as climate change or radon pollution (Henrikson & Frøyland, 2000; Laugksch, 2000). Other roles were related to professions, including teachers and informal educators, or social relationships, such as children and parents (e.g., Bromme & Beelmann, 2018; Shaw, 2002). Many articles mentioned people in power, such as the role of governments, industry representatives, and other "experts" in communicating science and technology advances to the public (e.g., Adams et al., 2011; Spoel et al., 2009). For instance, Wagner et al. (2002) noted the influence of various actors on the European public's perception of biotechnology. They asserted that "the interplay of interests in commerce, media, policy-makers, and NGOs makes power an important factor in the hunt for the public's imagination…" (p. 341).

One Delphi panelist noted that CSL involves roles with particular power when topics are "prioritized within local governments by decision makers and constituents." However, one Delphi participant echoed how each individual brings their own capacities and viewpoints associated with their specific roles to a community. They emphasized that CSL:

> Involves many different kinds of people, including youth and adults, none of whom need to be science "experts" and in range of combinations, working on/contributing to questions and problems that are authentic to their communities while drawing upon the tools of science, which

include knowledge/information, data generation and analysis, all towards potentially leading to answering those questions or problems.

Community Actors are Multigenerational

Community actors will likely be multigenerational, representing diverse ages from youth to adulthood. A small number of SLR articles mentioned multigenerational groups such as village elders, community youth, and families. For example, Ferreira et al. (2021) discussed how “young, elderly, students, fishermen, farmers, traders, teachers, [and] decision-makers” were all part of the Portuguese coastal community mobilized to increase their marine literacy in “a genuine process of intergenerational knowledge transfer” (p. 6). Similarly, in a study to increase community environmental health literacy, the tribal elders and researchers relied on middle school students to share their knowledge with “family, friends, and the community” (LeVeaux et al., 2018, p. 3).

Delphi participants also described how CSL involves “different generations that have knowledge about a local environmental/science issue.” A common multi-general group is the family, and Delphi participants mentioned these multigenerational interactions in which CSL is expressed when “families [who] do science-based activit[ies] on the weekend (visit science center, do kitchen science activity)” or when “families**…**talk about science-based topics at the dinner as sports topics.”

Community Actors are Multiscalar

Lastly, community actors exist at multiple scales beyond that of just the individual, offering places and spaces in which people can come together. Thus, community actors can comprise informal or structured groups of individuals, as well as organizational entities such as museums, universities, and government agencies.

In the SLR, some articles discussed such multiscalar actors and their role within CSL. For example, Henrikson and Frøyland (2000) identified the need to extend the role of museums in society, such that they are not static institutions and passive disseminators of knowledge but rather act as “meeting places,” “arenas for public debate,” and “dialogue institutions” (p. 394). The authors argued that at the institutional level, museums can aim to “provide opportunities for different interest groups to meet and interact, for instance, through arranging public debates or workshops on current science-related issues" (Henrikson & Frøyland, 2000, p. 394).

Delphi panelists also mentioned the role of community organizations, when considering science literacy at a community level. For instance, one participant noted the importance of "community organizations [that] actively seek science-based engagement with science-based topics (e.g., senior centers, Rotary and Kawanis) [which] actively seek to keep members scientifically informed." Additional social organizations named included: "community media," "afterschool science-based programs" such as "science Olympiad [and] First Robotics," "local K-12 schools, churches, governments," and "multiple economic and social groups." These community organizations serve an important function in communities. As one participant wrote, CSL is:

> The aggregate of individuals' scientific literacy in a community leveraged as more than the sum of its parts *through social institutions that allow for purposeful open exchange and collaboration* [emphasis added] at the local level.

Interactions among Actors

This element served as a corollary to the actors within a community, defining interactions as the rules for mutual engagement between actors. A few articles from the SLR sample explicitly described the nature of interactions between the different actors within a context. Often these interactions were implied or embedded within the discussion of the results or description of the context. The SLR articles described interactions as collaborations and communications, often relying on trust between experts and lay people. Delphi panelists offered similar rules of engagement, suggesting that the nature of such interactions should be "collaborative," "purposeful," "respectful," "trustworthy," "negotiated," and "with humility and appreciation for difference." Across the SLR articles and the Delphi panelists contributions, we have identified attributes contributing to the success of interactions, which include levels of collaboration, trust, appreciation, and respect.

Level of Collaboration

Level of collaboration was the most frequently described or indicated form of interaction within the SLR, which included actors cooperating with each other or openly exchanging information. For example, Adams et al. (2011) used a community-based participation approach to assess and minimize town residents' exposure to pollutants. Similarly, LeVeaux et al. (2018) emphasized the importance of using community based participatory research as a strong collaborative tool for a research partnership between a Native American community and university researchers to disseminate water quality knowledge. In a citizen science program called Neighborhood Nestwatch, scientists from a research institute collaborated with local families to collect bird data in their yards (Evans et al., 2005). Likewise, Dietrich and Schibeci (2003) noted the importance of active consultation and inclusion of the Australian public's perception of using gene therapy technology. This aligns with a Delphi panelist's view about interactions being "a property of the collective that depends on effective communication and collaboration." Conversely, a study in north England found the lay public had strong concerns about the lack of inclusion and willingness "to recognise, encounter and accommodate multiple and diverse public values: related to fracking while developing policies" (Williams et al., 2017, p. 99). Along similar lines, Shaw (2002) reported a lack of open exchange of information perceived by the public in the UK's Bristol region when asked about their understanding of GM food.

Level of Trust

In the SLR, being able to trust the other party or entity was the next most commonly described characteristic of a successful interaction. This trust mainly referenced the nature of interactions between experts and non-experts or lay people. For example, some articles indicated that trust is a necessary element for the public to accept and understand science, science-based developments and interventions (Bromme & Beelmann, 2018; Pickersgill, 2011). Examining the role of communication on a sensitive topic such as climate change science, Spoel et al. (2009) pointed out, "the logos of the scientific narrative must be integrated with a trustworthy ethos to scaffold the understanding…" (p. 77). Similarly, Lewis et al. (2017) indicated that the public who were interested in watching scientific movies showed trust in the science experts who attended the film screenings and viewed them as sources of knowledge.

Conversely, lack or loss of trust was seen as detrimental for CSL. For example, in their study on report-backs of environmental exposure data, Adams et al. (2011) observed that “all participants expressed low levels of trust in industry and government officials and high levels of trust toward [an environmental justice organization] and [a non-profit center]” (p. 188). Kreimer (2015) indicated how the interaction of Latin American society with science was based on a loss of trust in relation to science and technology development in the 1990’s. Likewise, in a study about public perceptions of genetically modified food, Shaw (2002) mentioned, “issues of trust in scientists, industry representatives, and politicians were very evident as people talked about who should be responsible for managing the potential risks in GM food” (p. 285). Similarly, Allen (2017) reported that residents of a French industrial town did not find state sponsored health reports credible, thus indicating a lack of trust. Dietrich & Schibeci (2003) examined the Australian public’s perceptions of gene technology and emphasized that the public tends to distrust scientists, whom they believe do not prioritize citizens’ concerns.

Similar to the SLR articles, trust was a recurring theme among the Delphi panelists’ views on interactions among actors in the community. Some panelists mentioned that interactions are “contingent on trust” and that there is a need for communities to have “trust in scientific institutions” and to have “an ability to collaborate with trusted experts.” One panelist noted that being “trustworthy” is “what we can rely on as a community, something that is a ‘shared bet’ but grounded in those knowledge building practices.”

Level of Appreciation

A few articles noted a level of mutual appreciation of others’ resources (e.g., knowledge, skills, and attitudes); however, it was usually described as a unidirectional appreciation of scientists by the public. For example, Sadler (2007) indicated that students should be appreciative of values, norms, and practices of the scientific community. Holbrook and Rannikmae (2009) stated that the public needs to appreciate science and the nature of science, thereby implying that this appreciation is unidirectional and not required for the experts to possess. Some authors contended that informal science educators need to incorporate the changing nature of science research and results of ongoing research, so that the public in turn can appreciate the “role of controversy in shaping the research process rather than viewing it as an indication of poor science or befuddled scientists" (Field & Powell, 2001, p. 423).

In contrast, Kolstø (2001) highlighted the need for bidirectional appreciation between science experts and the public. The author asserted that scientists must appreciate anecdotal evidence pointing to the existence of a problem and citizens must appreciate scientists' need for statistical evidence. Similar to Kolstø (2001), Delphi panelists offered a more bidirectional view of appreciation, observing how interactions are "dependent on the type and qualitative nature of connections among people" and should be such that there is a "fostering of epistemic humility" about each other's ways of knowing. Another panelist mentioned that there should exist "an ability for a community to interact with institutions of science on their own terms."

Level of Respect

Few articles in the SLR mentioned having respectful interactions between actors in a specific context. Halverson and Tran (2010) asserted that it is important to have a prolonged and mutually respectful relationship for a scientist-educator partnership to promote scientific literacy. They emphasized that mutual respect between scientists and informal science educators can be promoted through a "culture of honesty, open dialog, careful listening, and by recognizing distributed expertise" (p. 277). However, some authors maintained their preference for a unidirectional form of respect directed from the public towards the scientists. For example, Miller (2001) argued that "scientists and laypeople are not on the same footing where scientific information is concerned, and knowledge, hard-won by hours of research, and tried and tested over the years and decades, deserves respect" (p. 118).

Contexts

CSL is situated within the different places and public spheres of communities and, therefore, is highly contextualized. The key role of context for CSL was emphasized in both the SLR and the Delphi analyses. CSL was described by Delphi panelists as being found in contexts that were "community driven," "community relevant," "embedded," "grounded," and "responsive to community." As such, CSL is "variable in form and content across contexts." In light of the highly situated nature of CSL, one Delphi participant cautioned, "my main point is to avoid defining CSL as a typology [because] it is a set of variations that will vary with the populations within the community under consideration." Given this concern, context is included as an element so that it can be fully considered. Therefore, a robust conceptualization of CSL includes the coupled nature of the physical and socio-cultural-historical contexts of the community.

Physical Contexts

Physical contexts encompass the location, whether it is a geographical place or a virtual space, where a community resides and/or operates. This location can range from a neighborhood or city to specific physical spaces, including traditional science settings like K-12 schools, universities, science labs, and science centers. It also extends to non-traditional science settings like family kitchens, dinner tables, and non-Western institutions. Additionally, physical contexts extend to virtual spaces where people gather, such as online forums like Facebook groups; participatory citizen science projects using phone apps; or web-based social media platforms like Twitter; as well as curated, crowdsourced sites like Wikipedia.

In the SLR literature, scientific literacy was described as existing mainly in contexts of structured places of science learning such as universities, schools, museums, and science centers. Specifically, articles discussed the role of museums in increasing geological literacy (Reis et al., 2014), the role of academic institutions and university researchers in teaching students about science journalism (Nicholas, 2017), and the importance of implementing Vision III of science literacy— "a transformative vision" such that scientific literacy promotes individual and collective level social activism—in school science (Valladares, 2021, p. 558). Some authors focused exclusively on how scientific literacy is enhanced in school settings through language (Kelly, 2007), the inclusion of socio-scientific and cultural issues (Zeidler, 2007; Sadler, 2007), and development of student interest and scientific competencies (Fensham, 2007).

Everyday science learning, extending beyond traditional academic or designed settings, was a key focus in several studies, exploring diverse environments such as family homes, parks, self-help forums, and community groups. Articles in this vein primarily delved into participatory science research within towns, with studies related to participatory water conservation (Roth & Desautels, 2004; Roth & Lee, 2002; Roth & Lee, 2004); ocean literacy in a coastal community (Ferreira et al., 2021); and environmental health literacy on a Native American reservation (LeVeaux et al., 2018), in American coastal towns (Adams et al., 2011), and in French industrial towns (Allen, 2017). A few articles focused on online settings, emphasizing the roles of websites, citizen science forums, and online video games in enhancing science learning (Aristeidou & Herodotou, 2020; Britt et al., 2014; Ledley et al., 2014; Marino & Hayes, 2012; Norman & Skinner, 2006).

Delphi participants mentioned that CSL can be expressed in non-academic settings such as when "families in the community are just as likely to talk about science-based topics at the dinner [table] as sports topics." Delphi panelists often mentioned locality in their responses, which was linked to the local physical content, often related to the local environment. For instance, CSL is "an understanding of how *local* environmental/science issues affect *local* natural resources" and "interest in *local* environmental/science issues" [emphasis added]. In addition, this physical context includes an ecological component as well as an integrated social component: "science literacy for me means people are contributors to that, from different socio-ecological locations." We address this social component in more detail next.

Socio-Cultural-Historical Contexts

In addition to a physical context, CSL is situated in the social, cultural, and historical contexts of the community. Social contexts include aspects of the community's economic and political systems, as well as shared cultural aspects of the community, such as race, ethnicity, language, and identity. It can also include histories of the community, with sensitivity to people who have been systematically marginalized and disempowered.

Socio-cultural settings were some of the most commonly studied and mentioned in the articles. Liu (2009) argued that "science literacy is never context free" (p. 306). Along similar lines, multiple articles described the contexts of their studies as one of the influencing factors. Shaw (2002) asserted that, "... people actively negotiate and construct their understandings of science, health and food safety within their immediate *social context* [emphasis added], shaped by wider social and political factors in society." (p. 275). One study emphasized the necessity of "greater awareness of the social context of science" for lay readers to be "effective consumers of scientific information" (Zimmerman et al., 2001, p. 37). The authors highlighted the importance of understanding the background of science institutions and researchers, since these social contexts can be used to judge the quality of research when presented in the popular press (Zimmerman et al., 2001).

Adams et al. (2011) asserted the importance of cultural and historical contexts in their environmental exposure study comparing two coastal towns, noting how one town's history of environmental justice issues was reflected in its activism and the other town's "distrust of industry" was reflected in its "reclusive culture" (p. 188). In a community-based participatory research study, tribal leaders formed a partnership with university researchers and made sure "to enhance the participants' understanding of the connection between water and health, history, and culture of the Apsáalooke people" (LaVeaux et al., 2018, p. 5). Delphi panelists echoed these thoughts, noting that CSL is "likely to take different forms in different cultural contexts." One expert stated that CSL is "embedded in my community's cultural epistemologies—it encompasses our lived science."

Contexts are Coupled

Lastly, physical and cultural contexts are coupled, meaning that they are to be approached holistically due to their nested nature and interdependence. Within the SLR articles, a few articles considered science learning occurring as interactions across contexts. Laugksch (2000) described the coupled nature of SL in terms of historical time, geography and societies:

> If it is accepted that scientific literacy is essentially a socially defined concept, it follows that the concept differs for different eras in time (e.g., pre- and post-nuclear age), geographical regions (e.g., heavy industry- and agriculture-based local economy), and communities or social conditions (e.g., suburban and informal or high-density housing). (p. 85)

Some of the Delphi panelists also highlighted the interaction and interdependence between contexts. One Delphi participant wrote, "science is experienced as connected to elements of community identity—whether geographical, cultural, racial, ethnic, interests, and more." Another panelist expanded upon this idea of coupled contexts:

> Community science literacy operates across scales of activity, including time and place, e.g., Is not confined to traditional places of science such as labs or classrooms; is not owned by/defined by/carried out by those traditionally labeled as scientists or as smart in science. Instead, an individual must be able to find science useful in the communities where s/he lives, works and cares.

Topics

We defined this element as the different types of issues for which CSL may be exhibited. While SLR articles and Delphi panelists mentioned very specific topics (e.g., environmental issues such as water and land use, community health issues such as mask use and vaccines), we attempted to identify their underlying features to create more generalizable characteristics of topics that would be suitable for CSL. As such, topics have high science salience, high social salience, and are salient across a community.

Topics have High Science Salience

Because we are characterizing community level *scientific* literacy, topics have a high *scientific* salience. In the SLR, topics included climate change (Bauer, 2009; Hicks, 2017; Ledley et al., 2014; Spoel et al., 2009), gene technology (Morosoli et al., 2019; Sadler, 2007), food safety (Jansen et al., 2020; Shaw, 2002), and nanoscience (Pouliot, 2015). A very few articles were related to the public's understanding of technology, including data storage (Zou & Yilmaz, 2010) and big data (Michael & Lupton, 2016).

Delphi panelists remarked that CSL is "not generic—at least somewhat specific to a science domain or topic" or for "an issue or problem that has a STEM dimension." However, it was also noted that while the topic is related to science, it is not the only dimension involved. As one panelist stated, CSL is "the ability of a community to discuss or respond to issues where science can play a role (but maybe not answer everything)—what role does science play in that conversation."

Topics have High Social Salience

CSL topics also have high social salience, in which politics, social justice, social challenges, and economics are all relevant, connected, and important. In the SLR, we came across myriad issues, related to science and society; often mutually entwined; and existing within communal, family, or group discussions due to their shared nature. Articles discussed scientific literacy related to a community's environmental health literacy (Adams et al., 2011; LaVeaux et al., 2018), public healthcare (Norman & Skinner, 2006), and how the public of a country responds to behavior genetics based on prior social norms and beliefs (Morosoli et al., 2019). Spoel et al. (2009) investigated the role of trust and social significance to improve public engagement in climate change science, asserting that:

> By educating public audiences about climate change issues in accessible, engaging, and meaningful ways, these rhetorical works enable the development of public expertise on a topic of deep *social and ethical as well as scientific significance* [emphasis added]: helping to give people the means to participate in intelligent, substantive conversation with others—whether that be family, friends, communities, environmental organizations, policy experts, or scientists—about climate change issues. (p. 51)

Delphi participants, many of whom are experts in science education, used the term "socioscientific" to describe the interplay between science and society. For instance, CSL is "being able to engage in conversation with family and friends about socioscientific issues relevant in one's community" and involves the "capacity to respond to socio-scientific issues."

Topics are Salient across the Community

Lastly, topics are salient *across* the community, in which issues involve common concerns and shared futures. Also, salience arises from relevance to the community, in that issues are community-identified, and solutions are community-driven. A few articles mentioned the need for CSL to make informed decisions that are directed toward solving problems faced by entire communities (Allen, 2017; Ferreira et al., 2021; LeVeaux et al., 2018). Roth and Lee (2002) suggested that instead of "privileging disciplinary science, we ought to foster situations that allow conversations to emerge in which different forms of knowledge are negotiated and geared to particular problems *as these arise in the daily life of a* *community* [emphasis added]" (p. 53).

In the Delphi surveys, participants commonly mentioned "relevance" to the community. For instance, one panelist stated that CSL is "scientific awareness and connection that is relevant to the community, not the scientific enterprise." Another mentioned that CSL is "shared understanding regarding the STEM-related issues that are relevant to their community." This relevance derives from usefulness in a community's everyday life; CSL is evident when "members of a given community apply scientific concepts, practices and skills to their everyday life." A similar phrasing of "real world" problems expands on the notion that relevance pertains to practicality and usefulness. CSL is "a collective understanding of the value of scientific understanding and how it can be applied to real world problems faced by the community."

Purposes

We defined purposes as the goals or outcomes of communities that exhibit CSL. To understand how communities expressed CSL, we sought to characterize how and why they are using the different resources which are situated across the actors. Across the SLR and Delphi data, purposes are characterized as defined by the community, solutions and action-oriented, and socially just.

Purposes are Defined by the Community

A small number of articles identified the purpose as defined by the community, based on the community's goals and needs. Based on their ethnographic study about a community's water-related problems, Roth and Lee (2002) stated that "people learn by participating in activities that are meaningful because they serve general, common interests and thus contribute to the community at large, rather than making learning a goal of its own" (p. 34).

Similarly, Delphi panelists mentioned that CSL means "sharing common goals and questions" and its purposes showcase "the capacity of a community to use science to address issues of common concern." Another panelist noted that CSL is exhibited "when a community has the collective ability to help shape scientific research that meets its needs" and when "[a] community is positioned [to] collectively mobilize scientific knowledge and resources to advance their needs/goals." One panelist mentioned that CSL means "providing knowledge, tools and skills of science to a community so they can decide what community issues need to be addressed for the well-being of the larger group." Another panelist mentioned a similar purpose of CSL——that it is useful for "promoting science practices by respecting community practices and knowledge that is for the betterment of the community." Our panelists were thus indicating that those in the communities should be defining the purposes such that they are supportive of common goals and advance the community. This purpose is illustrated by a Delphi panelist who mentioned that CSL:

> Involves collective activity rather than individual cognition. The focus here on activity is important. Collective science literacy involves learning by participating in activities that are meaningful and consequential to people because they serve general, common interests and thus contribute to the community at large, rather than making learning a goal of its own.

Purposes are Solutions and Action Oriented

Purposes are useful and beneficial for the community, geared towards solutions and action. SLR articles mentioned that CSL is used to find solutions to common problems (Roth & Lee, 2002), to learn from each other (Halverson & Tran, 2010), and to communicate science knowledge for solving socio-scientific issues (Kolstø, 2001). Nicholas (2017) advocated forming Communities of Practice "that solve real-world problems and address issues like sustainability, health, and environmental justice" (p. 293). Henrikson and Frøyland (2000) stated, "being scientifically literate means not only having an understanding of a range of scientific concepts and processes, but also *being able to apply this understanding* [emphasis added], together with one's own experience and values, to a range of science-related matters in private or civic life" (p. 393).

Likewise, Delphi panelists mentioned the purpose of CSL is to be "goal oriented," "impactful," and involve "taking action on local environmental/science issues." One Delphi panelist noted that the purpose of CSL can be "supportive of participation in science—engagement with science, citizen science, participatory science–to support science research." However, the purpose can also serve the community. As one Delphi panelist noted that "members of the community make evidence-based personal decisions that impact the community (e.g., decide to use masks or get vaccines because it is good for the community).” Panelists also noted that when CSL is expressed it “involves bringing together different kinds of resources, discursive, epistemic, material, social, cultural, all towards people engaging in everyday collective decision-making processes” and that it is “obviously not a latent property—it may not develop until the issue or problem arises.”

Purposes are Socially Just

CSL is often expressed within a neighborhood or community with the intention of achieving community level change and well-being. This was indicated in some articles of the SLR which highlighted the outcomes of using CSL as promoting positive change which was equitable and just. One study promoted knowledge of sustainable development through a community beach clean-up (Ferreira et al., 2021). The authors described how marine literacy education content was developed for and with the community and made accessible to all members of the community, across several schools and free public spaces to enable “other elements of society to contact with the exhibition” (Ferreira et al., 2021, p. 10). Some articles in the SLR described the importance of CSL as being particularly supportive towards the marginalized and disadvantaged. Noting the need for individual and collective agency, Valladares (2021) cautioned against considering science education and literacy as a liberating and empowering force, which can easily tend towards “scientism and neocolonialism” (p. 581). Rather, the author supported a transformative type of scientific literacy that:

> Allow[s] students to understand, value, and relate to the world differently in their everyday lives, not only through canonic scientific ideas, but (a) fostering the dialogical and respectful exchange of diverse perspectives on the social and natural world; (b) taking advantage of the best of the different alternative forms of knowledge; and (c) cultivating their engagement, both with science and with their communities and cultures of origin. (p. 581)

Along similar lines, a Delphi panelist specified that “the key [to CSL] is [that] the community needs to drive the nature and practices of science that values community knowledge and practices *for social justice and equity* [emphasis added].” Additionally, CSL is “the ability of the community to propose, explore, and find potential solutions that the community needs for its well-being." Another panelist succinctly noted the overall purpose of possessing CSL is "thriving—doing more than surviving and getting by, flourishing in the sense of being happy, convivial, deeply connected to the cosmos."

Continuing Challenges with the Conceptualization of CSL

In survey #2 of the Delphi study, participants were asked their level of satisfaction with the definitions of each element as well as how important they saw each element as part of a complete conceptualization of CSL (see Table 4). The results indicated an average level of satisfaction that ranged between "neutral" and "somewhat satisfied," with a standard deviation ranging from 0.8 to 1.3. Participants saw high levels of importance for each element, ranging from "very" to "extremely" important, with a standard deviation ranging from 0.7 to 1.2. Overall, these results indicated that while participants agreed that most of these elements were important, there was less agreement about whether the definitions for each element were complete. Participants offered suggested changes and considerations to the definitions of each element, which were incorporated into the version presented in this paper.

Table 4

Delphi Survey #2 Quantitative Data

Element of CSL	Satisfaction Mean (SD)	Importance Mean (SD)
Resources	3.6 (1.3)	4.4 (0.7)
Attributes of Resources	3.8 (1.0)	4.1 (0.9)
Actors	3.6 (1.0)	4.2 (0.7)
Interactions among Actors	3.9 (0.8)	4.2 (0.8)
Contexts	3.7 (0.9)	3.7 (1.2)
Topics	3.8 (0.9)	4.0 (1.1)
Purposes	3.8 (1.2)	3.9 (1.1)

Of note, Delphi participants identified continuing challenges with conceptualizing CSL. For instance, they noted that this topic is "difficult to study" and "not well defined in [W]estern academia…in this case, they are closed minded to what definitions are accepted." One participant expanded on the divergent and interdisciplinary nature of CSL, stating:

> I am enough of a materialist and political scientist that CSL is not some form of knowledge or understanding that abstractly floats above a group of people. There seem to be some esoterically-influenced notions of this kind. For me, CSL defines itself best from the literature of political science, sociology and anthropology; it acknowledges the existence of the polis, and the various ways in which we think about group-based decision-making…CSL is an aspect of this work. It is neither new nor does it locate itself in the realm of education, learning or individual knowledge, understanding and capacity. But without understanding individuals as elements of a social decision-making system, and the complex social dynamic associated with that, it also fails to see the full picture.

It is our hope that this paper meets this challenge, serving as an initial attempt to articulate a full picture of the constructs and characteristics comprising CSL.

Discussion

Given the predominant conceptualization of science literacy at the micro scale of the individual, the purpose of this paper was to conceptualize scientific literacy at the meso scale of the community. While NASEM (2016) argued that CSL is important, the committee also acknowledged that this area is understudied and undertheorized. In particular, they identified that we need more work to assess CSL. However, in order to build a program of work around the measurement of CSL, we need to clearly define its constituent components. In this paper, we drew upon the existing literature base and a panel of experts to articulate the constructs of CSL. From data analyses and guidance from CHAT, we developed seven elements of CSL: resources, attributes of those resources, actors, interactions between actors, contexts, topics, and purposes. Characteristics for each of these elements were further described, with supporting evidence from the SLR articles and the Delphi participants. The resulting framework has the potential to serve as a foundation for further discussion, refinement, and research within the field.

Across the SLR and the Delphi method study, several similarities and differences in conceptualizations of CSL arose. First, the SLR articles overwhelmingly described the collective aspect of CSL as the aggregate of individuals. Whereas, the Delphi participants took a more holistic approach, conceiving of the community as an entity of its own. In general, Delphi participants took a strong stance that CSL is much more than the aggregate—that it is more than the sum of its parts. Second, scientific knowledge is an important resource for CSL. This holds with decades of published research and thinking on scientific literacy (e.g., DeBoer, 2000). However, Delphi participants emphasized other ways of knowing, presenting community knowledge as complementary to scientific knowledge. Furthermore, Delphi panelists described CSL as particularly sensitive to social embeddedness and inclusive of social power and capacity. Third, while these resources could be said to reside within individuals, CSL acknowledges the relational aspects of how these resources sit within and between individuals in a group. Both the SLR articles and the Delphi participants described the diverse, distributed, accessible, and dynamic nature of knowledge, attitudes, and skills. These relational characteristics are what set CSL apart from individual level scientific literacy. Hence, CSL also considers actors and their interactions with one another. Furthermore, both the SLR and the Delphi participants centered the contextual features of the community, setting social relationships and histories within the physical place. Lastly, a common critique of science literacy is that it suffers from being not "useful" both in terms of a driving concept for the field as well as for how people tend to live their daily lives (Feinstein, 2011). Both the SLR articles and the Delphi participants described the purposes of CSL. They argued that purposes are driven by the community and are oriented towards solutions or actions. Furthermore, Delphi panelists emphasized that these purposes should support social justice and well-being. These latter goals echo calls in the literature to reconsider the role of science education in schooling (e.g., Dimick, 2012; Donovan, 2016) as well as science learning in out-of-school settings (e.g., Calabrese Barton et al., 2021; Dawson, 2017) as a lever to promote social justice.

In conclusion, rather than an aggregate perspective, this paper offers a *relational* definition of community scientific literacy: whereby groups of people interact with one another to exchange their contextually situated resources and enact socially-just solutions for shared and commonly identified socio-scientific problems. While science knowledge, attitudes, and skills still hold prominence (much like an individual-level perspective of scientific literacy), this conceptualization of CSL also includes resources such as indigenous or non-Western ways of knowing, knowledge of the community, and social capital. Most importantly, these resources are considered communally rather than as possessions of individuals. Resources are diverse and interdependent, heterogeneously distributed, accessible among those in the community, and dynamically changing. When considering scientific literacy at a community level, it is imperative to delineate the "community." In this paper, we consider characteristics of the actors who comprise the community: actors are bounded in some way, such as through a common geographical location or a shared affinity, interest, or practice; actors are multigenerational and serve in various roles within the community; and actors can also include structured social groups and organizations. For these actors to mutually engage with one another, one must consider the degree to which there are opportunities for collaboration as well as feelings of trust, respect, and appreciation. CSL is highly contextualized, where resources and actors are embedded within the coupled biophysical environment and socio-cultural-historical background. CSL is best suited for topics that have both a scientific and a social component and are salient across the community. Lastly, CSL is driven by purpose; purposes are community-driven, oriented to action and solution-seeking, with impacts that are socially just and lead to community thriving.

This collective perspective of scientific literacy demands reimagining ways to support the development of CSL, both in as well as out of school, and to create and implement new forms of its measurement. For example, those who work in formal K-12 settings may ask: What does school science look like if, in addition to individual level scientific literacy, our goal was to support CSL? Or for those who work in out-of-school settings, one may ask: How might we restructure informal science education programs to also foster CSL? In addition, there are ongoing implications for research that attempts to measure or assess CSL in ecologically valid ways that honor its highly contextualized and relational nature. Given the many collective challenges that humanity faces—such as climate change, pandemics, and pollution—CSL offers a novel and needed reconceptualization of what the goals of science education and learning could be. The hope is that this paper offers a foundation for continued research and discussion about what comprises CSL and how it can be fostered and assessed.

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