Chapter 1

Computational Thinking and Social Studies Teacher Education:

What, Why, and How

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ABSTRACT

Computational thinking is highly applicable to social studies education, particularly decision-focused social studies. To better fit the disciplinary needs of social studies and align with social studies standards, we adapt and group computational thinking skills into a heuristic of data, patterns, rules, and questions (DPR-Q). We then propose a four-step model for social studies teachers to follow when planning lessons that integrate computational thinking within their curricular instruction. Both the DPR-Q heuristic and the instructional planning model are explained with worked examples from social studies classrooms. Successful integration of computational thinking into decision-focused social studies can both enrich the social studies curriculum and provide a curricular home for teaching computational thinking, bearing out Wing's claim that computational thinking is 'everywhere' and 'for everyone.'

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INTRODUCTION

Computational thinking and social studies may appear to be an odd pairing. The social studies lessons presented in elementary, middle, and high school classrooms can serve many purposes (see, for example, Barton & Levstik, 2004), but none emphasize computational thinking. However, the work of social scientists—economists, political scientists, geographers, and historians—increasingly involves the application of computational thinking. Historian Ed Ayers has called for a new, technology-enabled approach to social history (Ayers, 1999). Geographers have identified a new construct of geo-computational thinking (O'Sullivan, 1999). In this chapter, we explore the rationale, means, and processes for integrating computational thinking within social studies instruction.

WHY?

For the past two decades, social studies have faced a crisis of relevancy, squeezed first by the pressures of the No Child Left Behind Act, then by the ascendance of perceived high-value fields such as STEM (Fitchett & Heafner, 2010). In the current policy climate, then, social studies are not seen as essential--it is not part of workforce preparation, it does not prepare students for high-stakes assessments, and it does not speak to the other parts of the school curriculum. In fact, in one of our local school districts, social studies have been subsumed under literacy instruction; it has become secondary within the district's K-12 curriculum and not a priority in its own right. Our concern over this de-emphasis of social studies is further amplified by the fact that our current politics, news, and economy are in a state of tremendous confusion and polarization: Amid so many claims of "fake news" what is real news? In a time of economic mixed signals—low unemployment and high corporate profits versus stagnant wages and rising costs of housing and healthcare—which policies and parties should one choose to support? Do extreme weather events correlate with the onset of catastrophic climate change or are they merely outliers in the distribution of normal weather patterns? The many fault lines of contemporary politics demonstrate the truth of James Russell Lowell's famous distillation, that American democracy is not "a machine that would go of itself" (Moss, 2017). Social studies is needed now as much or more than ever to help students make sense of the society they are inheriting, and computational thinking can play a vital role.

Computational thinking can assist social studies educators in at least two ways. First, computational thinking is a highly valued STEM skill that is central to 21st century education (Dede, Mishra, & Voogt, 2013; Voogt, Fisser, Good, Mishra, & Yadav, 2015). For example, the International Society for Technology in Education (ISTE) has published computer science competencies for educators (ISTE, 2018), the culmination of a long-running effort funded by the National Science Foundation to bring computational thinking to life in K-12 classrooms (Barr, Harrison, & Conery, 2011). The STEM applications of computational thinking can therefore make a case to an audience that might not be as influenced by social studies' mission of civic preparation. Second, computational thinking can assist social studies teachers as they work in a curricular context which features expanding opportunities to use data and computing technologies. Examples abound: when studying the Great Depression, students can access a searchable database, posted at Lehigh University, of FDR's correspondence with the public, mapping the interactions by population density, proximity to radio stations, and time period, all indexed by the themes of Roosevelt's Fireside Chats (https://gisweb2.cc.lehigh.edu/fdr/). When studying terrorism, social studies teachers can make use of the Global Terrorism Database hosted by the University of Maryland (https://

www.start.umd.edu/gtd/), featuring data from 1970 to the present. Through the University of Minnesota's National Historical Geographic Information System (https://www.nhgis.org/), teachers and students can download census data and maps from any time period in U.S. history. Many readers will also be familiar with GapMinder (https://www.gapminder.org/), which provides visualizations and datasets for a wide range of global issues, from climate to health to economic indicators to infrastructure and more. Social studies educators have access to an ever-expanding set of data and tools with which to interpret this data; computational thinking can provide a framework for social studies teachers and students to use when connecting to these resources to reach new and powerful understandings of social studies topics.

Perhaps surprisingly, social studies can also benefit the field of computational thinking. First, social studies can provide a curricular home for the integration of computational thinking into K-12 instruction. The lack of emphasis on social studies in high-stakes assessment works to the advantage of computational thinking—a teacher or administrator may resist devoting time to computational thinking in mathematics, English/Language Arts, or science, given that these fields are subject to end-of-year, publicly-reported assessments. Why allocate precious instructional minutes to this topic? Conversely, social studies can provide that opportunity for curricular integration, particularly if the integration can connect to the academic and civic aims of social studies education. Second, the integration of computational thinking into social studies makes clear that computational thinking is a means to an end rather than an end in and of itself. The purpose of learning about computational thinking is to make better use of computational procedures and tools to solve problems. What a student learns about computational thinking in a social studies classroom is intended for transfer and translation into other contexts, whether other academic areas, workforce applications, civic life, or even personal decision-making.

WHAT?

Combining social studies and computational thinking literature requires making choices about *what kind* of social studies and *what kind* of computational thinking can combine and synergize. From the social studies literature, we adopt Engle's (1960) concept of decision-focused social studies. According to Engle, decision-making is the "heart of social studies" and takes place "at two levels: at the level of deciding what a group of descriptive data means…[and] at the level of policy determination" (p. 301). At either level, decision-making provides a point of focus that is appropriate to social studies education as well as the application of computational thinking. Furthermore, decision-making spans the many disciplinary boundaries within social studies—history, geography, civics, economics, and more—and thus allows for consistent integration of computational thinking for any topic.

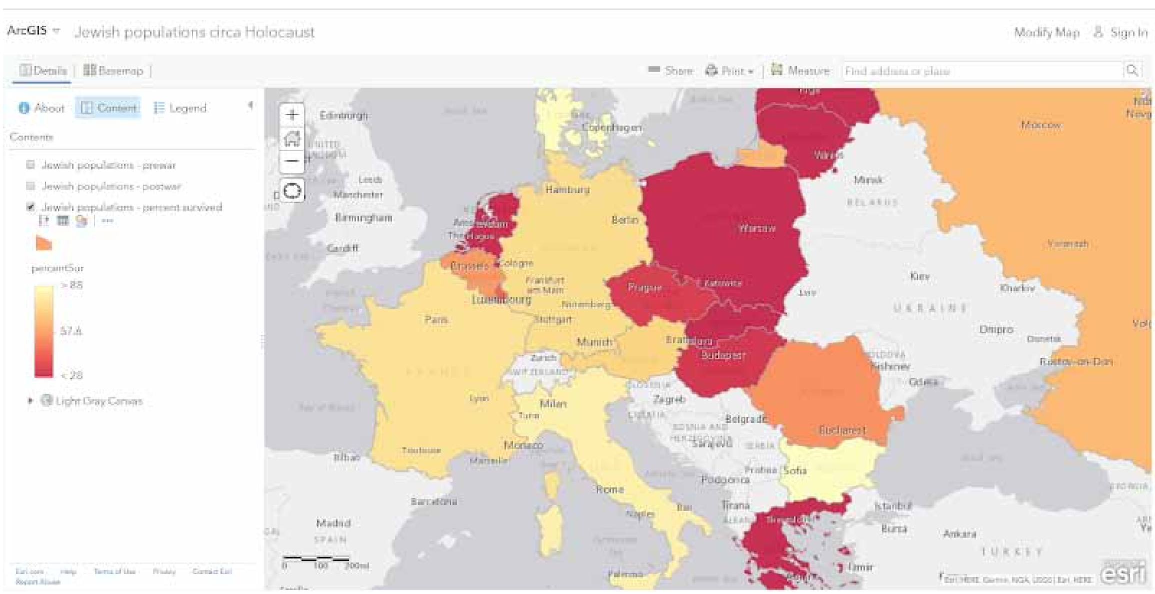
The question of what definition of computational thinking to use requires more thought. Wing's (2006) original formulation, which is often cited as the foundational framework for computational thinking, is highly technical and speaks almost solely to computer science. For example, she (2008) argues, "even at early grades we can viscerally show the difference between a polynomial-time algorithm and an exponential-time one" (p. 3721). Wing's argument is that computational thinking is "everywhere" and "for everyone." However, her framework is not highly accessible or relevant to social studies, which has specific disciplinary needs across its multiple curricular contexts: history, geography, economics, and more. Accordingly, we have selected and adapted a list of computational thinking skills for social studies purposes (see Table 1).

Table 1. Elements of computational thinking, selected and adapted for social studies purposes

Selected Elements of Computational Thinking*	**…Adapted and Explained for Social Studies**
• Symbol systems & representations • Abstractions & pattern generalizations • Algorithmic notions of flow control • Structured problem decomposition • Debugging & systematic error detection	→ Data definition: *What is being included? What is being excluded?* → Pattern recognition & generalization: *What do I see? Does it apply elsewhere?* → Abstraction: *Can I remove detail to make it easier to see patterns or connections?* → Rule-making: *Does a pattern* always *apply? Can it predict what will happen in a new situation?* → Automation: *Can technology help me identify or confirm a pattern?* → Decomposition: *Can I break this question or dataset into smaller parts?* → Outlier analysis: *Which parts of the data do not follow the pattern? What can they tell us?*

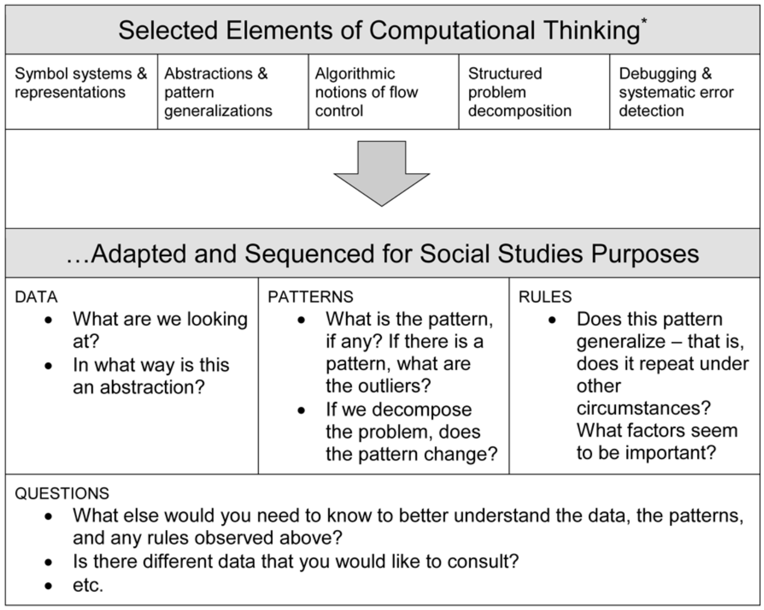
* Selections drawn from Grover & Pea (2013)

Figure 1: Map of Europe color-coded by survival rate of Jewish population through the Holocaust: Red = low survival / high mortality; yellow = high survival / low mortality. Population data drawn from Yad Vashem and mapped by authors. Interactive map available at https://arcg.is/1KnDSu



To illustrate the application of these computational thinking skills to social studies, we provide a worked example, drawing upon a familiar and vital social studies topic, the Holocaust. Figure 1, below, presents a map of European nations color-coded by the percent of the Jewish population that survived the Holocaust. The map itself is an *abstraction*, a simplification of the actual territory. The data displayed on the map is a *decomposition*--it sets aside the many complex variables of demography and focuses solely on the binary outcome of whether a person lived or died during the Holocaust. From this data display, students can begin to identify *patterns*--the Holocaust was far more deadly in eastern Europe

Figure 2. Adaptation and sequencing of selected computational thinking elements for the purposes of social studies instruction
** Selections drawn from Grover & Pea (2013).*



(Latvia, Lithuania, Poland, Czech Republic, Slovakia, and Hungary) than in western Europe. The map also raises questions that invite a different decomposition or level of abstraction:

Why was Belgium so much deadlier than the Netherlands?

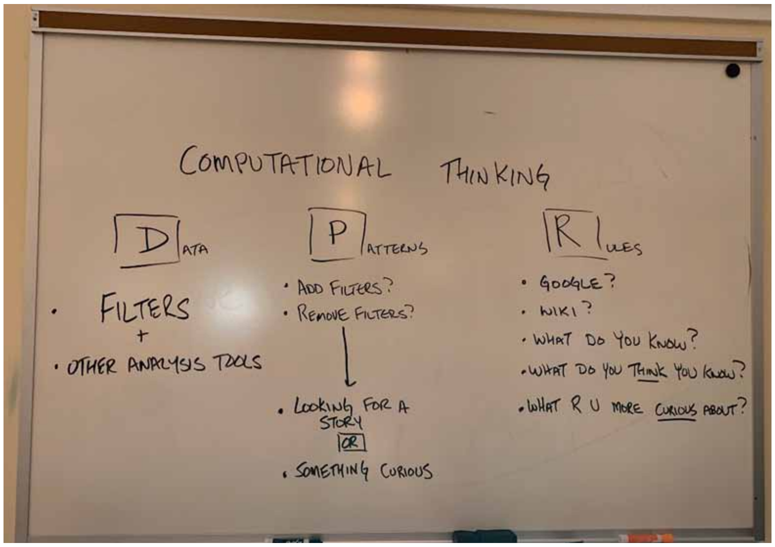
Why were Jews in Germany--within the epicenter of the genocide--able to survive at higher rates than in most adjacent areas?

To answer these questions, students will have to shift to less abstract, more detailed examinations (such as the life of Anne Frank) and bring in additional variables (a more urban and cosmopolitan Jewish community in Germany versus a more rural and isolated Jewish population in Poland). As the students work with these questions, they will engage in further pattern-recognition: the survival of the Jewish population goes up when the Nazi forces did not occupy the entire territory (for example, France and Italy) or where local governments limited their cooperation with the Nazis (Bulgaria).

After making the necessary selections and adaptations, the final step for teacher educators is to make computational thinking accessible to pre-service or in-service teachers. The complexity of computational thinking needs to be encapsulated in such a way that teachers can understand it, apply it authentically to social studies topics, and integrate it into their instructional practice. We have created a formulation of "Data, Patterns, Rules and Questions" (DPR-Q) as our heuristic for integrating computational thinking into social studies teacher education (See Figure 2).

To unpack this compressed version of computational thinking, we return to the Holocaust example. The first step is for students to understand the dataset being displayed. This takes place first at the level of the

Figure 3. Example board work following the DPR-Q approach for integrating computational thinking into a social studies lesson using a GIS



map -- Is the map shown accurate to the political borders in 1936? 1938? 1942? During the actual historical event, borders shifted as countries were conquered or absorbed; accordingly, any map that attempts to summarize the entire time period is necessarily inaccurate. The second layer of data to understand is the demographics displayed on the map, and particularly its source. As one example, consider the data for Bulgaria: out of a prewar population of fifty thousand, zero Jews were killed by the Nazis. This is a highly surprising fact for most learners, and may even arouse suspicions regarding its accuracy—how is it possible that such a deadly event left one population entirely unscathed? If nothing else, the data might be in error. In this case, the numbers are drawn from Yad Vashem, the most authoritative source for the Jewish experience during the Holocaust (https://www.yadvashem.org/holocaust/faqs.html). Given the source, this data can be trusted, or at least viewed as more trustworthy than other sources on this topic.

Once students understand the data, they next turn to patterns to ask: what is the main trend? In the case, there is a spatial gradient, in which the experience in eastern and central Europe was different than elsewhere. After the main trend, students can look for outliers, such as the Netherlands or Bulgaria, and more subtle patterns, such as collaborationist versus resistant governments. The third stage, exploring rules, allows teachers to connect across social studies topics. Questions raised might include: How does a genocide such as the Holocaust compare to the demographic collapse of indigenous Americans once European colonization began? The experience of enslaved Africans during the Middle Passage? Or how does it compare to other modern acts of genocide, such as the massacre of Tutsis in Rwanda? All of these steps involve decision-making at the level of data interpretation. At the rule-making level, however, teachers have the opportunity to engage students in decision-making as policy determination--what policies can be put in place to prevent genocide? Under what circumstances can they be invoked?

Throughout the entire process, the teacher and students are engaged in questioning. According to Engle (1960)

Table 2. Alignment between DPR-Q heuristic for computational thinking adapted for social studies and the C3 framework

	Data	**Patterns**	**Rules**
Adapted Elements of Computational thinking	• What are we looking at? • In what ways is this an abstraction?	• What is the trend? What are the outliers? • Decompose the problem.	• Does this pattern generalize/repeat under other circumstances?
Features of the C3 Framework	• Supporting **Questions** • Featured sources	• Formative performance tasks	• Summative performance task • Taking informed action

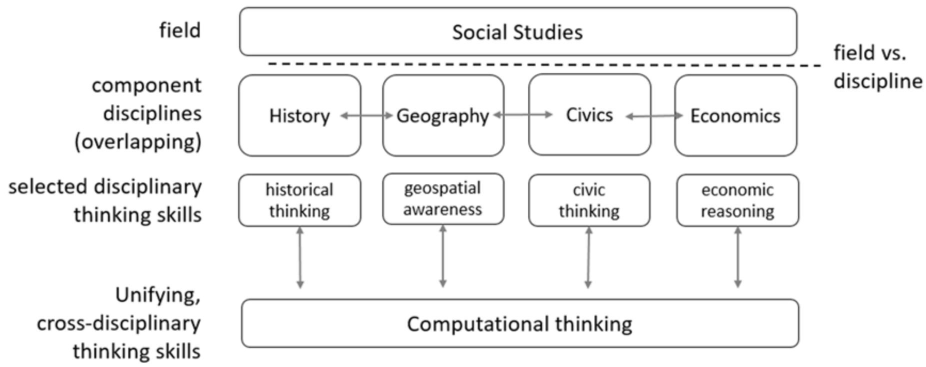
In marked contrast to the meticulous research orientation of the social sciences, the social studies are centrally concerned with the education of citizens. The mark of the good citizen is the quality of decisions which he reaches on public and private matters of social concerns. (p. 7)

Exploring data, therefore is a complex, highly open-ended process. Overall, "A social problem requires that the citizen put together, from many sources, information and values which the social sciences treat in relative isolation" (p. 7). Accordingly, we have added the element of "Questions." While this is not, strictly speaking, a traceable element of computational thinking, it is an appropriate adaptation for social studies purposes. Given that computational thinking will be applied to data sets, we must keep in mind that data *about* the people and places discussed in social studies are not to be confused with the people and places themselves. Recall, for example, Korzybski's aphorism that "the map is not the territory"—the abstraction (the map, a simplification of reality) should not occlude the thing itself (the territory, a far more complex object and one that cannot be reduced to a representation without losing at least some of that complexity). Accordingly, social studies students should not only engage in questioning *during* a computational thinking activity but also at its culmination: What do we wish we knew to better understand what we just observed? What new data would we like to obtain? In what ways, perhaps, is the territory different than the map we just studied? Figure 3 (below) provides an example of a teacher's whiteboard after once such sequence (data, pattern, rules), culminating in questions.

This DPR-Q heuristic serves at least two purposes for social studies education. First, it simplifies and sequences the application of computational thinking to a social studies topic—the heuristic is itself "a series of ordered steps" that enacts algorithmic thinking (Barr et al., 2011, p. 21). Second, the focus on decision making through questioning aligns with the *College, Career, and Civic Life (C3) Framework* (NCSS, 2013) for social studies instruction. C3 inquiries are organized according to an inquiry design model (IDM) which includes an overarching compelling questions, addressed through a series of supporting questions. In order for the questions to be compelling they must pose substantial issues of social concern. The final stage of C3 inquiry is engaging in civic action. IDM alludes to computational thinking to the extent that students must reference sources to develop arguments. Describing the *C3 Framework*, Parker (2019) asserts:

But when we teach for inquiry, we aim to develop students' ability to engage in this way of thinking: to make evidence-based arguments, whatever the content…the inquiry process becomes an end in itself, an instructional goal valued for the kind of reasoning it cultivates. (italics in original, p. 1)

Figure 4. Social studies as a single field vs. overlapping disciplines; computational thinking as a unifying thinking skill across the component disciplines of social studies

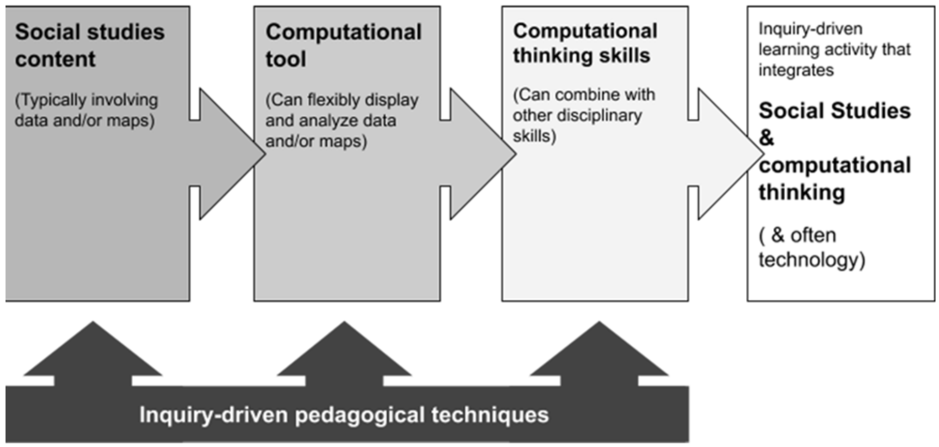


Teachers can more explicitly connect computational thinking to the *C3 Framework* by integrating the Data, Patterns, Rules and Questions heuristic as the formative instructional tasks students pursue to answer the compelling question. (See Table 2, below.)

By helping students think differently about the skills they are required to use to compete learning tasks associated with the *C3 Framework*, teachers can guide students more purposefully and effectively through the IDM. For example, by approaching the supporting questions and featured sources through a focus on data, students will come to see the featured sources (primary and secondary sources) for what they are -- the building blocks/evidence of a pattern or generalization that need to be analyzed, categorized, and compared. By asking questions such as "Can I remove detail to make it easier to see patterns or connections?" they move towards abstraction. This enables students to complete the formative performance tasks; students identify trends and outliers, decomposing the problem posed into its essential features. For instance asking, "How can I break this question or dataset into smaller parts?"—the decomposition may help them to see a pattern more clearly. As they work through the supporting questions and formative performance tasks, students return to the compelling question posed in the C3 inquiry to complete a summative performance tasks and, based on the argument they build, take informed action beyond the classroom. This process involves rule making and pattern generalization. For instance asking: "Does a pattern always apply? Can it predict what will happen in a new situation?" Here computational thinking provides a heuristic to support C3 inquiry, aligning each component of the IDM with computational thinking skills. Through this approach teachers can more explicitly guide student thinking.

In addition to connecting to the *C3 framework* and the inquiry design model, computational thinking can unify the disparate thinking skills associated with the social studies disciplines. While social studies comprises a single *field*, studying the human experience across a wide variety of historical and social contexts, it is made up of a variety of distinct *disciplines*, typically identified as history, geography, civics, and economics. These disciplines, in fact, preceded the creation of social studies as a school subject; as a result, in some contexts, social studies is referred to as "history and allied subjects" (Thornton, 2017, p. 11). Consequently, social studies teachers and students may struggle to hold the aims of the field in focus while at the same time engaging with a discipline-specific course such as a history class, or to make

Figure 5. Proposed instructional decision-making model for integrating computational thinking into inquiry-driven social studies



connections from one discipline to the next. In this context, computational thinking can assist teachers in making these connections by acting as a unifying framework that ties together the distinct, disciplinary thinking skills embedded within social studies coursework (see Figure 4, below). This integration is possible because computational thinking—once adapted for social studies purposes—complements or re-frames the disciplinary thinking.

To provide an example of integrating disciplinary thinking and computational thinking, we can select history as the precursor and dominant discipline within social studies. Historical thinking requires distinguishing between 'the past' (what happened) and 'history' (claims about what happened). Historical thinking proceeds through iterative stages including considering historical sources of information, evaluating these sources' status as evidence, and constructing one's own interpretation of the past (VanSledright, 2004). Historical thinking inter-operates with computational thinking starting with the data stage: what is the data with which one engages in historical thinking? Primary sources documents, artifacts, and geographic or geological evidence comprise the dataset that we use to know about and interpret the past. Within these data points, we then dig deeper into defining them: Who produced this primary source? When? Why? For what audience? How does this context influence the information it presents or the claims it makes? Next, students engage in Pattern-seeking as they work across different pieces of data to seek corroboration—for example, how do the American versus the British accounts of the Battle of Lexington agree or disagree? (For a detailed examination of this illustrative example, see Cowgill & Waring, 2017.) As students reach a conclusion about a historical topic, they are constructing a Rule, a claim about what happened and what it means. Throughout the process they will engage in Questioning and should conclude with further questions—after all, history is open-ended both as new events take place and as new evidence or new interpretations come to light to re-shape our understandings of the past.

Table 3. Colony names, sources, and categorizations as exonym or endonyms

State name	Source*	Categorization
Connecticut	From an Algonquian word (Quinnehtukqut) meaning "beside the long tidal river"	Endonym: Indigenous place name adopted by colonizers
Delaware	From Delaware River and Bay; named in turn for Sir Thomas West, Baron De La Warr	Exonym: Colonizer place name derived from patron
Georgia	In honor of George II of England	Exonym: Colonizer place name derived from patron
Maryland	In honor of Henrietta Maria (queen of Charles I of England)	Exonym: Colonizer place name derived from patron
Massachusetts	From the Massachusett people, whose endonym means "people of the great hills"	Endonym: Indigenous group name adopted by colonizers as a place name
New Hampshire	From the English county of Hampshire	Exonym: Colonizer place name referencing a location in Europe
New Jersey	From the Channel Isle of Jersey	Exonym: Colonizer place name referencing a location in Europe
New York	In honor of the Duke of York	Exonym: Colonizer place name derived from patron
North Carolina	In honor of Charles I of England	Exonym: Colonizer place name derived from patron
Pennsylvania	In honor of Admiral Sir William Penn, father of William Penn. It means "Penn's Woodland"	Exonym: Colonizer place name derived from patron
Rhode Island	From the Greek Island of Rhodes	Exonym: Colonizer place name referencing a location in Europe
South Carolina	In honor of Charles I of England	Exonym: Colonizer place name derived from patron
Virginia	In honor of Elizabeth "Virgin Queen" of England	Exonym: Colonizer place name derived from patron

* Source information retrieved from https://www.infoplease.com/us/states/origin-of-state-names

HOW?

The three previous conclusions—the synergy between decision-focused social studies and computational thinking; the adaptation of computational thinking into a heuristic of Data, Patterns, Rules, and Questions; and the alignment between DPR-Q and inquiry-driven social studies instruction—highlighted the need for an instructional decision-making model for social studies teachers to integrate computational thinking into their lessons. Given the many points of connection and interaction across computational thinking, inquiry learning, and the specific social studies content under instruction, teachers can greatly benefit from an organized sequence of planning a lesson that integrates computational thinking. This sequence should also include attention to instructional technology, as most—if not all—integrations of computational thinking will involve the use of at least one form of technology.

Our proposed model (see Figure 5, below) consists of four steps, starting with the close consideration of the specific social studies topic under instruction. Given that computational thinking requires data and often maps, the teacher should consider what available datasets and/or maps are relevant for the topic and accessible for the students. Note that these datasets can be extremely simple. Consider, as an example, the dates of settlement of the three main cities along the Lehigh River: Easton in 1739, then Bethlehem in 1741, then Allentown in 1762. All three cities are in sequence in terms of time but also geographic orientation: each city was founded further upstream than its predecessors, and each city sits at the confluence of two or more waterways. This small dataset provides an opportunity to apply the central ideas of

Figure 6. Colony name derivations sorted and color-coded in a spreadsheet

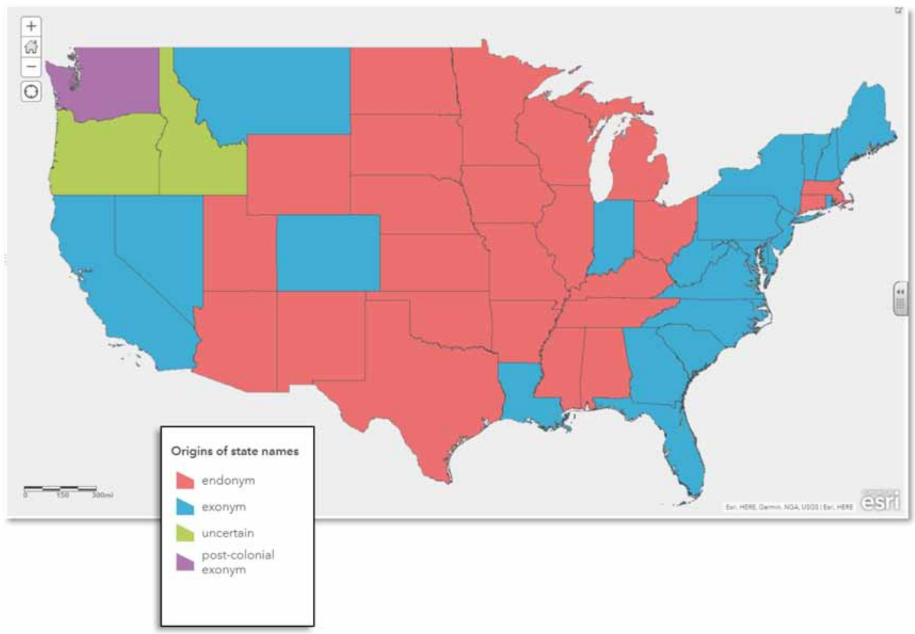
Colony name	Category	Explanation
Connecticut	endonym	Indigenous place name adopted by colonizers
Massachusetts	endonym	Indigenous group name adopted by colonizers as a place name
Delaware	exonym	Colonizer place name derived from patron
Georgia	exonym	Colonizer place name derived from patron
Maryland	exonym	Colonizer place name derived from patron
New York	exonym	Colonizer place name derived from patron
North Carolina	exonym	Colonizer place name derived from patron
Pennsylvania	exonym	Colonizer place name derived from patron
South Carolina	exonym	Colonizer place name derived from patron
Virginia	exonym	Colonizer place name derived from patron
New Hampshire	exonym	Colonizer place name referencing a location in Europe
New Jersey	exonym	Colonizer place name referencing a location in Europe
Rhode Island	exonym	Colonizer place name referencing a location in Europe

data (dates of founding, location and direction of the waterways), patterns (locations always upriver and at confluences), and rules (does this same pattern hold true for other rivers?). Concluding questions might include whether a change in technology—such as a shift to railroads or highways—would change this pattern. (For a more extended demonstration of this example, see Hammond, Oltman, & Salter, 2019.)

The next step in the model addresses the technology to be used. While computational thinking does not *require* the use of computational tools, we anticipate that the social studies content to be studied—the maps, datasets, or other media identified in the first step—will either be packaged within a specific technology (such as a GIS, as in the Holocaust example above) or will be imported to a technology once a dataset becomes sufficiently large and complex. Consider, for example, an elementary social studies lesson that wishes to not only teach the names of the 13 colonies but also their derivations—to unpack the "whys of where" that is so central to geographic thinking (Alibrandi & Sarnoff, 2006; Kerski, 2016). In this case, the decision to be addressed by the student is, "Why are the colonies called what they are called, and what do these place names tell us?" For the first objective, teaching the names of the colonies, the most basic of media will suffice: handouts, a wall-mounted map, a globe. The second objective, teaching where these names come from, could similarly be addressed via paper-based or static media, as in Table 3, below. However, students will probably be better served by having the information available within a spreadsheet that allows for sorting, color-coding, and so on (see Figure 6, below). In the spreadsheet, the relative proportions of exonyms (names coming from the colonizing society) vs. endonyms (names coming from the indigenous society) are clearly visible and can even be broken down into sub-components. The affordances of a spreadsheet will quickly become more attractive as the dataset grows larger—consider, for example, addressing all 50 states and not just the original 13 colonies, or applying the same questions to the 67 counties of Pennsylvania. Alternatively, presenting the data in a GIS would allow students to more easily explore larger datasets as well as spatially-related questions, such as "Are the European-derived place names concentrated within a specific region? If so, why?" Accordingly, our model for integrating computational thinking addresses the specific technology to be used.

After identifying the social studies content and the effective technology, the teacher next considers the connection to computational thinking. As we have adapted computational thinking to Data, Patterns, Rules, and Questions, the teacher can use these categories as the starting point: Which data are represented

Figure 7. State name derivations color-coded on a GIS display, available at https://arcg.is/COTKy



on the spreadsheet or GIS? How can it be sorted or re-categorized to create more abstracted or more detailed presentations of the data? In Figure 6, above, the label of "exonym" or "endonym" has been split out into a separate column, allowing the student to sort the colony names into two different categories. Our example then uses color to split the exonyms into two categories, creating a total of three categories. In this step, the teacher should consider when and how to use the capabilities of the tool (sorting, filtering, summing, and so forth) to step through the DPR-Q sequence to best unpack the social studies content being studied. In the example presented above in Table 3 and Figure 6, the teacher may decide to expand the scope from the 13 original colonies to include a slightly larger dataset—by examining the first 25 states, for example, students will be able to see the relative concentration of patron-derived exonyms in the original 13 colonies (8 in all) versus the much higher occurrence of state names derived from endonyms (Kentucky, Tennessee, Ohio, Mississippi, and so forth) as the US expanded west. A larger dataset will also expose new patterns, such as French-derived place names (Vermont, Louisiana) and Spanish-derived place names (Florida and the much later, western states of Colorado, Nevada, and Montana). From these patterns, students can generate rules—"Endonyms in the United States are more common the further west you go"—and then test them out: The furthest-west states of Alaska and Hawaii are both, indeed, endonyms. The teacher should also plan some questions for students to consider at the end of the sequence, as well as those along the way. In this case, students could be asked to look elsewhere in the world—in Canada and Mexico, for example, can we see the same pattern of endonyms and exonyms? Would they have any particular geographic gradient? Students will likely generate their own questions, but the teacher should have at least one prepared to use in the event that they do not.

As noted by the bottom element of the model, every step of the teacher's planning should be informed inquiry-driven teaching techniques. We have two reasons for this. First, decision-focused social studies are by definition open-ended, and only inquiry-driven learning allows for the open exploration of a topic.

Second, computational thinking is a problem-solving skill, and social studies problems never have a single solution. Accordingly, social studies lessons that integrate computational thinking should be built as inquiry-driven lessons: guided by questions, ready for multiple pathways that lead to divergent—or at least non-identical—outcomes. Consider, for example, the map in Figure 7, below. In one classroom, the lesson on place names may conclude with the rule outlined above: "Endonyms in the United States are more common the further west you go." By contrast, in another classroom students may arrive at a very different rule: "Over time, the exonyms switch from referencing Europe (Georgia, Rhode Island) to referencing the colonizers' terms for landscape (Montana, Nevada, Colorado)." Computational thinking can and should help structure the process of working through an inquiry, but teachers should not expect to constrain the outcomes too tightly.

CONCLUSION

With proper selection, adaptation, encapsulation, social studies teachers can introduce computational thinking into social studies instruction. This integration will serve multiple agendas: It will enhance students' understanding of computational thinking and its applicability to multiple disciplines, and it will enhance the teaching of social studies, particularly those topics that draw upon accessible datasets. It is an embodiment of Wing's assertion that computational thinking is indeed, 'everywhere' and 'for everyone' (Wing, 2008). The social studies classroom is an ideal place to make that statement true.

In order to capitalize on Wing's ideas and apply them to social studies, we propose a two-step adaptation of computational thinking, first simplifying the concepts (abstraction, decomposition, pattern-recognition, and so forth) and then grouping them into a heuristic of Data, Patterns, Rules, and Questions. The simplification and grouping of DPR-Q makes computational thinking easier to manage as an open-ended instructional process—the teacher can use the stages to guide students through a problem-solving process ("You've identified a pattern; do you think it's a rule?") or direct them back to an earlier step ("Take another look at the data fields—what's included? What's excluded?") as needed. DPR-Q also makes computational thinking an easier topic for teacher education—it is a heuristic for working with datasets in exactly the same way that SCIM-C (Hicks, Doolittle, & Ewing, 2004) or APPARTS (Greer, 2006) are heuristics for reading primary sources. Additionally, DPR-Q aligns with the inquiry design model embedded within the national social studies standards (NCSS, 2013) and also provides a cross-disciplinary thinking skills that can inter-operate with the discrete thinking skills embedded within social studies. To further guide social studies teachers, we link computational thinking to Engle's (1960) conception of decision-focused social studies as being appropriate for open-ended explorations of data using computational thinking. Finally, we propose a four-step process for social studies teachers as they design inquiry-driven lessons, with appropriate consideration of the content, the technologies to be used, and the integration of computational thinking skills.

Further work remains to be done in articulating each stage of this work—how to adapt computational thinking to social studies, best practices for teaching social studies with integrated computational thinking, and strategies for teacher education about this integrated approach. This chapter distills several years of our own work on these topics but is by no means conclusive; our understandings continue to evolve as we work with teachers and students to design, development, implement, and refine social studies instruction that integrates computational thinking. One particularly pressing need is assessment strategies for students' learning outcomes about computational thinking—as a result of an integrated social studies lesson, what do they know and understand about computational thinking? What are they able to do with it? Are they able to transfer these understandings and skills to other social studies topics or other tasks outside of social studies? We welcome comment and collaboration with other researchers in social studies and/or computational thinking, and we anticipate continued progress in making effective, meaningful integrations of computational thinking and social studies instruction.

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KEY TERMS AND DEFINITIONS

College, Career, and Civic Life (C3) Framework: An instructional framework for the social studies that is focused on four dimensions: Dimension 1: Developing Questions and Planning Inquiries, Dimension 2: Applying Disciplinary Concepts and Tools, and Dimension 4: Communicating Conclusions and Taking Informed Action

Computational Thinking: Summarizes habits of mind or skills characterized by using computers to solve complex problems or, borrowing from computer science, developing problem-solving skills such as abstraction, pattern generalization, algorithmic thinking, decomposition, automation, and recursion.

"Data, Patterns, Rules and Questions" (DPR-Q): A heuristic that applies computational thinking to social studies instruction and guides students through a four-part framework for problem solving.

Decision-focused Social Studies: Social studies instruction organized around student decision-making, whether policy formulation or data interpretation.

Inquiry Design Model (IDM): Basis of the C3 Framework for developing inquiries focused on compelling questions, supporting questions, and taking informed action.