A CLOSE READING AND ANALYSIS OF THE NEW YORK STATE COMPUTER SCIENCE LEARNING STANDARDS

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ABSTRACT

In this paper, we perform a close reading of the New York State Computer Science/Digital Fluency Learning Standards document to determine its coherence and areas of incoherence and disconnection. This investigation, which utilizes content/discourse and textual analysis tools and methods from the tidytext tools developed for the R programming language, sought to understand the structure of the document itself, as well as the types and patterns of the language used in this document by analyzing word frequencies and networks of terms (engrams). The findings indicate a coherence across document in terms of its articulate of key ideas and principles of computer science and digital fluency. The findings describe an incoherence/disconnection between that the language used to articulate high level goals and objectives articulated in the executive summary of the standards document, such as interdisciplinarity, addressing the learning needs of all students, and equity of access, is mostly absent from the articulation of the standards themselves. In addition, the language used in the standards heavily addressed Bloom's lower level thinking skills (such as identify, discuss, and explain) and less so Bloom's high level thinking skills (such as design, create, and analyze). Implications for teacher education and curriculum design are addressed. Implications for teacher education and professional development in the development of rich curricular experiences in computer science and digital fluency are discussed.

KEYWORDS

Computer science education; teacher education; learning standards; curriculum design.

1. INTRODUCTION

Since the onset of No Child Left Behind by the Bush administration and Obama's Race to the Top, a great emphasis has been placed on teacher and student accountability, and this emphasis has led to the creation of learning standards in several content areas, such as Common Core English and Mathematics learning standards (CCLS) and Next Generation Science Standards (NGSS), to name just a few. Typically coupled with these standards are mandatory high stakes assessments, which are used to evaluate teachers, students, and school districts in ways that have had both positive and negative outcomes [1, 2].

At the same time, there has been a large push for the teaching of computer science, along with computational thinking, in public K-12 schools. Much of this prioritization has come from organizations sponsored heavily by the tech industry, especially Code.org. These efforts have led to the development of learning standards having been designed and adopted in each of the 50 United States. After almost ten years of the implementation of CCLS, with both intended and unintended outcomes, many researchers and teachers have been critical about the role of stakeholders from outside of education on what happens in public school classrooms [3]. Therefore, a detailed examination of these computer science learning standards documents is both

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necessary and timely. This paper represents the first time that this type of close reading analysis of computer science learning standards has been performed. This study has been conducted to address the following research questions:

1. What do computer science learning standards documents articulate and imply about the teaching of computer science to students in grades K-12?
2. What implications do these computer science learning standards document have for computer science teacher education and computer science curriculum design?

2. REVIEW OF THE RELATED LITERATURE - THE IMPLICATIONS OF LEARNING STANDARDS ADOPTION

In a process that began in the early 2000's, 48 of the United States adopted the Common Core State Standards (CCSS) starting in 2010, making it "an unprecedented change in American education" [2, p. 414]. The stated goal of this initiative is college and career readiness and the development of critical thinking and problem-solving skills:

> Today's students are preparing to enter a world in which colleges and businesses are demanding more than ever before. To ensure all students are ready for success after high school, the Common Core State Standards establish clear, consistent guidelines for what every student should know and be able to do in Math and English language arts from kindergarten through 12th grade [2].

The standards were drafted by experts and teachers from across the country and designed to ensure students are prepared for today's entry-level careers, freshman-level college courses, and workforce training programs. The Common Core focuses on developing the critical-thinking, problem-solving, and analytical skills students will need to be successful [4].

However, the CCSS were also strongly focused on student and teacher accountability: "The new standards also provide a way for teachers to measure student progress throughout the school year and ensure that students are on the pathway to success in their academic careers" [4]. The Obama administration's Race to the Top initiative was instrumental in aggressively tying student performance on Common Core tests to teacher evaluation metrics. This double-edged focus on teacher and student accountability has perhaps become the most controversial aspect of the implementation of the CCSS: "The CCSS and the assessments designed to measure student achievement will be the primary vehicle for determining school effectiveness under federal legislation. As such, the implementation of CCSS in states, districts, and schools has become an urgent priority" [2, p. 415]. Whether these consequences were unintended or not, their effects were real [3].

It is this focus on high stakes testing and teacher and school district accountability that has had the biggest impact on teacher practice and thus, teacher education/teacher training and curriculum development. For example, in response to the implementation of the Common Core Learning Standards (CCLS) in New York State in 2011 for the 2012-2013 school year, the New York State Education Department (NYSED) established a resource called EngageNY:

> EngageNY.org is developed and maintained by the New York State Education Department (NYSED) to support the implementation of key aspects of the New York State Board of Regents Reform Agenda. This is the official web site for current materials and resources related to the Regents Reform Agenda. The agenda includes the implementation of the New York State P-12 Common Core Learning Standards (CCLS),

> Teacher and Leader Effectiveness (TLE), and Data-Driven Instruction (DDI). EngageNY.org is dedicated to providing educators across New York State with real-time, professional learning tools and resources to support educators in reaching the State's vision for a college and career ready education for all students [5].

The curricular materials and resources developed by EngageNY defined the scope, sequence, as well as day-to-day instructional goals and learning activities in the areas of mathematics and English Language Arts (ELA) in grades pre-K to 12 [6]. This work was promoted by the New York State Education Department (NYSED) as a service to teachers who had been charged with implementing a brand new and extensive curriculum in the CCLS. Whether intentionally or not, EngageNY, has had the practical effect of changing the role of teaching and teacher training in curriculum design in meaningful ways. Instead of designing curriculum to meet the needs of their very real students, a teacher can instead be reduced to implementing a curriculum and learning activities which were designed by others and whether or not the associated learning objectives, pacing calendars, and assumptions about students' prior knowledge are accurate, appropriate, or relevant. Some researchers have likened this situation to robots teaching little robots [1].

The adoption of high profile learning standards such as CCLS has had an immediate and telling impact on teacher education and preparation [1,2,3]. Rather than preparing teachers to design innovative curricula and learning activities that meet the needs and aspirations of their students and the local communities, teacher candidates are instead trained to read these standard documents, and then to use those documents to plan their teaching. Rather than merely serving as resources, then, these standards documents become strong determinants of curriculum design. In some cases, this has led to the development of scripted lessons and units, which essentially remove the teacher from the equation [1,6]. Though room remains for skillful, creative and caring teachers, in many places, the bounds within which teachers have been allowed to exercise their craft have become very limited [2]. Additionally, some research has described variable levels of coherence between learning standards as written and the assessments developed to evaluate student learning outcomes related to those standards [7,8,9].

Webb's framework for evaluating learning standards and their coherence (or lack thereof) with associated assessments is a particularly good one for the work at hand in this study [9]. Webb's analysis compares learning standards to the associated assessments. In this study, we will be comparing the coherence between the principles articulated in the learning standards document and the coherence (or lack there) of these principles in the learning standards themselves.

Importantly, the development and adoption of the Common Core Learning standards was influenced by a great deal of political and corporate agendas and other outside interests [10]. In this way, the situation is analogous to the development and adoption of computer science learning standards at least partially in response to influence from tech companies and their owners/executive from organizations like Code.org, which describes membership from Facebook, Microsoft, Google, Twitter, and other large and influential tech corporations [11]. We are not asserting that this influence is in some way nefarious or that the promoters of an agenda that includes a presence of computer science education in K-12 schools is somehow misguided. Rather, the research thus far into the CCLS and its impact on teachers and teaching [6] underscores the importance of close analysis and understanding of other learning standards, such as those for computer science education.

3. METHODS

Textual analysis is a set of methods within social science and educational research for investigating texts of various kinds [12,13]. This study employed methods of textual analysis in order to interrogate the New York State Computer Science/Digital Fluency Learning Standards (NYCSDFLS) document such as: determining word frequencies and relative word frequencies in a whole document as well as its parts; and engrams, connections between sequences of words in a text, in which word networks and connections between words were examined.

The NYCSDFLS document has two major sections. The first is untitled, and we will refer to it here as the *Executive Summary*. The Executive Summary contains several subsections: Introduction, which gives the background of the need for such learning standards; Background, which describes the process of the design and refinement of the learning standards; Guiding Principles, which outlines the four guiding principles used in the design of the learning standards (Equity and Access, Interdisciplinary Connections, Coherence, and Relevance and Engagement); Computer Science and Digital Fluency for All Students, which discusses the importance of both digital equity and the need to include all learners in these standards; and Concept Areas, which describes each of the Concept Areas included in the learning standards (Impacts of Computing, Computational Thinking, Networks and Systems Design, Cybersecurity, and Digital Literacy).

The second section is an articulation of the learning standards themselves. This is in the form of a table which identifies the grade band in blue across the top, CS/DF Concept and sub-concept involved, the standards themselves, and a clarifying example for each standard. For example, Figure 1 provides an example of this layout in the form of a screenshot. We consider the formatting of this document to be an important part of its design. In this example, the Concept is Impacts of Computing, the sub-concept is Society, and the standard and the clarifying examples are articulated for each of the four grade bands.

NYS K-12 Computer Science and Digital Fluency Standards

Impacts of Computing

	Grades K-1	Grades 2-3	Grades 4-6	Grades 7-8	Grades 9-12
Society	**K-1.IC.1** Identify and discuss how tasks are accomplished with and without computing technology.	**2-3.IC.1** Identify and analyze how computing technology has changed the way people live and work.	**4-6.IC.1** Describe computing technologies that have changed the world, and express how those technologies influence, and are influenced by, cultural practices.	**7-8.IC.1** Compare and contrast tradeoffs associated with computing technologies that affect individuals and society.	**9-12.IC.1** Evaluate the impact of computing technologies on equity, access, and influence in a global society.
	Common tasks include sending a letter by email vs. post, taking a picture with a smart phone vs. camera, buying something with an app vs. with cash at a store.	The focus should be on how advancements in computing technology have changed careers and lives.	The focus should be on how computing technologies both influence and are influenced by society and culture.	Topics that could be addressed include, but are not limited to, free speech, communication, and automation.	The focus should be on how computing technologies can both perpetuate inequalities and help to bring about equity in society.
	K-1.IC.2	**2-3.IC.2**	**4-6.IC.2**	**7-8.IC.2**	**9-12.IC.2**

Figure 1. Sample Learning Standards from New York State Computer Science/Digital Fluency Learning Standards document

For this study, each of the two sections of the learning standards document was analyzed by performing a close reading using a set of the tidytext tools in the R programming language. Then some of the features in each were compared in order to identify trends and correlations. The tidytext set of libraries written for the R programming language provide a very powerful set of tools for this type of textual analysis [14,15]. These tools allow for the ordering, sorting, and other types of manipulation of the textual data, such as determining word frequencies and relative word frequencies, which are word frequencies normalized against total words in a segment of text (dplyr); tokenizing text, meaning extracting meaningful segments of text for analysis, like words or sentences or engrams (tidytext); analyzing networks for words (igraph); and creating visualizations of these data in various ways (ggplot2). Each of these tools were utilized in this study.

The data analysis tools employed in this study is depicted in Figure 2.

Figure 2. The data analysis tools employed in this study

4. FINDINGS

In this section, we will discuss the findings of our close reading of the New York State Computer Science and Digital Fluency Learning Standards document. This presentation will start by an examination of the relative word frequencies of each portion of the document, and will then continue with an analysis of the networks of terms comprising each portion of the document and how they compare to one another.

4.1. Relative Word Frequencies

For each portion of the learning standards document (*executive summary* and *standards*), both the word frequencies (how often each word is used in each portion) and relative word frequencies (the word frequencies relative to the number of words in each section) were calculated. These analyses are visualized in Figures 3, 4, and 5.

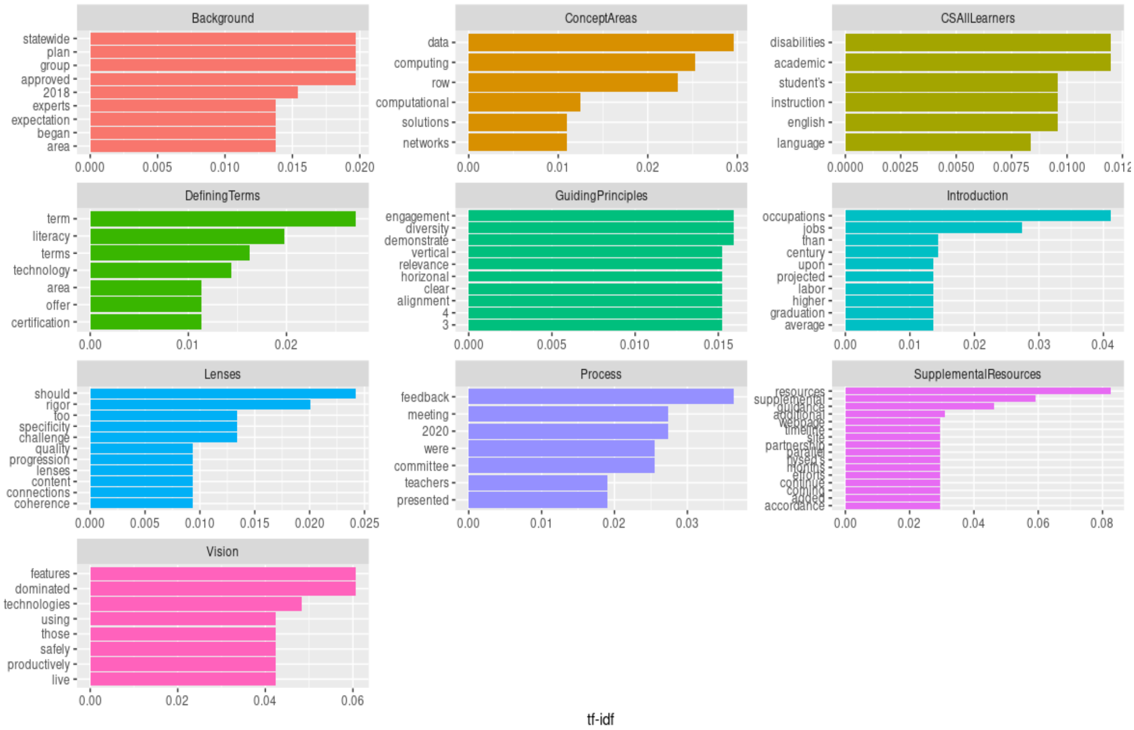

Figure 3. Relative word frequencies for each section of the Executive Summary

Figure 3 depicts the most relatively frequent works in each section of the executive summary: *background*, *concept areas*, *computer science and digital fluency for all students*, *defining terms*, *guiding principles*, *introduction*, *lenses*, *process*, *supplemental resources*, and *vision*. These graphs provide a sense of what is most important in each of these sections. For example, in the guiding principles section, *engagement*, *diversity*, and *relevance* are clearly important, as indicated by their relative word frequencies. The relative word frequencies of the Standard portion of the learning standards document organized by Concept Area are depicted in Figure 4.

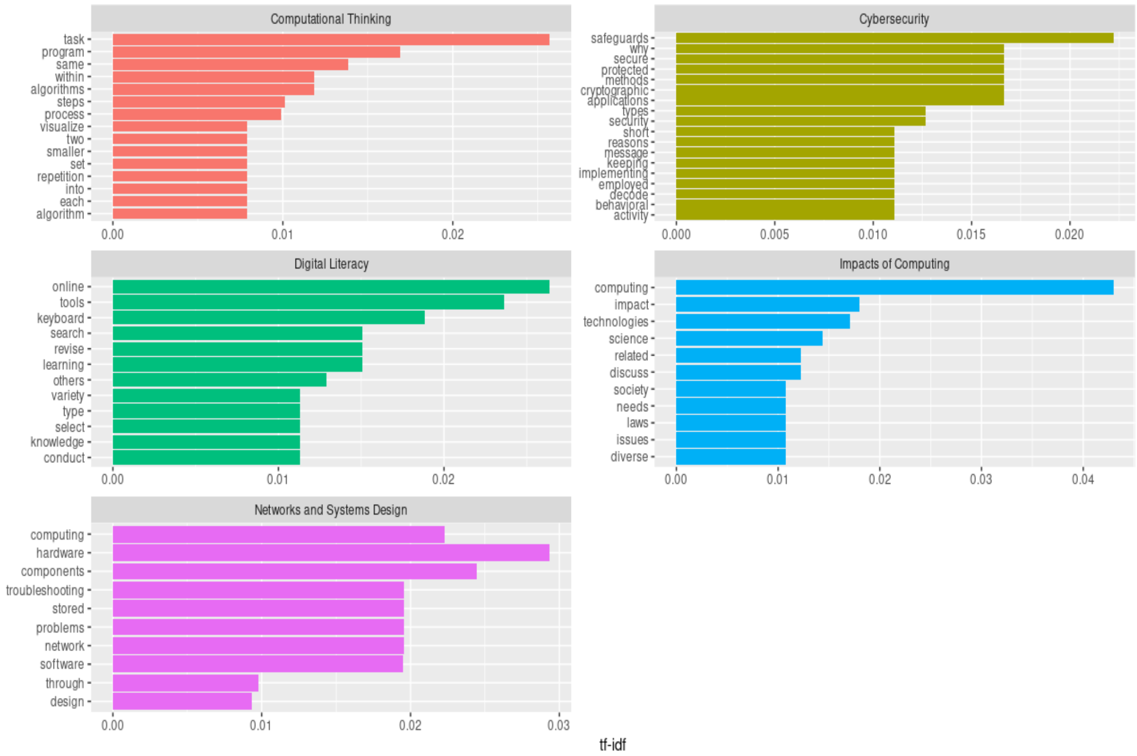

Figure 4. Relative word frequencies for the Standards organized by Concept Area

This analysis allows us to see which terms are the most important in each concept area, as determined by their relative word frequencies. For example, the concept Digital Literacy is comprised of online, tools, keyboard, search, etc., and the concept Networks and Systems Design is comprised of computing, hardware, components, and troubleshooting, all of which is evident from a plain reading of the learning standards.

The relative word frequencies of the Standard portion of the learning standards document organized by Grade Band are depicted in Figure 4. Again, this type of analysis demonstrates which terms are most important for at each grade level.

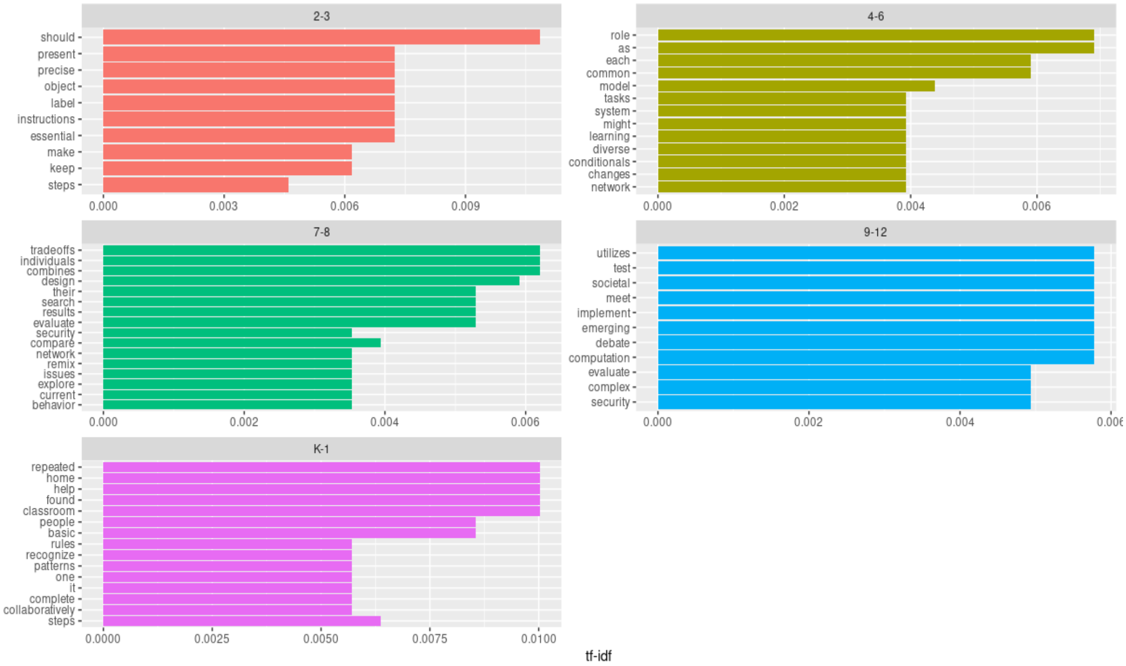

Figure 5. Relative word frequencies for the Standards organized by Grade Band

For example, the terms repeated, home, help, and classroom are among the most important in the K-1 Grade Band, whereas, tradeoffs, individuals, design and search are among the most important in the 7-8 Grade Band. Once again, this analysis is confirmed by a plain reading of the learning standards themselves.

4.2. Verb Frequencies

The frequencies of verbs used in each of the standards were calculated and visualized by Concept Area and Grade Band. These analyses are depicted in Figures 6 and 7.

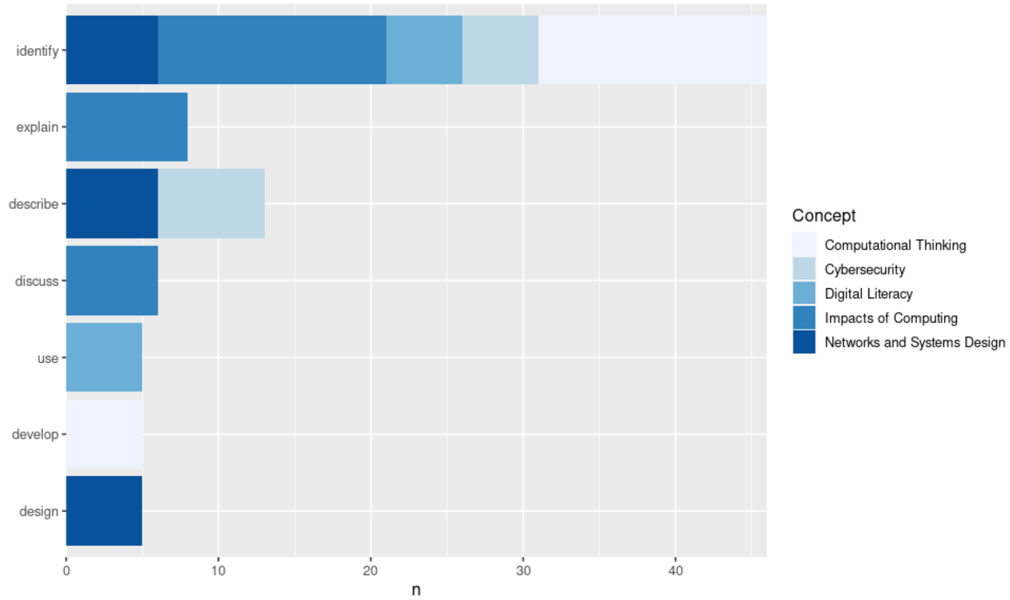

Figure 6. Verb frequencies in the standards by Concept Area

The verb frequencies by concept area are shown in Figure 6. We can see that identify is the most frequently used verb in the standards across each of the Concept Areas. In contrast, *develop* is only found in Computational Thinking, typically in the appropriate context of develop a program or develop an algorithm. *Design*, on the other hand, is found only in Networks and System Design, for example, in the appropriate context of design a user interface.

The verb frequencies by Grade Band are show in Figure 7. We can see again *identify* is the most commonly used verb across all Grade Bands. *Describe* is also frequently used in all Grade Bands, except K-1. In contrast, *design* is only frequently used in the 7-8 and 9-12 Grade Bands, and *compare* is found frequently only in the 7-8 Grade Band.

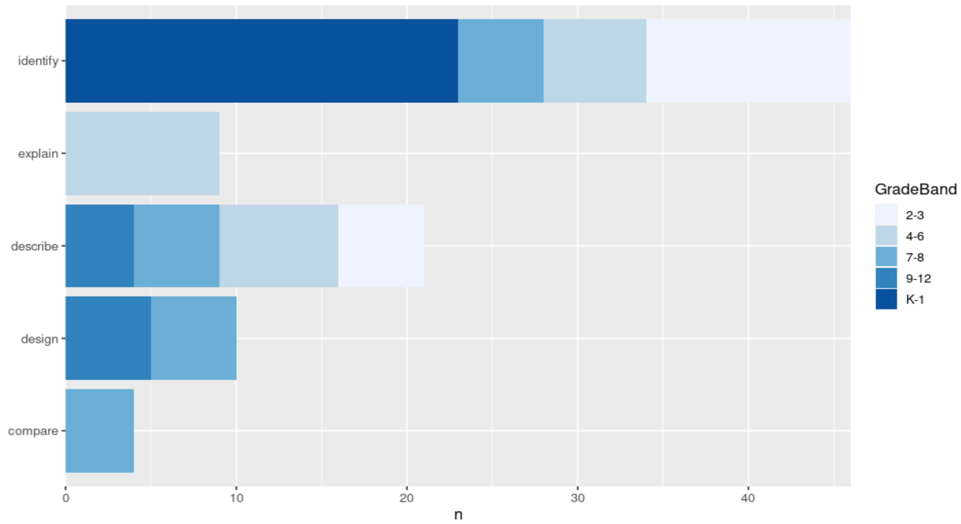

Figure 7. Verb frequencies in the standards by Grade Band

In both of these verb frequency analyses we observed a fairly flat cognitive or epistemic space defined by these verbs, primarily defined by *identify*, *explain*, and *describe*, all consistent with lower order thinking skills described in Bloom's taxonomy [16]. Additionally, the verb used most frequently with high order thinking skills described by Bloom, *design*, is only used in standards addressed to the upper two grade bands (7-8, and 9-12). This suggests that students below grade 7 are only infrequently, if at all, asked by the standards to engage in higher order thinking skills.

4.3. Networks of Terms – Bigrams

In order to investigate the networks of words employed in both main sections of the learning standards document, we also performed analyses of the standard section of the learning standards document that involved bigrams, that is frequencies of two- word groupings. For example, consider the learning standard: "Evaluate the impact of computing technologies on equity, access, and influence in a global society". This sentence can be broken down in a number of bigrams: evaluate the, the impact, impact of, of computing, etc..

We used the tidytext tools in R to break each of the two main sections of the document (executive summary and standards) into bigrams and then to determine the frequencies of each those bigrams. Next, we generated a network analysis of these each of these sets of bigrams using the igraph tool, which treats the bigrams as nodes in a network of terms as well as the connections between these two-word terms. Finally, we visualized these networks using ggraph. Figure 8 depicts the visualization of the most common bigrams in the executive summary portion of the document and Figure 9 depicts the visualization of the most common bigrams found in the standards portion of the learning standards document.

In the bigram network visualized in Figure 8, we see a wide range of collections of terms. Some of these collections of terms pertain to the content contained in the areas of computer science and digital fluency, such as *computing→system*, *computational>thinking*, and *digital>technologies*. Additionally, some of these collections of terms reflect the guiding principles, computer science for all learners, and lenses described in the executive summary such as: *digital>citizenship*, *culturally>responsive*, and *multiple>expressions*.

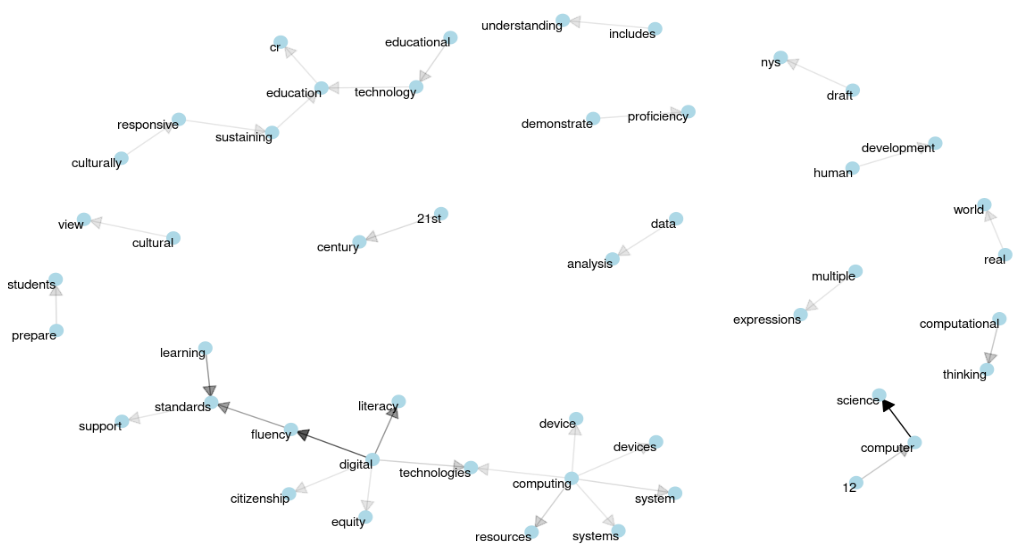

Figure 8. Network graph of bigrams identified in the executive summary section of the learning standards document.

In the bigram network visualized in Figure 9 we can see several collections of terms. For example, computer forms frequent connections with systems and science, and that software application is a frequent bigram in this text. All of this makes sense, given the computer science and digital fluency content addressed by these learning standards. It is also interesting to note what is missing from this network, which are any terms related to cognition or understanding, such as the verbs depicted in Figures 6 and 7. Given the frequency of these verbs in the learning standards portion of the document, we might expect them as contributing to some of these bigram networks, and yet they are completely missing. We believe that this suggests that the content represented by the standards are more important to the document than the cognitive skills to be employed by teachers and students.

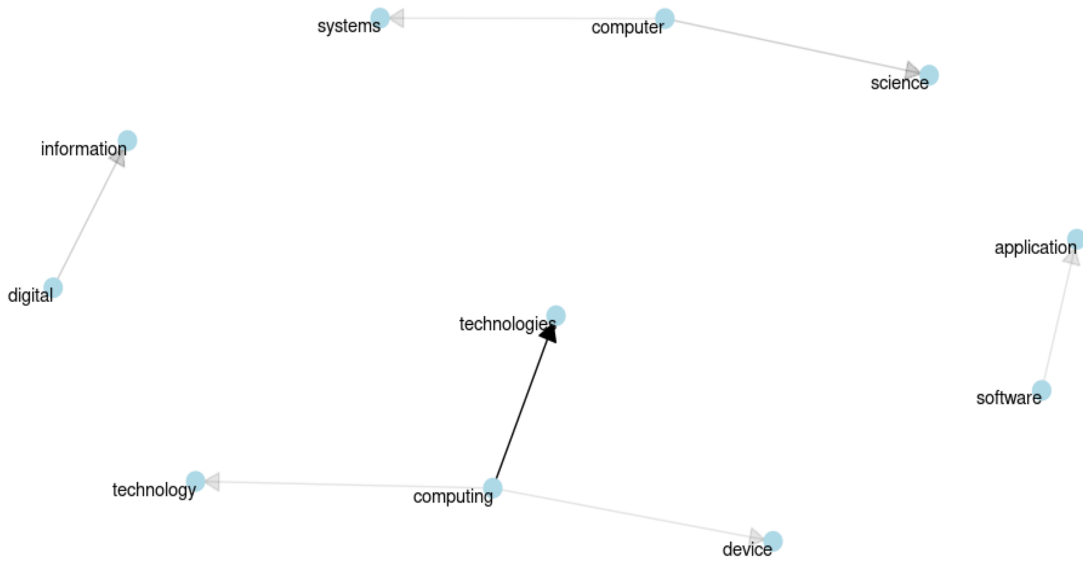

Figure 9. Network graph of bigrams identified in the standards section of the learning standards document.

5. DISCUSSION

This study performed a close reading of the New York State Computer Science/Digital Fluency learning standards document, in order to investigate these research questions:

1. What do computer science learning standards documents articulate and imply about the teaching of computer science to students in grades K-12?
2. What implications do these computer science learning standards document have for computer science teacher education and computer science curriculum design?

In this study, two types of textual analysis were performed on the two main portions of the learning standards document, the executive summary and the learning standards themselves. The first was an examination of the relative word frequency of the learning standards document and its various sections, along with the verbs most frequently used in the standards portion of the document. The second was an investigation of networks of two-word terms (bigrams) found in each portion of the learning standards document.

This section of the paper discusses these findings and their implications.

5.1. Coherence

The first major finding of this study is that each of the two main portions (executive summary and standards) of the learning standards document demonstrate a coherence within each of its sections as evidenced by the terms with relatively high frequency. For example, the Executive Summary section “Computer Science and Digital Fluency for All Students” contains exactly the terms we would expect, such as disabilities, academic, students, and language (referring to English Language Learners). We see the same coherence in the “Guiding Principles” section, which contains engagement, diversity, and relevance.

The same trend can be found in the Standards portion of the document when we examine the terms with the highest relative frequencies filtering for both Concept Area and Grade Band. In the Concept Area of Computational Thinking, we find appropriate terms used most frequently, such as task, program, and algorithms. In Cybersecurity, we find *safeguards*, *secure*, and *protected.* An analysis of the terms with the highest relative frequencies across Grade Bands, we see a progression from *people*, *classroom*, and *home* (K-1) to *present*, *label*, and i*nstructions* (2-3) to *role*, *model*, and *tasks* (4-6) to *tradeoffs*, *combines*, and *design* (7-8) to *utilizes*, *societal*, and *implement* (9-12). These terms move from more concrete terms to more abstract ones, as is appropriate across the academic and cognitive development of children at these progressing grade levels.

This coherence in the language across and within the learning standards document is consistent with that called for by Webb’s descriptions of categorical coherence and DOK (Domains of Knowledge) consistency [9]. We assert that this type of coherence represents both a consistent point of view and consistent design within this learning standards document, which we believe to be of critical value.

5.2. Incoherence/Disconnection

The second major finding of the study is an apparent disconnection between the two main sections of the learning standards document. We see this disconnection as occurring in two ways. The first involves the thinking skills as described by Bloom addressed in the learning standards portion of the document. The second involves a disconnect in the networks of terms found in the two main portions of this document.

The frequencies of verbs used in the learning standards portion of the document, as depicted in Figures 6, which looks at these verb frequencies across Concept Area, and Figure 7, which looks at these verb frequencies across Grade Band. In each, we see a prevalence of verbs associated with Bloom’s lower order thinking skills, such as *identify, discuss,* and *describe*. This finding indicates that most of the work called for in the standards are described is addressing only lower level thinking skills. In practice, teachers can certainly design curricular materials and activities that expand the practice of these standards to address higher order thinking skills, but we have seen, in the case of the Common Core Learning Standards and their implementation by teachers as restrictive and proscriptive [1,3].

The visualizations of the networks of bigrams in each section of the learning standards document demonstrates an even larger area of incoherence between the executive summary and the learning standards themselves. The network of bigrams from the executive summary (Figure 8) depicts a very rich cognitive space, one that contains both key areas of computer science and digital fluency concepts, such as *computing→system*, *computational>thinking*, and *digital>technologies.* However, this network also contains the ideas represented in the more philosophical portions of the document, the Guiding Principles, and Lenses, such as *digital>citizenship*, *culturally>responsive*, and *multiple>expressions*.

In contrast, the bigram network for the learning standards themselves, as depicted in Figure 9, describes a far narrower cognitive or epistemic space, and one focused primarily on learning content, such as *computing>technologies*, *digital>information*, and *software>applications*. This type of content is certainly expected in learning standards. However, what is missing from this cognitive space are any bigrams that could be correlated to the bigger ideas described in the Guiding Principles, Lenses, and Computer Science and Digital Fluency for All Students sub-sections of the executive summary. There is certainly nothing in the document limiting teachers from including those extremely important concepts and attitudes in their teaching and their development of curricular plans and materials. As discussed above, it is all a matter of how these computer science teachers perceive the degree of proscriptiveness in the standards document as well as the actual levels or frequent or constraint that they experience in their schools and school district as they engage in the development of their curriculum plans and activities

5.3. Implications for Teacher Education and Curriculum Design

Given these findings, we believe that key takeaway from this study is that much work is needed to develop teachers and teacher candidates to be able to integrate/connect CS Learning Standards into existing content areas: mathematics, ELA, history/social studies, science, art, and music. Additionally, further work is necessary to investigate how CS practices, concepts, and skills can be taught effectively to all students, regardless of any special needs or level of English language fluency.

We also believe that the key factor in terms of the impact of this computer science/digital fluency learning standards document is the assessments which will be used to assess student learning and, ultimately, teacher effectiveness. As we have seen with the CCLS, the assessments associated with them, and their high stakes nature, has had a large influence on both teaching and curriculum design. There is, then, a causal relationship between testing/what is being tested and the teaching/curriculum design produced. If, in the case of the these computer science and digital fluency learning standards, the assessments address the entire document, including its Guiding Principles and Lenses, as well as the richness of each of the Concept Areas, then teachers will be empowered incentivized to design curriculum that addresses this richness. If, instead, the assessments are more narrowly focused on the strict wording of the learning standards themselves, then it is possible and perhaps likely that, in general, teaching and curriculum design will become in turn also much more narrow.

Teacher preparation programs in Computer Science Education can mitigate this risk by developing CS teachers who are immersed in the full richness described in this these learning standards document. We have begun to follow this pathway, and work is currently underway to design workshops for teachers and teacher candidates consistent with this approach. The work of several key practitioners and researchers have informed these efforts, including foundational work in understanding the possibilities of children and computers by Papert and Solomon [17]; the work by Weinstock and his colleagues on computational thinking and younger students [18-20]; and research by Yadav and his colleagues on the development of teachers in the teaching of computational thinking and computer science [21,22]. Additional work on the evolution of the key documents influencing this learning standards document as well as others adopting by other states, is also underway.

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