A Longitudinal Analysis of K-12 Computing Education Research in the United States: Implications and Recommendations for Change

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Abstract

The availability of computer science education in primary and secondary schools in the United States has grown rapidly over the last decade. Computing education research in K-12 has been increasing as well. In this study, we conducted a longitudinal analysis of seven years of data (2012-2018), curated from over 500 articles across 10 publication venues to identify trends in K-12 computing education research such as geographic location and curriculum and concepts taught. The data shows a decrease in the number of studies covering K-12 students receiving computing education even while there is an increase in the number of states adopting and implementing standards. The number of different concepts being researched is increasing, potentially reflecting the growth in what is being taught in the classroom. Demographic data is underreported (e.g., socio-economic status (SES) and disabilities of participants) which could directly limit generalizability of the studies to different learners as well as the ability to replicate and compare studies. We conclude with recommendations for how to better position this work for others trying to use the results to guide their efforts in creating standards or adopting techniques into their classrooms.

CCS Concepts

• **Social and professional topics → Computing education**; **Computing education programs**; **Computer science education**.

Keywords

Primary education, secondary education, K-12, research, experience reports, CSEdResearch.org, disabilities, gender, race, locations, concepts, camps, schools, curriculum, activities, socio-economic status, SES

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1 Introduction

Computer science education in primary and secondary schools has been increasing over the last decade. More countries, states, and municipalities have developed, adopted, and implemented standards for teaching computing in the K-12 classroom. With the CS for All movement pushing the integration of computing education into grades as early as Kindergarten and even preschool, the research of this integration process also remains of interest to researchers as they seek best practices in teaching computing to students [4, 25, 33]. As more schools begin to develop, adopt, or implement standards, this research provides an understanding of what has worked, what needs to be improved, and what impact this has on students [30].

Previous research studies conducted in the field have reported on some of the major trends of K-12 computing education across the United States (US), including student demographic and program data. Some reports have stated that the decentralized education system in the US has resulted in inconsistencies in the education policies throughout the country [16]. However, a 2018 report by the Code.org Advocacy Coalition shows the positive relationship between the number of policies adopted by a state and number of high schools offering CS education [9]. With 44 of the 50 states having some number of policies in place to bring computing into its K-12 schools, computer science is becoming more of an option for students. These reports, however, are not at the point of measuring the enacted curriculum, particularly across demographic and socio-economic (SES) differences. For example, how do high poverty areas integrate and develop computing as part of their curriculum [12]? Are girls and boys experiencing the same K-12 computing education? Do students in rural communities and urban communities receive equal access to computing?

Although still in its infancy compared to other STEM fields, K-12 computing education research is carefully being tracked for the purposes of empirical investigation [13, 29]. This is not unlike computing at the undergraduate level [5, 15, 24] and the traditional sciences [8, 23] which report on challenges, trends, and recommendations in these educational fields. The overarching research question for this study was: *Over the last seven years, what have been the major trends in K-12 computer science education research in the US?* For of this study, we define major trends to include:

- Locations of students/interventions studied
- Type of articles (e.g., research, experience, position paper)
- Program data (e.g., concepts taught, when activity was offered, type of activity, teaching methods),
- Student data (e.g., disabilities, gender, race/ethnicity, SES)

This study is important to all sectors of computing education, from teachers and researchers to policy makers, to begin to understand what has been and what still needs to be researched. Given the growth of computing in K-12 in recent years, understanding this is crucial to promoting best practices for both research and classroom pedagogy that can be generalized.

2 Methodology

For this study, we used data from csedresearch.org, a site that houses summaries of articles focused on K-12 computing education [26]. We limited our data to the US since the current dataset is predominantly populated with US research and the CS for All movement in the US remains raw, interesting, and worthy of its own consideration. Including data from other countries fails to take into account educational differences and the relative proportion of data from other countries remains limited (though efforts are underway to curate data from less US-centric venues).

Data was curated from ten publication venues (2012-2018) consisting of journals and conference proceedings related to computing education. Each article was examined to determine if it focused on K-12 computing interventions, and if so, the data from the article was manually curated and added to the dataset. The data curation process is explained in greater detail in prior studies and at csedresearch.org [14, 26, 27, 29]. For this set of data, we focused only on those articles that had K-12 students as participants in the study.

To extract the data needed to identify the major trends across seven years, one of the researchers constructed and ran SQL queries over the entire dataset to extract the pre-specified subsets of data to be analyzed. The results were verified and imported into Tableau [34]. Only descriptive statistics (count and percentage) were calculated for the predetermined trends being examined for this study. The first author then used Tableau to construct infographics for each set of results. The results of each analysis in this section have different counts, which reflects the incompleteness of the data as reported in the articles.

3 Results

This section presents highlights of the analysis, including program data and student demographic data.

3.1 Type of Articles

Of the 178 articles considered for this analysis, 85 (48%) were research papers, 89 (50%) were experience reports, and 4 (2%) were position papers. Figure 1 shows the breakdown of the article types by year. The most popular type of articles have been research articles, followed by experience reports and then position papers. By far, 2015 was the most prolific year with 43 articles (24% of the 178 articles) published.

3.2 Locations of Students by State

For this analysis, we considered all types of articles (research, experience reports, and position papers) where the students were the learners (i.e., excluding professional development). Of the 178 articles that identified students/interventions, 121 of these articles specified the location of these students by state (see Figure 2). Seventeen (17) of the articles specified regions like "Southeast" or "Midwest", and these have been excluded for the purpose of this analysis.

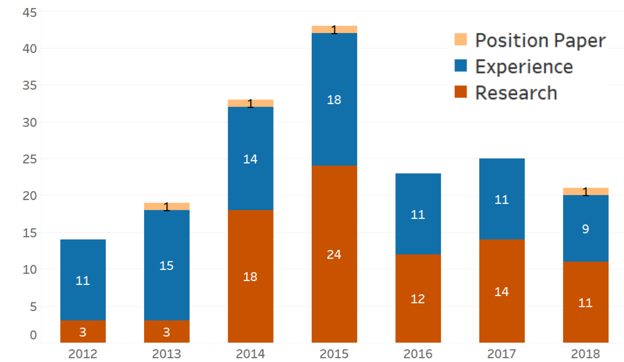

Figure 1: Type of articles, presented by year.

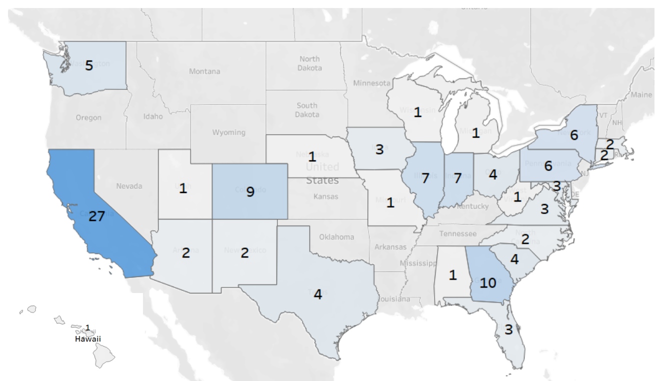

Figure 2: Locations of the student participants studied.

Students in the studies were located in only 29 of the 50 states (58%). Students in California are by far the most represented within these publication venues, comprising 28 (23%) of the 121 articles. Georgia and Colorado are the next most active states with 10 (8%) and 9 (7%) each. No students in the published articles were located in Alaska.

3.3 Program Data

In this section we present the program data, or data related to the curriculum or activity, including the curriculum and concepts taught, when the activity was offered, the type of activity, teaching methods, and tools, languages, and environments.

3.3.1 General Curriculum and Concepts Taught The data includes information about curriculum used in the interventions described in the articles (e.g., Exploring Computer Science (ECS), Computer Science Advancement Placement Exams (AP CS A and AP CS Principles, Beauty and Joy of Computing, CS0, CS1, and CS Concepts (general)). There has been a significant increase in the variety of the curricula taught over the years (Figure 3). From having only a single curriculum reported in the research in each of the years 2012 and 2013, there were a total of 7 different curricula taught in the year 2018.

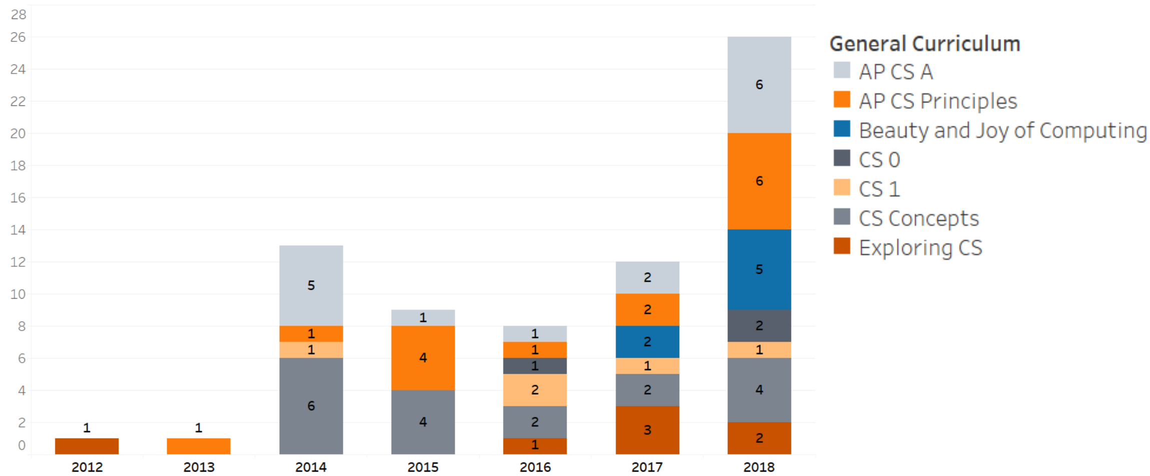

Figure 3: General curriculum taught in the research studies, presented by year.

Table 1: Snapshot of most frequent concepts taught.

2012	2015	2018
Programming (11)	Programming (20)	Programming (6)
AI (3)	Problem Solving Skills (12)	Computational Thinking (4)
Design Skills (3)	Computational Thinking (12)	Abstraction (4)
Problem-Solving Skills (3)	Abstraction (8)	Variables (3)
Video Game Design and Dev (3)	Iteration (7)	Game Programming (2)
Video Game Design (2)	Video Game Design (6)	Video Game Design (2)
Computational Thinking (2)	Algorithms (4)	Debugging (2)
Internet (2)	3D Modeling (4)	Cybersecurity (2)
Cryptography (2)	Algorithm Logic (4)	Computing Concepts (2)
	Mobile App Development (4)	
	Robotics (4)	

The data also provides information about specific concepts taught as part of or in addition to the curriculum being named. Table 1 presents information about frequency of concepts mentioned at three time points in the data set (2012, 2015, and 2018) as a way to look for trends over time. Programming is still the most frequently mentioned concept taught. However, computational thinking coupled with abstraction is becoming more frequently mentioned. Another frequently researched topic is video games with video game design, video game design and development, and game programming included in the most frequently mentioned concepts across these three years.

3.3.2 Type of Activity Of the 172 articles that specified the type of activity studied, there has been a noticeable increase in classroom activities as a part of formal curriculum (see Figure 4). With this increase, other forms of activities (e.g., Hour of Code, other outreach programs) have been studied and published about less frequently.

3.3.3 When Activity was Offered Figure 5 shows data related to when a researched activity was offered as times throughout the year (e.g., school hours, after school, summer). Research of activities held after school hours declined, while research on activities held during the school year and during school hours increased.

3.3.4 Teaching Methods Figure 6 shows that Lab and Lectures were the most popular teaching methods. Even though there is fluctuation in the exact nature of the teaching method, non-lecture methods dominate in the reporting of the activities.

3.3.5 Tools, Languages, and Environments Tools, languages and environments are applications or platforms used by the students in the research study. Table 2 presented the most frequently mentioned TLEs at three points in time (2012, 2015, 2018). The most commonly used TLEs in the activities were Scratch (32%), followed by Java (10%), App Inventor (9%), Python (9%) of the 265 articles.

3.4 Student Data

In this section, we present the demographics, (e.g. gender, race/ethnicity, disability status) of the student participants as reported in the articles.

3.4.1 Grade Levels The graph in Figure 7 represents the number of articles that had activities within each school group (elementary,

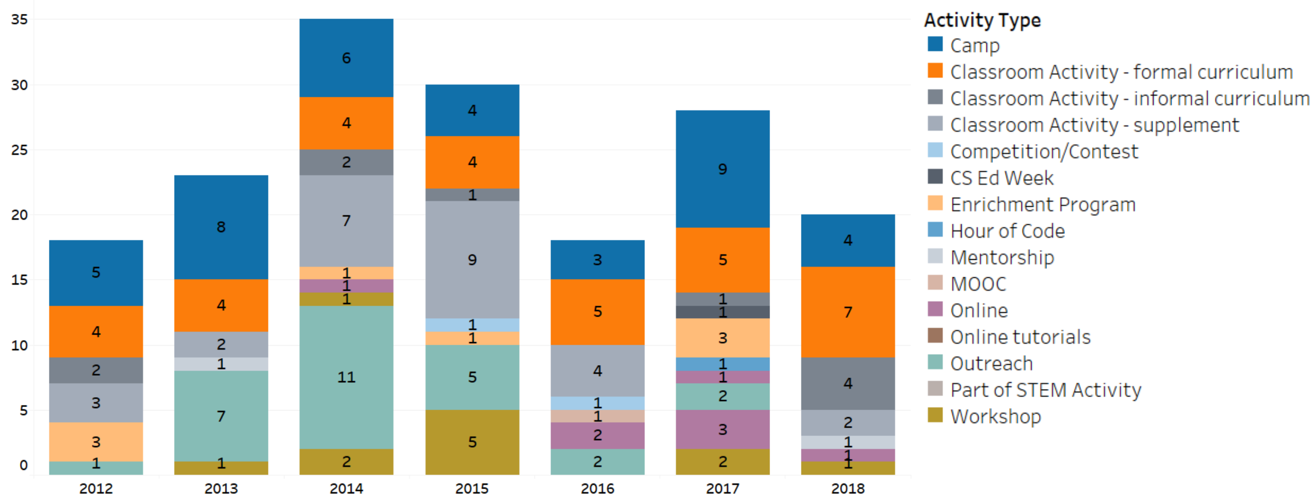

Figure 4: Type of Activity reported in the articles, presented by year.

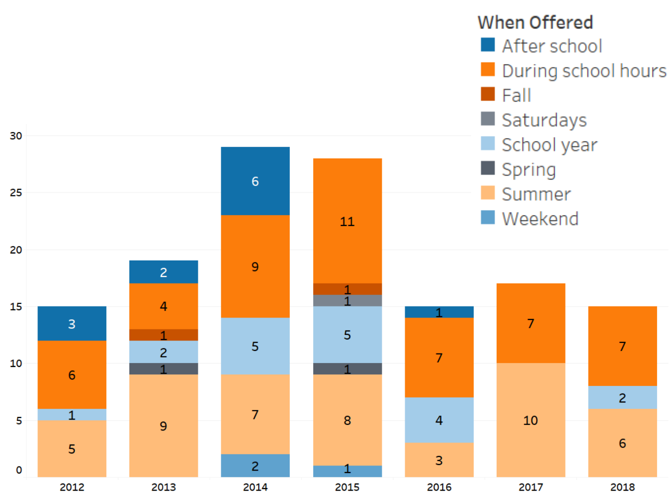

Figure 5: When activities were offered as reported in the articles, presented by year.

Table 2: Snapshot of top tools, languages, and environments.

2012	2015	2018
Scratch (9)	Scratch (19)	Scratch (15)
CS Unplugged (3)	Java (6)	Java (4)
Java (2)	AppInventor (6)	Python (4)
App Inventor (2)	Python (4)	App Inventor (3)
Python (2)	Arduino (3)	Arduino (3)
Alice (2)	Alice (2)	
CSS (2)		

middle school, and high school). Research articles covering high school students were published the most. However, half or more of the articles discuss interventions at the elementary or high school level in most years.

3.4.2 Disabilities Of the 178 articles, only 5 (3%) reported any information related to student disabilities [3, 17, 18, 31, 35]. For disabilities, three pieces of information were curated: disabilities, receiving disability services, and disability instruction.

3.4.3 Gender Most of the articles reported activities for both males and females, while some were only targeted at girls, or unspecified. Based on how the gender information was reported, the majority of activities were targeted towards women in computing.

3.4.4 Race/Ethnicity The data for race and ethnicity shows that articles are more likely to report this data if the study focused on diversity. For the years 2012, 2015, and 2018, Black/African American was the most reported race of students in the articles (7, 15, and 13 respectively), with Whites (5, 9, and 6), Asian/Pacific Islander (2, 9, and 11), and Latinos (3, 9, and 12) rounding out the top four identified in the articles. Although this data appears to provide little information, the lack of reporting of this data influences this result [29].

3.4.5 Socio-Economic Status (SES) Socio-economic status is infrequently reported in these articles. However, 25 (14%) of the articles reported the SES of students as either low or free/reduced lunch (Table 3). Only a handful of articles (9) reported on location as rural/suburban/urban. While location may or may not influence SES, it is another piece of information that can be important in understanding the environment in which the study took place.

4 Discussion

Based on our observations of the trends in this data over the past seven years, we offer some implications, recommendations, and limitations of this analysis.

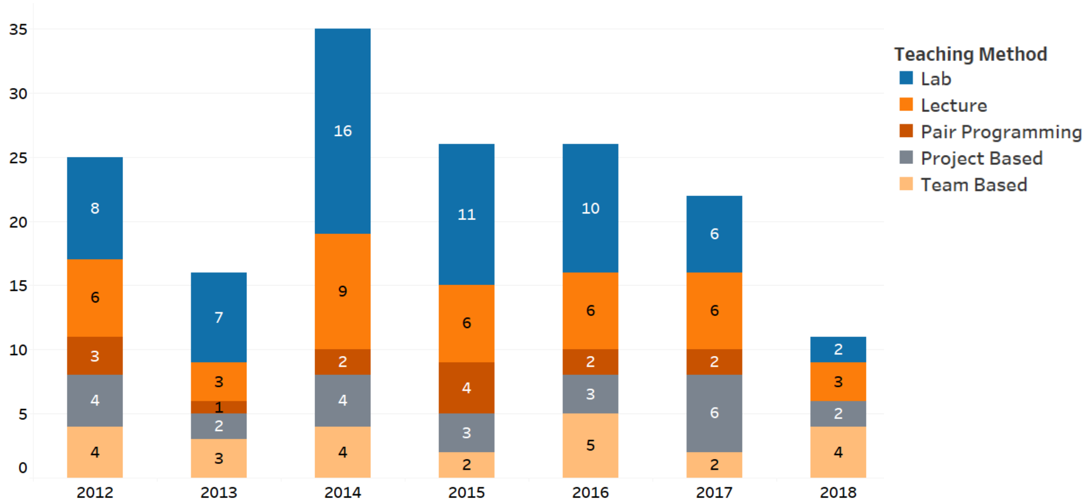

Figure 6: Teaching methods as reported in the articles, presented by year.

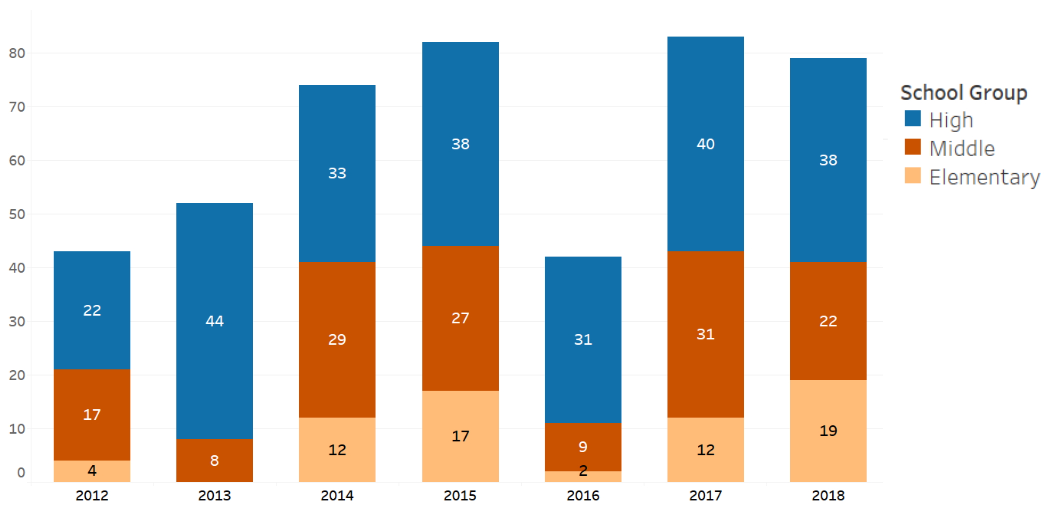

Figure 7: Grade level of students as reported in the articles, presented by year.

Table 3: SES as reported in studies. Low SES reflects low income and/or Free/Reduced lunch.

	Low SES	Working Class	Middle SES/Professional	High SES
2012	1	0	0	1
2013	0	0	1	0
2014	9	0	0	0
2015	3	0	1	0
2016	1	0	0	0
2017	7	0	1	0
2018	4	1	1	1
Total	25	1	4	2

4.1 Implications and Recommendations

There were fewer K-12 articles that included student participants published across these publication venues in 2018 than in the previous four years. This is counter to what we would expect, since the growth of computing education in K-12 has risen [10]. This may be due to a lack of education researchers pursuing this type of research, that K-12 articles are not reviewed favorably in these venues, or that focus has shifted to K-12 professional development studies. This is a concern that is worth further study to ensure that there is a clear pathway for studying programs and curriculum for efficacy and sharing these results.

In 2013, only 14 states (plus Washington DC) had at least one policy involving computer science education for their K-12 schools, with that number rising to 44 in 2018 [9]. What that number does not tell us is the level of integration of the specific policy into the state's curriculum. Despite the policies, estimates of the number of high schools that actually offer computer science classes to students ranges from 16% to 78%. It is also known that black, Hispanic, poor, and rural students are less likely than their peers to attend a high school that offers computer science classes [9].

Regionally, the data shows that publications detailing studies with students located in California are the most frequently published research (with 27 publications), followed by Georgia (10) and Colorado (9). California's inaugural K-12 state computer science standards became official in September 2018 [19, 37]. While it may be the case that standards and other policies may influence computing activities in the state [9], the dataset only reflects work published up through the end of 2018. More recently adopted policies and standards would not yet be reflected in published articles. Proportionally, though, California is the most populous and Texas is the second most populous state, and students in Texas were only represented in four publications, indicating that there are other factors at play [7].

As computing becomes part of the formal class curriculum, the number of outreach programs and workshops being researched appears to be decreasing. By adding computing education to the formal curriculum, we would expect more instruction to be offered during school hours. Teaching methods reported in most of the articles show that lab and lecture based methods have been the most popular throughout the years. Formal curriculum is well-suited for lab and lectures. Team-based learning has been studied more recently. Soft skills like teamwork are considered one of the most valuable skills in the computer science profession and adopting team based learning is a positive approach for students [22].

Likewise, there is a rise in the variety of curricula being studied in the K-12 level. This could be a result of the introduction of the new AP CS Principles course in the 2016-2017 academic year and the rate of adoption of that course into high schools [6] and other similar new programs. AP CS Principles had the largest launch of any AP exam in the history of The College Board [6]. The rise of the new course, coupled with the fact that computing is becoming one of the most popular career fields [10] could be adding to the increase in the variety of courses and topics being taught.

The reported student demographics give an overview of participants included in the research studies and shows a marked increase in the work being done with students prior to high school. This is mostly likely due to the increase in adoption of standards throughout K-12 [1]. However, despite previous evidence that student SES impacts academic achievement [20, 21, 32, 36], the lack of reporting of participants' SES in studies suggests that it has not been considered an important factor in K-12 computing education. Similar to SES, there is insufficient data to determine whether or not students with disabilities are being included in research studies and experience reports. Since there are 14% of K-12 students (approximately 7 million) in the U.S. who report having some form of disability, there is a disparity that can only be addressed through better collection and reporting of data [2, 11]. To achieve CS for All, the research should reflect efforts regarding inclusion of all learners at all levels of ability. With evidence that SES impacts access to computing in K-12 spaces, carefully articulating SES and disabilities of the students will allow better tracking and can provide insight into how well CS for All is meeting its goals. This is similar to previous findings, confirming similar calls for better reporting of data in computing education research [28].

4.2 Limitations

It is important to recognize some of the limitations of this analysis, some of which are due to the nature of the data source. As with any study that relies on manually curated and coded data, there is the potential for data entry errors. To help prevent this, articles in the curated dataset underwent two reviews, the first to initially enter the data and the second to help ensure that the data was entered correctly.

The methodology of the data curation only categorizes the location of the students/intervention if the authors of the articles explicitly state where the intervention took place. If the authors are based in the US, it is not automatically assumed the study is as well and likewise for state location. Therefore, there are likely a number of articles in the dataset that are not reflected in the heatmap in Figure 2, because the articles did not explicitly state the location of the intervention.

Several articles may have reported on the same study, increasing the likelihood that certain data is overreported. For example, four articles may have reported different aspects of the same study in which only females participated, thus leading to the over representation of that demographic. However, it has also been found that there is significant data underreported in articles, such as the number of participants, gender, race/ethnicity, and SES [29]. Both have potential to skew the data and should be taken into consideration.

Though this study is limited to the US, it serves as a model for collecting and analyzing similar data from other countries so that this analysis can be conducted on other countries as well.

5 Conclusion

This study analyzes seven years of K-12 computing education research data to offer a glimpse into its current state in the US and how the research landscape has started to change. While it is clear that computing has entered the K-12 space, what is still not clear is how equitable the access is to the computing due to data that is either not being collected or analyzed or is being under-reported. Whether it is lack of investigation or reporting, the lacuna in these areas is problematic for those looking to further adopt and expand K-12 computing education. Unfortunately, the lack of reporting of key demographic data for students, particularly around SES and disabilities, as well as program data (i.e. data about how the intervention is implemented) is a concerning trend that is not yet improving in published work.

As efforts increase to include more students in more states and from more backgrounds, being able to understand the experimental design and the student population that the intervention was tested with will be key in understanding how the intervention may work in different settings with different students. What may have worked in a primarily white upper-middle class suburban school may not work for a primarily poverty level rural school or ethnically diverse urban school. And what may have worked for neurotypical students may not work for students with reading disabilities. As computing education moves into more K-12 classrooms, this information will possibly be the key in ensuring that there is success in having CS for All.

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