Professional Development for Data Science Educators

Elayna Whiteman
The University of Chicago
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thePaulDouglasinstitute DataScience4everyone

Recommendations

1. Establish a dedicated Data Science Officer, under the Department of Education, for each state and one at the federal level to oversee professional development programs. These individuals can provide oversight as Data Science programming and curriculum are adopted nationwide
2. DS4E should create a country-wide mentoring program. Teachers and faculty already implementing Data Science in schools should have a medium to mentor and aid teachers new to data science
3. Creating professional development programs that not only help teachers gain skills in Data Science but also provide lesson and curriculum plans to decrease barriers to entry (link)
4. Data Science classes should be encouraged for graduate students pursuing degrees in teaching
5. Expand the available professional development programs teachers can use to increase preparedness and knowledge
6. Inform and encourage districts to use Title IV Part A Grants

Introduction

Today, implementing data science education into the K-12 curriculum is more important than ever. According to the Bureau of Labor Statistics, employment in data science careers is expected to grow by 36 percent in the next decade. Lessons provided in classrooms today prepare students to extract meaning from and interpret data for future careers.

One important aspect of implementing data science education in schools is having qualified teachers. However, under the No Child Left Behind Act of 2002, teachers must have at least a bachelor's degree, and a teaching license in their state, and (depending on the grade level) must have additional credentials or advanced degrees. This means hiring faculty who are familiar with the material into schools is difficult.

Furthermore, current K-12 teacher shortages require careful implementation of data science lessons. Burdening existing teachers with hundreds of hours of classes or the task of creating their curriculum discourages the adoption of data science lessons in classrooms.

A major solution to these issues is the adoption of professional development programs. These programs provide existing teachers the opportunity to become more well-versed in data science without having to go back to school to gain extra credentials or experience. Many teachers already take professional development courses to maintain their teaching licenses. Therefore, using these programs to prepare K-12 teachers for integrating data science into their schools is an exemplary solution. Existing teachers can fulfill local or state requirements to maintain their teaching credentials, and schools can easily integrate lessons into classrooms.

Both general STEM and data-science-specific policy case studies demonstrate the positive effects of professional development programs. Teacher-led groups foster collective learning amongst individuals participating and allow knowledge sharing from teachers already well-versed in data science curricula. These programs additionally provide methods and lessons teachers can bring back to classrooms, lowering the barrier to entry for implementation.

One major issue with previous attempts to use professional development programs in the data science field is funding. Federal Title IV, Part A funding can fill this gap. These grants have no cap on spending so long as it falls under one of three categories, including effective use of technology and providing students with a well-rounded education. These grants then can be used by districts to enroll their teachers into new professional development programs or already existing programs offered through third parties or universities. The flexibility of these block grants affords opportunities that otherwise would not be available to K-12 faculty.

Literature Review

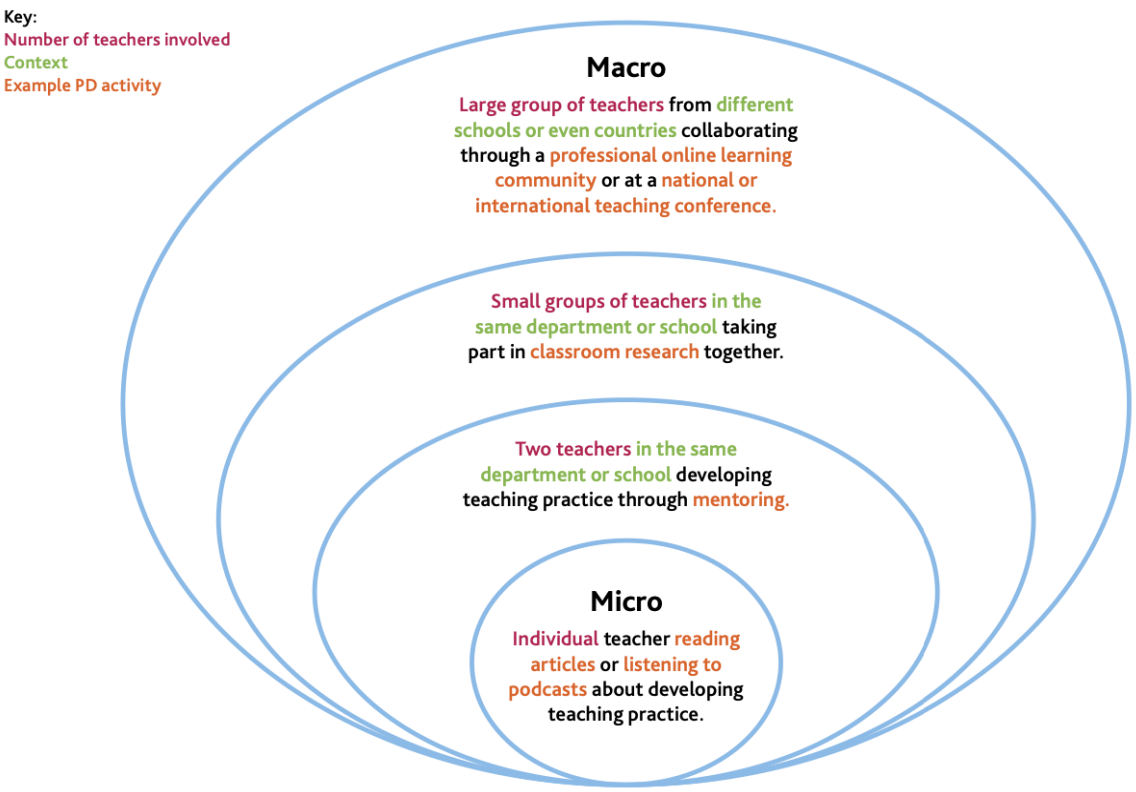
What Is Professional Development?

Assessing the implementation of a new curricular program requires measurement of both accessibility and outcomes. Accessibility measures capture the availability and distribution of data science opportunities in schools and the composition of students within those offerings. Outcomes measures report the effectiveness of these programs in promoting student learning and preparation for postsecondary education or careers.

According to Continuing Professional Development (CPD) Certification Service, *"The term Professional development usually refers to the process of tracking and documenting the skills, knowledge, and experience to enhance an individual's current work practice and future career. It is a record of any experiences, learning, and practical applications gained beyond any initial training"*

Professional development programs have been shown to develop better community and group-led discussions and lessons, encouraging group learning. In an evaluation of the *Professional Learning Network for Computer Science*, programs have increased teacher confidence, and primed individuals to be able to receive new information on data science and data science education as new curriculums are developed.

Figure 1: Micro to macro scale engagement with PD activities



Why Professional Development?

Currently, there is a massive shortage of teachers in K-12 schools. All efforts to bring new lessons and topics into school should be as easy on teachers as possible to reduce attrition or burnout (link)

Teachers need to be prepared to teach students. However, there are few options for teachers to gain new skills in a rapidly changing landscape where Data Science is not being taught in most colleges, let alone K-12 schools

Furthermore, new teachers do not have opportunities to gain these skills while pursuing their degrees, so solutions to past degree requirements are necessary (link)

Professional development allows teachers to hone specific skills while still maintaining their teaching degrees. Many times, teachers are required to complete a certain number of classes or hours of Professional Development to maintain their position as faculty

Furthermore, under the No Child Left Behind Act of 2002, teachers must, depending on the grade level taught, gain advanced certification or credentialing (link)

Professional development increases teacher self-efficacy. Teachers can only learn the necessary skills for applications within classrooms It also empirically Increases student's performance in class (link)

How can we expand the number of teachers bringing data science into schools?

- Paraeducators, or teaching assistants, serve to assist teachers in classrooms (link)
- Paraeducators could provide support as existing faculty take necessary steps to become more well-versed in the data science curriculum
- These individuals could bring specific data science curricula into classrooms by enrolling in professional development to alleviate stress on existing teachers

Challenges with preparing teachers for data science.

- Rural teachers may get left behind: many resources provided are done so online, which can add a prohibitive cost and burden for teachers working in rural and underprivileged areas (link)
- Making sure resources can be accessed on paper are crucial

Examples of Professional Development Policies

Massachusetts' Department of Elementary and Secondary Education

- Massachusetts has Digital Literacy and Computer Science (DLCS) learning standards
- There is a significant focus on easing both faculty and students into the new Data Science curriculum.
- DLCS has a Test of Educator Licensure (MTEL) to be a licensed digital literacy and computer science educator and has Licensure Requirement tools accessible for educators to identify requirements for different types of licenses.
- Furthermore, the DESE provides Professional Development resources, including but not limited to links to overviews of the DLCS standards, a self-paced course created by the Georgia Department of Education, and General PD planning guidance.

Illinois Computer Science Education Task Force and findings

- Public Act 099-0647 had the State Board of Education establish a Taskforce on Computer Science Education
- The task force was focused on analyzing the current state of computer science education in Illinois, making recommendations to the General Assembly focused on substantially increasing CS education and practices to be educated in computer science, and making funding recommendations

Virginia, California, and New Jersey

- All states that have computer science standards that include data science components
- New Jersey: Has a teaching certificate with the Computer Science Technology Certificate #4148. Allows teachers to teach certain programs including Data Processing. It further allows teachers to use college degrees to gain certification. Furthermore, it allows individuals who have a different experience, whether that be self-employment experience or a degree not included may help an educator get their certification
- Virginia: For CS, has separate standards for each grade and different curriculum frameworks
- California: Includes specific policy on being written in "language accessible to teachers, curriculum leaders, and students." Furthermore, breaks up the curriculum into smaller chucks (K-2, 3-5, 6-8, 9-12), guides writing, reading, and modifying existing algorithms

Data Science for Educators: American Statistical Association

- The ASA provides a free online course that provides K-12 teachers with an introduction to data science and its applications in education. The course covers topics such as data visualization, statistical inference, and machine learning, and includes hands-on activities and case studies.
- Offers meetups (via Zoom) to distribute and discuss K-12 statistics topics, and programs like Meeting Within a Meeting Statistics Workshop for Mathematics and Science Teachers support teachers with both teaching conceptual understanding and real-world applications of data science.

Data Science in Education Using R: DataCamp

- An online course that provides K-12 teachers with an introduction to R, a popular programming language used for data analysis. The course covers topics such as

data manipulation, visualization, and statistical analysis, and includes real-world examples and case studies.
- Open Source PDF for teachers to learn how to use R (a free and open source coding language for data analysis) and can be freely shared

Case Studies

Broward County Public Schools

- Dr. Lisa Milenkovis oversees STEM and CS Operations in the Broward County Public Schools in Florida
- The first step was partnering with Code.org, which provided professional development funding and interconnected links of "master teachers" who were already experienced in developing CS curricula. This further outlines the necessity to have interconnected networks for teachers and educators to gain experience not just from classes but interpersonal relationships as well
- Dr. Milenkovis also received grant funding through the Computer Science Teaching Association to create an online PD course for CS teaching certification in the state of Florida.
- A further aspect of the latter grant was providing monetary educator support through paid time off.
- Through these policies, the district has been able to expand CS classes to not just high schools, but also middle schools within their district

Chicago Public School's Computer Science Requirement

- Difficult to write a curriculum while also learning how to teach and finding qualified teaching staff
- CPS developed a sequence of courses to help teachers acclimate to teaching introductory courses (link)
- To aid teacher attrition and opportunity costs, Discover Partners Institute provided a grant from Amazon to provide tuition support for teachers who want to get endorsements in Computer science.
- The district still struggles to provide CS classes for several reasons
    - Introducing CS into high school classrooms, while necessary, leaves many underprivileged and minority students still unable to access these classes
    - Implementing CS into elementary schools would allow students to feel primed and prepared, meaning developing PD programs for teachers depending on their grade levels is necessary

    - While the grant money from Amazon has helped aid many teachers, a more stable form of funding (whether that be through the city, state, or federal government) is necessary for the maintenance

Weber School District

- The Utah district sought to adopt CS education into their K-6 schools and to prevent over-burdening teachers, utilized teaching aids
- The teaching aides used already existing resources (Skill Struck) and led lessons
- 82.7% of the K-6 students enrolled in a Computer Science course from 2021 to 2022.

Areas for Future Research

- Longitudinal research is currently lacking in the literature. Once more states adopt Data Science requirements and programs, further research into the effectiveness of PD programs is necessary. Specifically, surveying teachers to see where these programs fail and what gaps need to be filled will be useful
- What are the most effective Professional Development programs for teachers? There are a multitude of different types of PD programs that range in difficulty, cost, and time commitments. Should teachers attend yearly conferences, one-off summer-long programs, or something altogether different?
- What is the role of teacher aids in the classroom? While teaching assistants are useful and paraeducators have been useful in the past, how can districts best integrate these individuals into classrooms? More importantly, how can these individuals help support teachers when time is short or states don't yet have the time or resources for pre-established programs?
- What is the best way to prime teachers to teach data science while they're still pursuing their degrees? Many colleges and universities don't have data science requirements for teachers as general education requirements, meaning that many faculty have no exposure to Data Science prior to teaching and are forced to play catch up. What are better ways to integrate Data Science principles into teaching degree requirements?

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Data Collection & Reporting

Evaluating Program Implementation and Measuring Outcomes

Micayla Roth
The University of Chicago
May 2023

thePaulDouglasinstitute DataScience4everyone

Recommendations

1. States should use a two-pronged approach to data collection and reporting, using inputs as a measure of accessibility and equity, and outcomes as a measure of proficiency and progress.
2. States should integrate data science into standard assessment of educational progress while also considering alternatives to traditional multiple-choice examinations. Multi-modal assessment can relieve some of the testing strain from students while providing a more nuanced view of the state of data science education in the country.
3. States should measure longitudinal outcomes across agencies and departments in order to understand how K-12 data science programs can promote success in higher education and lifelong careers.

Introduction

Of the top ten jobs with the highest projected growth between 2023 and 2027, eight require a foundation in data science, including AI and Machine Learning Specialists, Data Analysts and Scientists, and Big Data Specialists. However, most American students are not exposed to data science education until post-secondary schooling, if at all. K-12 math and science curricula are grounded in an outdated need for Cold War and space race engineers. Low achievement in algebra and calculus can hold back students from pursuing STEM careers in a world driven by statistics, computer science, and big data.

The implementation of fundamentally different learning pathway programs cannot exist without ongoing data collection and reporting that seeks to evaluate what is working, who has access, and where improvements need to be made. In a future where data science is an established educational pathway within K-12, progress will be assessed alongside other subjects like reading. The critical thinking exploratory analysis skills underlying data science applications present a challenge for large-scale assessment. Recent pushback against standardized testing and "teaching to the test" as an educational model has encouraged more open-ended experiential learning and assessment, which is difficult to achieve on a national scale.

This playbook considers how states can collect data equitably and in a way that allows for comparisons across states. It explores how other data collection and reporting systems have operated historically, how the computer science model has navigated data more recently, and how systems can be adapted to the needs of data science education.

Literature Review

The need for data collection

Assessing the implementation of a new curricular program requires measurement of both accessibility and outcomes. Accessibility measures capture the availability and distribution of data

science opportunities in schools and the composition of students within those offerings. Outcomes measures report the effectiveness of these programs in promoting student learning and preparation for postsecondary education or careers.

The National Forum on Education Statistics (NFES) identifies the following roles of education indicators:

- Purposes:
    - Track progress over time
    - Observe potential imbalances between groups
    - Observe the influence of data on teacher practices
    - Access multiple sources of data in one place
    - Assess financial decisions and resource allocation
    - See the impact of professional development
    - Understand different levels of accountability data
- Uses:
    - Identify student needs and gaps between groups
    - Target interventions
    - Evaluate program success
    - Establish benchmarks
    - Evaluate achievement
    - Public reporting
    - Forecast college and career readiness
    - Evaluate educator preparation and effectiveness
    - Project the future of the workforce and economy

Critically, the NFES acknowledges that any given policy priorities in these areas inform which metrics are selected to be measured; on the other hand, measurements inform the policies that are created, modified, or eliminated to improve results.

The system strives for "comparable and uniform data collection." When data are compared across states, strengths and weaknesses of varying programs can be identified, and successful programs can be transferred to new school systems or scaled up to reach more students. The success of programs within a state cannot be compared without uniformity between datasets.

Data collection & reporting in computer science

Recent efforts to integrate computer science into the national curriculum provide a launchpad for data science education. The existing precedent also allows for the critical identification of any challenges or ineffective practices within data collection. Code.org has championed the push for computer science education, and they provide a collection of policy resources that assist local decision makers in implementing policymakers in their states and districts.

Code.org produces an annual State of Computer Science Education report, which thus far has focused on the availability of computer science courses and enrollment data by state. Data is collected from state education agencies through direct collaboration or portal access; for schools without data systems, data is collected through direct contact with school employees and course catalogs. At this time, computer science-specific standardized testing exists only within the College Board's Advanced Placement (AP) program. While these exams are standardized and administered nationally, enrollment is not representative and offerings vary between districts. Because standardized testing in computer science outside of AP exams is limited, the State of CS does not publish outcomes data at this time. States must be held accountable to computer science standards using other means, which often include letters of assurances or monitoring by the state.

Methods of collection

The National Forum on Education Statistics defines three main types of indicators when measuring educational progress:

1. Cohort indicators that follow and describe a particular group over time,
2. Annual indicators that measure variables each year, and
3. Longitudinal indicators connect a measure across years for a particular group.

These allow a holistic view of short-term and long-term achievement to evaluate improvements in programming as well as changes in student success. The NCES suggests using both "leading" and "lagging" indicators for this purpose, so that achievement can be used as both a predictor of future success and a reflection on the instruction and programming received. Metadata, common data standards, and data dictionaries encourage data transparency and ease of use.

Collection methods depend on what is being measured. Inputs, such as course availability or enrollment, can be collected from local education agencies (LEAs). Outcomes, such as proficiency or progress made by students, are typically measured through standardized testing. Currently, no standardized testing exists for data science education, and computer science testing is limited to the College Board Advanced Placement program; while passing rates are sometimes used, even that is not always possible when localized numbers are small enough to pose a privacy risk. Focus groups and surveys are also used to gather qualitative information on people's opinions, satisfactions, and critiques associated with their educational experience.

Input measures capture where data science courses are offered, who actually takes them, and whether the courses are of sufficient quality. The Code.org State of Computer Science report, for example, maintains a series of enrollment and offering metrics that are meant to assess the accessibility of computer science courses (see example below). These metrics capture which schools offer computer science courses as well as who actually enrolls in them. Ensuring that students at all kinds of schools have access to computer science, and that students of all populations, especially those traditionally underrepresented in computer science, are both critical goals in the development of successful K-12 computer science and data science programming. The

Brookings Institution recommends looking at representation gaps to compare enrollment by gender or race in order to understand who is being reached.

Recent pushback against the increasingly overwhelming standardized testing administered to students has called into question how to measure progress for a new discipline such as data science without adding another exam to the agenda. While complete elimination of testing may not be possible, methods exist to measure the effectiveness of programs while minimizing testing. Strategies include testing only samples of the population (as the National Assessment of Educational Progress (NAEP) does), stealth assessment collected through educational technology platforms like Khan Academy, longitudinal data collection across agencies, portfolio-based measures, and school inspections. Google and Gallup have administered interviews via online surveys on perceptions regarding the importance of computer science, which captures the subject's centrality in the larger curricular context. Their study also measures the availability, access, and quality of computer science education, as well as confidence and interest.

Examples: Data Collection & Reporting on the National Scale

National reporting systems inherently allow for the same data to be collected across states and compared. While less receptive to state-specific contexts, established national collection and reporting systems can act as a guide in developing data science-specific systems for states.

Code.org: State of Computer Science

- The State of CS focuses on having their data represent 100 percent of public high schools, so they focus on enrollment data and then extrapolating access, rather than outcome data, which is more limited:
    - "76% of U.S. high school students attend a school that offers a foundational computer science course, but across 36 states with enrollment data, only 5.6% of students are enrolled in a foundational computer science course (up from 4.7% of students enrolled in 2021). Across 36 states, 32% of students enrolled in computer science courses are female."
- The State of CS report presents a summary for each state that tracks the following information:
    - Whether each of the nine policies are present in the state
    - Overall student trends in access & participation
    - Percent of public high schools offering "foundational CS" courses for any years in which a dataset was available
    - Percent of high schools in each community type (urban, suburban, rural) offering foundational CS
    - Access by free or reduced lunch population
    - For states that do not provide participation data in all foundational computer science courses, College Board AP program data is used; however, this can skew

the data because of private school participation in the AP program but not in the rest of the data.

- Using this data, the report finds that there are fewer gender and racial disparities in K-8 participation than in high school.
- Data is collected from state education agencies through direct collaboration or portal access; for schools without data systems, data is collected through direct contact with school employees & course catalogs.
- School IDs are cross-referenced with data from the US Department of Education to determine geography and demographics.

Civil Rights Data Collection

- Every other year, the Department of Education Office of Civil Rights administers the Civil Rights Data Collection to collect data on education and civil rights issues in public schools in the United States.
- The CRDC is conducted as a set of surveys for Local and State Education Agencies with questions and enrollment tables to complete:
    - For reporting, LEAs often maintain information in a student information system (SIS); there's often discrete data systems for school, staff, and finance data.
    - Sometimes vendors will assist the LEA, and SEAs in some states have been taking over reporting.
- The CRDC site provides a school and district search tool, detailed data tables by school, data analysis tools including comparison graphs and an outcome rate calculator, an education equity report builder, yearly national and state estimations, data reports and presentations, and downloadable data files of all data from a given year.
- Relevant questions asked of schools focus on course availability and technology access:
    - Number of courses of a given subject – currently, computer science is accounted for, but not data science
    - Number of students enrolled in courses of a given subject
    - Number of students passing a given course
    - Number of CS classes taught by teachers with a CS certification/license/endorsement from the state
    - Whether the school has fiber-optic connection and WiFi in every classroom
    - Whether the school allows students to take home school-issued devices to access the Internet
    - Whether the school allows students to bring their own devices to access the Internet
    - Number of Wi-Fi enabled devices provided by the school to students for student learning use
- Relevant questions asked of LEAs focus on enrollment and LEA-wide resources:
    - Most importantly, the survey asks whether there is a civil rights coordinator for a LEA. Code.org cites establishing computer science positions in state and local education agencies as one of their nine policy priorities. Tracking data science

coordinator leadership would be important for understanding which states have individuals dedicated to data science program implementation.

- The LEA reporting process is as follows:
    - Map CRDC data elements to corresponding locations in LEA data system
    - Extract data
    - Aggregate data
    - Format the file
    - Submit data into CRDC Online Submission System (by loading files into system or manually entering data into online survey forms)
    - Review
    - Certify
- LEAs are asked to verify the schools in their districts using the CRDC Advance Website Support Tool
- On the CRDC site, users can search up a school or district and look at demographics, staffing & finance, college & career readiness, and discipline.
- Data tools include:
    - Data tables: a user can look at data from a school across years, select desired variables, and export a dataset.
    - Data analysis tools:
        - Comparison graphs & data – a user can select school, district, or state.
        - Detail graphs & data – a user can select two schools within a district and compare them to each other and the district as a whole.
        - Outcome rate calculator: a user can compare multiple schools or districts.
    - Education equity report builder.
    - Yearly national and state estimations (enrollment, school programs, course enrollment, college preparatory exams, student retention, school staff, school climate, etc.).
    - Data reports & presentations.
- Downloadable data files of all data from a given year are also available.

National Assessment of Educational Progress (NAEP)

- The NAEP focuses more broadly on reading and math overall, but tracks "Data Analysis, Statistics, & Probability" as a content area within math.
- Resources & data tools:
    - NAEP Data Explorer: Using Nation's Report Card, can choose subject, grade, year(s), scale; choose jurisdiction; choose variables for analysis (focuses on disaggregating by race/ethnicity); choose statistics for analysis; create report; create a significance test to see if the numerical results are statistically significant; and create charts
    - State profiles: a map shows state performance compared to the nation; can select a state to view its profile:

        - Overall trends & snapshot reports, summary statements (average scores by grade & subject, plus percent above proficient or basic), demographics, comparisons to other states, student groups & gaps (by gender, race/ethnicity, National School Lunch eligible/not eligible)
    - A district profiles section is also available, but it only has data available for 26 large districts.
    - Users can also map state proficiency standards onto NAEP scales.
    - Bigger datasets have restricted access; EdSurvey statistical package in R can assist in analysis.

Case Studies

At this time, no state uses standardized testing to measure data science or computer science progress. Exploring how states track outcomes and extend them longitudinally in other areas provides insight into how data science could be incorporated into existing systems, or inform altogether new collection and reporting methods. The states below utilize a combination of longitudinal data accessed across state agencies, publicly accessible dashboards and data access tools, and state-specific functions that could be beneficial at a larger scale.

Delaware

Delaware Educational Data Reports maintains a collection of reports addressing programs within larger categories such as Student Enrollment Data, School and Student Performance, and Educational Spending. In 2021, House Bill 198 required all public and charter schools to teach Black history, which has a report under the School and Student Performance category. A state could similarly have a section devoted to data science education.

Because the statewide assessments have not yet responded to the curriculum on exams, each district is required to submit a Google Form answering close- and open-ended questions addressing implementation. The data is primarily qualitative and would not assist in comparability between states or outcomes measurements. Such a form could, however, act as a set of accessibility measurements, particularly during the early stages of program implementation when there is limited established knowledge on curriculum execution and the types of questions and coded answers that should be presented. While not adequate as a long-term collection of measurable student outcomes, crowdsourcing information during initial implementation can point states towards the questions they should be asking when more formal data collection is administered down the road.

California

California maintains a more robust data and statistics system consisting of reports, downloadable data files, interactive tools, and a longitudinal data system. The California Basic Educational Data System (CBEDS) is the state's annual data collection reported through an Online Reporting Application. It consists of a County/District Information Form (CDIF), a School Information Form

(SIF), and a District of Choice Supplemental (DOCS). A CBEDS coordinator from each LEA is in charge of data submission, validation, and certification.

The state created the California Longitudinal Pupil Achievement Data System (CALPADS) to comply with No Child Left Behind reporting requirements in 2009. The system centralizes demographic data, program participation, enrollment data, discipline, and statewide assessment data. CALPADS is used to calculate the accountability metrics on the state dashboard, register students for statewide assessments, ensure that students are receiving special education support, and provide information to the public and researchers. The system created their own naming conventions for certain data elements that could subsequently be adopted by other Department of Education data systems. LEAs submit data on an ongoing basis and review certification reports biannually, which CALPADS uses to create aggregated reports.

The DataQuest system allows users to request data and statistics at the school, district, county, and state levels. Depending on the request, DataQuest either provides the data or directs users to the site with the information they are looking for. Categories include assessment data, enrollment data, and course enrollment data. Data reports are organized by topic, and include both data reports and downloadable data files. The California School Dashboard provides a lookup tool that anyone can use to access school or district data. The interactive tool provides a glimpse of general metrics which can be further explored for a deeper understanding of a particular statistic. The variety of data collected and reported provide a solid basis for the various methods that can and should be used when focusing specifically on data science education.

Alabama

Alabama maintains a computer science "expansion report" dashboard displaying the number of schools offering CS, enrollment data, and teacher information. The associated PDF lists the number of students obtaining a passing score on either of the two AP Computer Science exams and the number of students earning postsecondary graduate credit for a dual-enrollment course. These are broken down by gender, race, ethnicity, and socioeconomic status. The report also tracks which districts are meeting state CS requirements and highlights schools that do not have students enrolled in CS. Information for each district can be accessed via a Google Drive folder of Google Docs that list enrollment data by school, but test scores are not available at this time.

The state also maintains the Alabama Math and Science Achievement Indicators dashboard. Users can select a school system or look at the whole district. The dashboard displays a breakdown of demographics and graphs of proficiency over time across the district, by racial and socioeconomic subgroup, and by grade.

The interactive Math and Science Achievement Indicators dashboard could provide a model for what a data science dashboard may look like. The Google Docs, while useful for members of the general public who are curious about their own district's computer science implementation, are

less useful for merging local datasets into a larger, comparable dataset. A set of accompanying spreadsheets would allow for better analysis of inputs and outcomes.

Idaho

The Educational Analytics System of Idaho joins information from the Idaho State Department of Education, the Idaho State Board of Education, and the Idaho Department of Labor. This allows the extension of educational data within the K-12 system to lifelong employment outcomes. The state also maintains the Idaho System for Educational Excellence, a longitudinal data system.

Given the applicability of data science education to real careers, understanding the link between data science programs, assessment outcomes, and educational and career outcomes is critical to measuring the success and room for improvement of such programs. A collaboration between departments would be particularly beneficial to data science education as a means to extrapolate data science achievements in school to lifelong outcomes.

Georgia

Georgia maintains a series of data dashboards. The statewide longitudinal data system, known as GA•AWARDS, links education and workforce data from the Georgia Department of Education, Georgia Student Finance Commission, University System of Georgia, Georgia Professional Standards Commission, Georgia Department of Labor, and the Governor's Office of Student Achievement, among other relevant agencies. A data matching algorithm consolidates the data into a data warehouse with the goal of evaluating "(1) effectiveness of educator preparation programs; (2) effectiveness of strategies and interventions implemented within the State, and (3) educational background of students who experience the least difficulty in transitioning to college." This allows the creation of unique dashboards, such as the High School Graduate Outcomes Dashboard and the Georgia Higher Learning and Earnings Dashboard. Given the relevance of transferability of data science skills to careers later in life, such a dashboard may be beneficial to a state assessing the effectiveness of its data science programs as a means of preparation for real-life jobs.

The state also maintains the Schools Like Mine dashboard, which allows users to pick a school and two comparison criteria, and then displays similar schools in the state along those metrics. This could be a powerful tool when implementing a new data science program. If a school has an unsuccessful program, district leaders could analyze successes in similar schools in the state and adapt the programs accordingly. Learnings from successful schools could be transferred to other schools with similar demographic or systemic characteristics. This could permit for expansion of successes and identification of gaps, allowing schools and districts to pool knowledge and improve programs through joint analysis.

Georgia Special Education Services provides data collection systems that teachers fill out on behalf of students. To measure pre-school outcomes, for example, teachers input the number and

percentage of students that satisfy a particular statement, such as "Percent of children who did not improve cognitive functioning." While this does not substitute the role of standardized testing, it is one option that states can work with to alleviate the standardized testing burden on students, A state that practices sampled testing could supplement with similar surveys that still allow for the collection of proficiency information for the school, district, and state as a whole.

Field Needs & Areas for Future Research

Data science outcome evaluation requires a more robust system for data collection and reporting. Today's state and national standardized testing is grounded in outdated math and science standards that do not reflect the reality of present-day STEM careers. Data science must be incorporated into the standard national curriculum and its assessments. Future research should consider how data science content can be assessed, a process that can be developed in tandem with computer science.

States must grapple with how to collect context-specific information while also producing data that can be analyzed and compared nationally. An assortment of measurement tactics are necessary to collect qualitative data addressing individuals' experiences, the availability and equitable distribution of data science programming, proficiency of students engaged with data science curricula, and the long-term outcomes of students who enter the data-driven workforce.

The introduction of an entirely new discipline into the educational landscape presents a unique opportunity to rethink how students should be assessed. While single-answer multiple-choice testing is the norm in standardized exams, the ever-increasing availability of AI tools like Chat-GPT commands thinkers who can approach open-ended problems creatively and analytically. Open-ended examination presents a challenge for large-scale assessment of educational progress, particularly in a way that allows comparability between schools, districts, and states. Additional research is required to explore how to measure proficiency and progress equitably and innovatively, while also sufficiently uniformly to compare implementation across states nationally. Innovative curricula requires innovative means with which to measure it, and we must act with urgency in order to prepare the next generation of leaders in a data-driven world.

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Data Literacy Requirements in K–12 Data Science Education

A Complex Policy

Josie Barboriak
The University of Chicago
May 2023

thePaulDouglasinstitute DataScience4everyone

Summary

- Given the growing demand for and interest in data science in K-12 classrooms, there is a need for **practices to encourage and measure data literacy** in education.
- Graduation requirements in statistical literacy areas would increase equity in data science education but **require a data science education and teacher base to be established beforehand**.
- Successful computer science and statistics graduation requirements have benefited from supports that are not yet in place in most states.
- It may be a better course of action to **incorporate statistical and data reasoning skills into mathematics and science education** through policies like the Next Generation Science Standards than to have data science as a separate class.

Recommendations

1. We do not recommend a universal data literacy graduation requirement at this time.
2. We recommend that every school develop a data literacy plan.

Introduction

The Need for Data Literacy Evaluation in Data Science Education

We live in a data-driven world. Scientific conclusions, policy decisions, and business choices made in the wider world, all of which influence our lives daily, are based on data. All of our biggest challenges — climate change, poverty, social justice, food insecurity— are informed by data. Understandings of quantitative data are helpful at every scale; they can be channeled into community-based projects or long-term modeling. The modern citizen is confronted with data-based conclusions each day; it is crucial that one develop a healthy amount of skepticism with which to evaluate these conclusions. To be data literate is to be able to determine truth and meaningful conclusions from raw statistics.

For the individual, data literacy is now more than ever becoming a critical skill in employment outcomes. A 2018 report from the Business Higher Education Forum found, “At some moment in the future, many of the high levels of skill that currently seem confined to the upper reaches of the digital economy, or to larger, more complex organizations, will become the norm among jobseekers, incumbent employees, and workplaces” (BHEF 2018 publication, p. 18). The United States Department of Education has recognized the need for data literacy from an equity lens which can support positive identity by rethinking statistical and mathematical education (Ed.gov, p. 13). Clearly, it is becoming not only an individual asset but a civic duty to be able to separate truth from falsehood in data, yet schools are still adjusting to these demands.

However, developing standards for and evaluating data literacy can be difficult. Below, we outline the current landscape of data literacy assessment in K-12 education and propose ways forward from the policy perspective. We evaluate whether or not a data science graduation requirement would be helpful in public schools at this time.

Literature Review

What is Data Literacy?

- "The Data-Pop Alliance defines data literacy as 'the desire and ability to constructively engage in society through and about data' (Bhargava et al., 2015). This is a very high-level definition, but it has the merit of pointing at two basic components of data literacy: using data and understanding data" (Van Audenhove *et al.*, 2020).
- "Fostering data literacy includes fostering mathematics, statistics, quantitative, media, and discipline-specific literacy to equip students with the knowledge and resources needed to make sound, informed decisions and to solve problems arising in their personal and professional lives as members of society" (Ed.gov, p. 11).
- Students must be able to question the data that is presented to them (data skepticism).

Promoting Data Literacy

- "The best way to help people attain statistical literacy is to begin their statistics education in the elementary grades and keep strengthening and expanding students' statistical skills throughout middle school and high school years" (Bargagliotti et al, 2020) (p.5).
- It is more important to understand big data sets and draw conclusions from them than to program because it's more universal and applicable.
- "A couple big integrated community connected projects each year can be a great place for a data science integration"-- use data to help the community, keep it application-based.

Obstacles To Data Literacy

- Equity issues – how can we increase data science access in underrepresented communities?
- It is hard to encourage graduation requirements, and there is currently an anti-standardized testing movement.
- "The first issue is the representation of data as cognitive authority, in which data is presented as direct measurements instead of as indicators. In this form of

representation, the accuracy of data can be overestimated" (Van Audenhove et al., 2020).

Examples of Data Literacy Requirements

Required Computer Science Classes

- The official policy of Code.org's State of CS states that "Computer science should be a flex credit that can substitute for a core requirement. States that count computer science as a core graduation requirement see 50% more enrollment in their AP Computer Science courses and increased participation from underrepresented minorities."
- AP Computer Science: Maryland currently has the highest proportion of students passing AP Computer Science (a high school metric) (Reboot Representation, 2021).
    - Data science is part of the new AP CSP exam.
    - It's important to not only implement standards but fund resources like "teacher training and a dedicated center at the University of Maryland" to create a culture around learning data science
- Focus on expanding CS education in under-represented demographics (women and students of color)
- "In addition to the nine policies to make computer science foundational, graduation requirements have made headway in bringing unprecedented numbers of young women and students from underrepresented groups into the computer science classroom" (State of CS, 2022)
- The vast majority of teachers (66%), principals (73%), and superintendents (75%) say that offering computer science is just as or more important as other required subjects such as math, science, history, and English (Gallup Polls)

Data Science Curricula

- Introduction to Data Science Curriculum (IDS) implemented in 55 districts throughout 10 states, most of which are in California and Ohio
- Teachers needed to develop statistical thinking practices, such as posing statistical questions and using data, before effectively teaching the curriculum (Gould *et al.* 2016)

Case Studies

South Carolina

- After South Carolina implemented its graduation requirement for computer science, graduation rates increased as a whole and for every racial and ethnic group tracked by the state (State of CS, 2022).
- Though the national average of women participating in foundational computer science courses is 32%, South Carolina is one of three states with a 40%+ rate (State of CS, 2022).
- **Conclusion**: Graduation requirements are an effective way to increase equity in data literacy.

Chicago Public Schools

- "Although only about half of the high schools in CPS offered any computer science classes in 2016, CAFÉCS research provided the Board with confidence that the ECS curriculum and professional development could spread to all schools in CPS" (McGee, Dettori, Rasmussen, 2022, p. 3).
- "It is important to note that CPS would not have been able to achieve the goal of Computer Science for All students if it had relied solely on fully endorsed computer science teachers… In summary, the graduation requirement created a significant need for computer science teachers and the professional development program initially supported by the Taste of Computer project provided the means to increase capacity at a much higher rate than through fully endorsing teachers alone" (McGee, Dettori, Rasmussen, 2022, p. 6).
- "By securing federal funding, CAFÉCS implemented two key strategies for supporting equitable results: a robust computer science curriculum and professional development program and research to support the program, thus developing the capacity of CPS to enact the graduation requirement policy" (McGee, Dettori, Rasmussen, 2022, p. 13).
- **Conclusion**: Schools should focus on capacity building, specifically referring to teachers, before enacting robust policies.

Another Option: Arkansas Flex Credit

- "To address the rapid expansion of high school computer science courses across the state, the Arkansas Department of Education created a "computer science flex credit". A student receiving this credit can substitute it for the 4th math credit requirement or the 3rd science credit requirement (4 math and 3 science credits are required for graduation). Critically, the computer science flex credit is not a math or science credit. It substitutes for the requirement, mitigating the

departmental and teacher certification concerns mentioned above" (Code.org, 2016).

- "Recognizing that teachers are the most important component of CS education, the Arkansas Department of Education prioritized teacher training programs. The state created clear pathways for certification and cash incentives for in-service teachers that participate in training activities. Meanwhile, policymakers have coordinated with state universities to create a sustainable pipeline of qualified teachers by including CS coursework in preservice teacher training programs" (Fowler and Vegas, 2021).
- **Conclusion:** Prioritize teacher training programs before implementing graduation requirements, and consider flex credits as part of the requirement.

Areas for Future Research

Next Generation Science Standards

- More complicated than a simple "data science graduation requirement" is the incorporation of data science into other subjects. The Next Generation Science Standards, or NGSS, have been adopted in 20 states and the District of Columbia.
- "Analyzing and Interpreting Data" benchmark goes well with other courses (for example, geoscience and feedback loops at HS-ESS2-2 Earth's Systems | Next Generation Science Standards).
- Data science can be incorporated into other subjects; think of data science like we think of reading (Vander Ark, 2017).

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