Using Collaborative Open Science to Advance K-12 Computing Education

Monica M. McGill
Department of Computer Science, Knox College
CEO/Founder, CSEdResearch.org
Galesburg, IL 61401
monica@csedresearch.org

***Abstract*—Open science in computing education has been focused primarily on the data collected by automated learning systems such as those developed in intelligent tutoring systems and rote drill exercises. There is another aspect of data collection that is being continually conducted throughout K-12 and post-secondary computing education through surveys, summative assessments, interviews, and other methods to measure cognitive (e.g., algorithms, data structures, pointers) and noncognitive (e.g., self-efficacy, grit, attitude) factors. As a new field, we have the unique advantage of being able to build and share practical and comparable datasets in K-12 computing education that meets some of the new guidelines and best practices being put forth by the National Science Foundation and Department of Education. This short paper describes the data being collected that is now available as part of CSEdResearch.org, what is needed to add the capability to collect and compare additional data through collaborative open science practices, and a path towards meeting those needs.**

This work furthers Open Science by defining how to access the data that already exists in CSEdResearch.org as well as what is needed to create additional tools for researchers and evaluators to enter K-12 computing education data directly on the site. By creating the infrastructure for shareable data that meets current and evolving open source guidelines, the community can start to use this data to develop best practices from empirical evidence.

***Keywords* - collaborative open science, computing education, K-12, CSEdResearch.org, resource center**

1. Introduction

Recently, the U.S. National Science Foundation (NSF) and the Institute of Education Sciences (IES) provided an overview of issues related to the lack of replication and reproducibility studies along with suggestions on how to overcome these [1]. This is in addition to an overall movement by the NSF's 2018-2022 Strategic Plan (as well as other organizations and agencies) toward defining, cultivating, and supporting best practices for data [2], [3]. The Plan states that "[s]tewardship and management of research data will be crucially linked to the credibility of research results and public access to those results." With additional calls for building and maintaining a tech-savvy workforce, discovery and decision-making of best computing education practices must be made through data that meets standards, can be collected and shared for reproducibility[1] and replication[2], and can be compared across various settings and studies.

A formal process has been undertaken to build and track the field of K-12 computing education research through CSEdResearch.org [4]. This Resource Center houses data manually curated from over 500 articles related to K-12 computing education research across ten publication venues and over 90 evaluation instruments that can be used in computing education [5], [6]. The dataset is continually growing and the meta-data on these evaluation instruments and articles can be accessed currently by request, with future plans to build the capability for users to access this existing data directly, in either textual or visual form.

For the remainder of this short paper, we describe the current dataset in the background section followed by a consideration of how we envision moving this resource center forward to create an open science framework for the computing education research community. This, in turn, will build the infrastructure and provide a vehicle to collect the data needed to inform better decision-making based on empirical evidence.

2. Background

The CSEdResearch.org dataset consists of over 50 pieces of manually-curated data from published articles (journals and conference proceedings) (Table 1) and over 24 pieces of researched data from evaluation instruments, including (where possible) the instruments themselves (Table 2). The manual curation process in the articles can be time-consuming and tedious, but the resulting set of data provides us with the capability to present not only a longitudinal look at the data, but also examine the research for reporting gaps and identify ways in the community to address those gaps [7], [8].

CSEdResearch.org was released in late 2018, and after one full year, there are several guides that now exist on the

1. *Reproducibility* is defined as "...the ability to achieve the same findings as another investigator using extant data from a prior study." [1, p.1]

2. *Replication* is defined as the process of "...collecting and analyzing data to determine if the new studies (in whole or in part) yield the same findings as a previous study." [1, p. 1]

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TABLE 1. DATA MANUALLY CURATED FROM ARTICLES. * DENOTES FIELDS THAT DOUBLE AS SEARCH FILTERS, ** DENOTES FIELDS USED IN SEARCH BAR, AND *** DENOTES FIELDS USED IN BOTH FILTERS AND SEARCH BAR.

Data Curated from Articles			
General	**Student Data**	**Instructor Data**	**Activity Data**
Title **	Number of Students	Number of Instructors	Course Curriculum Content*
Authors **	Gender ***	Prior Experience	Goals **
Keywords **	Race ***	Instructor Race *	Learning Objectives **
Page Numbers	Ethnicity ***	Instructor Ethnicity *	Curriculum Used
Abstract **	Disability ***	Instructor Gender *	Average Number of Students
Abstract Page Numbers	Disability Instructional Setting ***	Instructor Type	Tools/Languages Used ***
DOI	Disability Services		Elective/Required **
Venue***	Socio-Economic Status **		Type of Activity **
Year Published***	Prior Experience		Duration *
Report Type*	Location ***		Assignments
Focus Area ***	Age ***		Teaching Method ***
Basic Study Design *	Grades ***		
Research Approach *			
Research Questions**			
Study Duration			
Experience Report Description**			
Gender Analyzed			
Race/Ethnicity Analyzed			
Socio-Economic Status Analyzed			
Concepts Taught ***			
Evaluation Measures **			
Measurement Frequency			
Measurement Type			
Type of Effect Size Reported			
Statistics Reported			
Evaluation Instruments Used ***			

TABLE 2. DATA MANUALLY CURATED FROM EVALUATION * DENOTES FIELDS THAT DOUBLE AS SEARCH FILTERS, ** DENOTES FIELDS USED IN SEARCH BAR, AND *** DENOTES FIELDS USED IN BOTH FILTERS AND SEARCH BAR.

Data Curated from Evaluation Instruments	
Title**	Cost to Use***
Type (Computing, STEM, General)***	Time Required to Take
Description**	Type of Questions**
Authors**	Target Demographic*
Measure Program Evaluation	Article Referenced
Year Published***	Evidence of Reliability*
Number of Questions*	Evidence of Validity*
URL	Citation Bibliography
File/MS Word	Citation APA
Qualtrics	Cognitive Constructs*
Additional/Related Materials	Non-Cognitive Categories*
Qualitative or Quantitative*	Non-Cognitive Concepts*

site to help researchers design and implement their research studies. Plans are currently underway to first manually curate data from published articles and also house research data imported to the site as simple spreadsheets.

There are, however, several procedural flaws in this approach. First, collecting the data after papers are published presents its own issues. Data is not always fully included in the articles (in whole or in aggregate), data entry errors can be introduced, and it is inefficient to enter bits and pieces of data when it is very likely that a full dataset for each study already exists elsewhere in digital form. Second, comparing untagged data in spreadsheets still leaves a significant burden on researchers when comparing and contrasting datasets.

3. A Path Forward

In earlier work, we presented potential solutions based on work being conducted in other fields to help the community address the lack of research reproducibility, replicability, and meta-analysis in the field [9], [10]. These include:

- Improving individual research studies,
- Study pre-registration,
- Transparency and better access to results through open science,
- Large-scale collaborative science,
- Power analysis and effect size reporting,
- Tools to support reproducibility, replication, and meta-studies, and
- Culture of Improved Practice.

Though each of these can be examined in an effort to advance the computing education research community, there are three inextricably linked items: 1) transparency and open science, 2) large-scale collaborative science, and 3) tools to support reproducibility, replication, and meta-studies. To address these three components, a centralized infrastructure needs to built to record, store, and analyze this data. This can be achieved in several ways and the best path may changed based upon movement within organizations that store articles and conference proceedings to also provide a way to store datasets as well. However, given where the community is at the moment, and the fact that CSEdResearch.org already houses evaluation instruments, there is a path towards incorporating a system similar to the REDCap project out of Vanderbilt (or that incorporates

this free-to-use software) into CSEdResearch.org so that surveys can be taken directly within the system [3] [11], [12]. Data would then be stored in CSEdResearch.org in such a way that similar constructs (e.g., self-efficacy) across various instruments can be compared and studied based on the level of demographic homogeneity set by the user (e.g., middle school students in rural communities using Scratch).

Once the data collection process is fully built, additional tools to support reproducibiliy, replication, and meta-studies can follow. For example, a meta-analysis tool that provides the capability for users to choose several studies measuring the self-efficacy among middle school students in after schools programs using unplugged activities would then provide a summary effect size to determine if these activities are effective in improving self-efficacy when compared to other activities [10]. By extending the CSEdResearch.org platform to collect such data from many researchers, the system effectively promotes collaborative open science in which better decision-making on best practices for any demographic group can happen.

4. Conclusion

CSEdResearch.org currently houses open data, and a path toward expanding this dataset is needed to make it more robust. By so doing, the empirical evidence needed to make decisions about best practices for various types of learners, whether they are Kindergartners in rural Minnesota or pre-service teachers in Texas will more robust. Although the datasets housed in CSEdResearch.org are still relatively small compared to other education datasets, our goal is to extend the open data already collected and build a foundation for collecting and analyzing data for decades to come. Small, open source datasets can face many of the same challenge that large datasets with millions of records also face. Navigating these challenges in this early preliminary design stage is crucial for creating a robust platform. For example, one of these challenges is how to present and store data collected from research studies ethically and we have begun investigating best practices to do so.

Researchers may be resistant to some of the shifts in culture that come from open science initiatives. These challenges are well worth discussing within the community and are in fact necessary to change the culture of the community to accept and use collaborative open science practices.

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3. "REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources." (https://www.project-redcap.org/resources/citations/)

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