Improving Research and Experience Reports of Pre-College Computing Activities: A Gap Analysis

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ABSTRACT

This paper provides a detailed examination of pre-college computing activities as reported in three Association of Computing Machinery (ACM) venues (2012-2016). Ninety-two articles describing informal learning activities were reviewed for 24 program elements (i.e., activity components, and student/instructor demographics). These 24 program elements were defined and shaped by a virtual focus group study and the articles themselves. Results indicate that the majority of authors adequately report age/grade levels of participants, number of participants, the type of activity, when the activity was offered, the tools/languages used in the activity, and whether the activity was required or elective. However, there is a deficiency in reporting many other important and foundational program elements, including contact hours of activity participants, clear learning objectives, the prior experience of participants (students and instructors), and many more. In conjunction with previous work, this paper provides recommendations to reduce these deficiencies. The *Recommendations for Reporting Pre-College Computing Activities (Version 1.0)* are presented to help researchers improve the quality of papers, set a standard of necessary data needed to replicate studies, and provide a basis for comparing activities and activity outcomes across multiple studies and experiences.

CCS CONCEPTS

• **Social and professional topics → Student assessment**; **K-12 education**; *Computing education programs*; Informal education;

KEYWORDS

K-12 education, pre-college activity, outreach, summer camps, workshops, after-school, informal education, research quality

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1 INTRODUCTION

As many countries move forward with a CS for All mindset for pre-school, primary, and secondary school students, delivery of computer science continues to evolve and take many forms. For some countries, particular cities, and school districts, the push to move forward is being formed within formal curriculum [9–12]. For those organizations that have not adopted a formal curriculum yet, computer science education is delivered mainly through informal activities, such as after-school programs, summer day camps, hour of code, and career days [8, 13], like on-line tutorials, earned badges through scouting programs, and enrichment camps at post-secondary institutions [1, 3–5].

Many studies evaluate these activities, though mostly to determine their immediate and short-term impact [7, 8]. However, as previously discovered, no standard method of reporting student demographics and other related variables exists. Without identifying the attributes of many standard variables, or what Craig [6] refers to as "inputs", we limit our ability as researchers and instructors to:

- Replicate the activities,
- Replicate the experimental research on the activities,
- Compare activities to each other,
- Compare the effectiveness of the same activity presented by different instructors, in different settings, or to different student populations, and
- Compare the effectiveness of different activities.

In previous work, we examined limited forms of data reported in the articles, including what was measured in the studies (i.e. attitudes, grade point average, self-efficacy, enjoyment), as well as a broader look at student demographics (i.e. gender, race/ethnicity, number of student participants) [7, 8, 13]. These analyses led to a broad list of recommendations for conducting preliminary research steps, specifying the data to be collected, and tips for reporting. For this study continuation, the overarching question was more narrow: In order to promote replication of the activity and/or research, what program elements should be defined by authors reporting on the research or experience of pre-college computing activities?

Within this study, we focused primarily on two previously unexamined reporting areas: activity components, or elements of programs/activities, and instructor demographics. We also highlight and expand the reporting of student demographics in context with previous work.

This study is important for designers, instructors, and researchers of pre-college computing activities, since it defines a set of program elements that have been chosen to improve the ability to replicate

Table 1: K-12 CS Ed Articles in SIGCSE, ICER, ToCE

	SIGCSE		ICER		TOCE		All	
Year	#	%	#	%	#	%	#	%
2012	23	17.8%	2	9.5%	2	8.3%	27	15.5%
2013	33	25.6%	6	28.6%	1	4.2%	44	23.0%
2014	24	18.6%	1	4.8%	14	58.3%	39	22.4%
2015	18	14.0%	9	42.9%	5	20.8%	32	18.4%
2016	31	24.0%	3	14.3%	2	8.3%	36	20.7%
	129		21		24		174	

Table 2: PCCA CS Ed Articles in SIGCSE, ICER, ToCE

	SIGCSE		ICER		TOCE		All	
Year	#	%	#	%	#	%	#	%
2012	13	12.9%	1	4.5%	1	5.9%	15	11.1%
2013	15	13.4%	3	13.6%	1	5.0%	19	11.2%
2014	16	5.6%	1	5.6%	6	25.9%	23	18.2%
2015	10	26.9%	7	26.9%	1	5.6%	18	13.5%
2016	14	3.7%	1	3.7%	2	11.1%	17	12.9%
	68		13		11		92	

the activity and the research. On a larger scale, it also enables the collection of data in order to conduct larger meta-studies that compare different activities and (potentially) their effects on participants.

The remainder of this paper defines the methodology used in this study, examines the results of the descriptive analysis, and defines guidelines for reporting on program elements.

2 METHODOLOGY

To begin, we identified all papers pertaining to primary and secondary CS education in three ACM venues: *Special Interest Group on Computer Science Education* (SIGCSE), *International Computing Education Research* (ICER), and *Transactions on Computing Education* (ToCE). We found 174 articles in the SIGCSE, ICER, and ToCE venues, including articles on professional development and formal curriculum (see Table1). These represented nearly 60% of the ToCE articles in 2014, nearly 43% of articles of 2015 ICER articles, and over 24% of articles at SIGCSE in 2013 and 2016. The data indicates a slow, upward trend in articles covering K-12 topics, with approximately 1 in 5 articles accepted into these venues covering K-12 topics, up from approximately 1 in 7. The anomaly in 2014 ToCE can be attributed in part to the June 2014 ToCE Special Issue on Computing Education in (K-12) Schools.

We then further reviewed each article to determine whether it reported on formal education curriculum or professional development; or whether it reported on pre-college computing activities as defined for our study. For the purposes of this search, we defined a pre-college computing activity as:

A pre-college computing activity is an activity or process that teaches computing or computational thinking and is experienced outside of a K-12 school's formal in-class curriculum. The term 'formal in-class curriculum' refers to curricula that fulfill state/national education requirements and/or content that is offered as part of a required or elective course or module. Activities or processes that supplement formal in-class curricula, however, are included.

For example, pre-college computing activities that were considered were after-school or out-of-school computer clubs, summer camps, robotics leagues, activities associated with CS Education week, or a computer scientist coming into class to speak on career day. Alternatively, activities that were not considered as pre-college computing were, for example, course materials developed for Exploring Computer Science or the AP CS exams.

Of the 174 articles, 92 met the requirements of 1) being either a research report or an experience report and 2) covering pre-college computing activities according to our definition (see Table 2). Thus, all professional development and formal curriculum articles as well as position articles were removed and the focus was kept on articles detailing activities related to informal education initiatives. We also note here a slow, upward trend in articles, albeit at a slower growth rate than overall articles related to K-12 education.

The process for identifying research articles and experiences reports was fundamentally straightforward. First, we identified the program elements (as well as other data) from the first set of 10 articles. The articles were reviewed at a foundational level to get an understanding of the content. As we began this process, a summative breakdown of the content was created. This included aspects such as the participant and instructor gender, what concepts were taught, identification of research questions, and many more variables. Through our sample 10 papers, we identified 24 program elements that were being reported and could be defined as independent variables, grouping them into three categories: student demographic data, instructor demographic data, and components of the activity.

After identifying the initial set of variables, we created a mySQL database to house the data and an entry form using html, php, and json. We then reviewed all 92 articles, collected the data and added the variable attributes into the database. Once completed, we performed a second review of each article and every element coded to help ensure accuracy and to mitigate inter-rater differences.

For the purposes of this study, we limited our analysis to program elements that are important for contextualizing and replicating the activities, with near-future plans to perform analysis on additional data collected. We conducted an analysis of the data over the course of two weeks using descriptive statistics formed using a combination of mySQL statements and an Excel spreadsheet.

3 RESULTS

This section focuses on the reporting of activity components, instructor demographic data, and student demographic data.

3.1 Activity Component Data

Activity components were defined as curriculum components of the activity, such as concepts taught, learning objectives, tools/language taught, goals of the activity, when the activity was offered, and activity duration. We provide highlights here from the reporting of these areas, in order to support the discussion in the next section.

Table 3: Activity Components

Element	Specified #	Specified %	Unspecified #	Unspecified %
Type	86	98.9%	1	1.1%
Required vs Elective	79	90.8%	8	9.2%
When Offered	78	90.7%	24	9.3%
Tool/Language Used	76	88.4%	33	11.6%
Teaching Method	72	84.7%	39	15.3%
Duration	66	78.6%	51	21.4%
Curriculum Used	57	67.1%	52	32.9%
Average # of Students	35	41.7%	62	58.3%
Learning Objectives	22	25.9%	80	74.1%

The majority of articles offered some important activity data, including the type of activity (formal curriculum supplement, outreach, camp, workshop, online, etc.); whether the activity was required (8.0%), elective (79.3%), or both (3.4%); and when the activity was offered. The tool/language used and the teaching methods (lecture, lab, pair programming, team-based, etc.) were reported less frequently. The duration of the activity and the curriculum used was reported only half of the time, and the average number of students participating in one section of the activity and the specific learning objectives were rarely reported.

We limit discussion here to reporting of these elements, rather than the details of the activities themselves (e.g., what tools were used). We note here several anomalies:

- Clear learning objectives (what students are expected to learn or know by the end of the activity) are an important part of determining whether the activity was successful. However, only 1 in 4 articles reported learning objectives.
- Roughly one-third of articles did not report the curriculum that was used. This includes whether the activity was designed by the authors (i.e., self-created) or whether it used other curriculum (e.g., CS Unplugged, Scratch tutorials, etc.).
- Some studies were quite large with multiple instructors, multiple groups of students, and multiple locations. Though the number of students and instructors may have been reported, only 41.7% of articles reported the number of students per class or provided enough data for the reader to calculate this.
- Duration of activity was reported 78.6% of the time. However, even with this high number, we found that the explicit number of contact hours with the instructor or outside the activity setting were often not specified. An article may report that the activity was part of a week-long summer camp, for example, but the number of hours that the students were immersed in the activity and the time commitment of the instructors was not reported.

Though these are just a subset of activity components, these are important for replicating the activity and comparing the activity and its results to others.

3.2 Instructor Demographic Data

The demographics of the instructors were rarely provided in these articles. For these elements, only six categories were captured: number of instructors for the activity, who taught the activity, and instructor gender, race, ethnicity, and prior experience.

The number of instructors for the activity was only specified in 25% of the applicable articles (i.e., not a retrospective study). Twenty-five of the articles (28.4%) reported information on who taught the class. Some descriptors were vague ("The researchers for the project taught"), while others provided more specificity ("mathematics and computer science undergraduates").

Only 6 of the 88 articles (6.8%) reported on the prior experience of the instructors. The level of reporting was fairly consistent, and authors provided moderate definitions in each, such as "Taught by experienced instructors". Two were more specific, stating that the instructor "learned material along with students as she taught" and "two years of experience teaching after school e-textile workshops".

Instructor gender was only reported in 9 (10.2%) of the articles, with 6 reporting both female and male instructors, male only instructors in 2 and female only instructors in 1. Instructor race/ethnicity was rarely reported, with only 4.5% of articles reporting.

Table 4: Student Demographic Data

Element	Specified #	Specified %	Unspecified #	Unspecified %
Age or Grade	90	97.8%	2	2.2%
Number of Participants	77	83.7%	15	16.3%
Grade	68	73.9%	24	26.1%
Gender	59	64.1%	33	35.9%
Location	52	57.1%	39	42.9%
Age	41	44.6%	51	55.4%
Prior Experience	39	42.9%	52	57.1%
Race	30	32.6%	62	67.4%
SES	12	13.0%	80	87.0%
Ethnicity	9	9.8%	83	90.2%

3.3 Student Demographic Data

Reporting on student demographics varied widely among the articles. In Table 4, we note which student demographics are reported within the articles. Nearly every article (97.8%) reported the age or grade of the participants. However, many failed to report important demographic data, including the level of prior experience the students had in computing (only 42.9% reported) and the socioeconomic status of the students (only 13.0% reported). Authors only reported the location of the activity in 57.1% of the articles.

With 83.7% of the articles reporting the number of participants in the study, we note here that the minimum was one participant and the maximum was 10,000. The mean (n=382), the median (n=45), and the mode (n=26) were also calculated based on the aggregate data. The study with 10,000 participants were part of a large scale study, while the article reporting only one student was a case study.

Age was specified in 44.6% of the articles, while grade was specified in 73.9%. Several articles (19 or 20.7%) reported both age and grade. While some articles stated student grade levels explicitly, others stated "middle school" or "high school". Within the U.S., the grade levels at these schools can differ across school districts. Middle school can include 5th-9th grade levels, or a subset thereof, while high school can include 9th-12th grades or 10th-12th grades. Additionally, these terms are U.S. centric and requires the non-U.S. reader to understand how 10th grade may relate to their country's grade level system. Providing both ages and grades of student participants will serve as an additional guidepost for readers.

Prior experience was reported in only 42.9% of the articles. We grouped these responses into three categories: vaguely defined, moderately defined, and explicitly defined (Table 5). Only 35.2% of articles either moderately or explicitly described the prior experience of students.

Student participant gender was reported 64.1% of the time, with the majority (48.9%) indicating that participants were both male and female. Race/ethnicity was reported in approximately one-third (32.6%) of the articles.

Only 12 (13%) of the articles noted the socio-economic status (SES) of the students. Some were specific and provided the number or percentage of student participants "receiving free or reduced lunch" or were from an underrepresented minority. Others were more vague, noting that student participants were from a financially depressed area in the community. Defining student participants as "receiving free or reduced lunch" is U.S. centric, and may not interpret well for readers of other countries. Assumptions are also made that require the reader to know, for example, that Atlanta is an urban city with a population consisting of 61.4% minorities underrepresented in computing fields [2].

Location of the activity was only specified 60.4% of the time, with 55 in the U.S., 3 in Finland, 2 in Germany, and 1 each in Israel, Mexico, Canada, and the United Kingdom. Of the articles that did not specify location, the reader could potentially guess where the activity took place based on the authors of the study. However, since this method could be prone to error, we did not code the location of the author(s) as the location where the activity took place. Some activities were presented in multiple locations, and in two instances the school name was provided, but the school location was not. Likewise, a U.S. city name was provided in one article, but the country and state were not.

4 RECOMMENDATIONS

As part of the analysis, we calculated the percentage of applicable program elements that are actually reported by the articles reviewed. The results show a slightly positively skewed bell-curve (Figure 1), with the majority of the articles reporting between 30% and 70% of applicable elements. This begs two questions:

(1) Is the list of program elements we define appropriate? and
(2) If so, what can authors of these articles do to improve reporting on the elements needed to replicate the activity and compare its impact against other activities?

We defined these 24 program elements through coding variables identified in the 92 papers as well as a virtual focus group conducted as part of a different, currently ongoing study. To encourage further discussion about these program elements in an effort to increase the quality of reporting, we provide Version 1.0 of the *Recommendations for Reporting Pre-College Computing Activities* (see Table 6). With this first version we balanced inclusiveness with the realization that a lengthy checklist may overburden authors and researchers–and thus not be used.

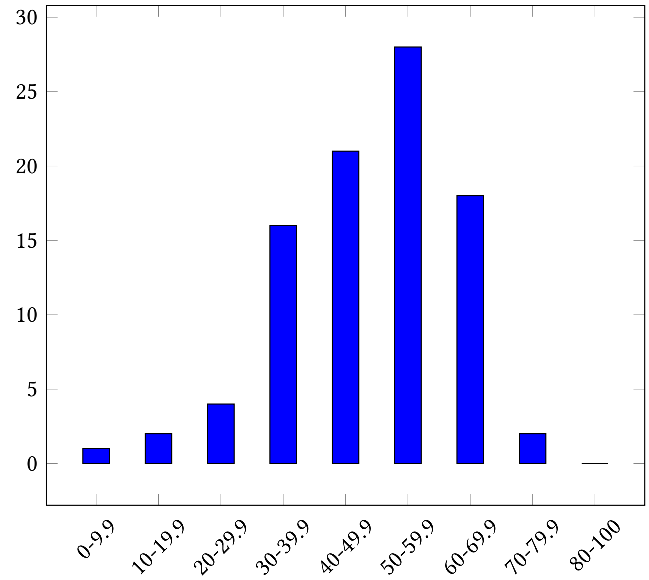

Figure 1: Percentage of Applicable Elements Specified within Articles

As previously mentioned, many of the articles take a U.S.-centric view in reporting program elements, such as referencing "middle schools", grade levels of students, or locations by a city name. To make these articles easier for readers to understand, for replication, and for comparing results, we encourage authors to be specific in their reporting. For example, in addition to referring to grade levels in terms of the country for the study, list ages or age ranges of participants for additional clarity.

We recommend reporting composition of participant gender in an activity with a count (at a minimum) of females and males. If gender is self-reported, take care to include non-binary genders in surveys and report on those genders as well. If specific numbers were not collected, we recommend reporting if the participants were of all one gender or a mix. Readers may not know that school X is an "all-girls school". Likewise, an activity that happens at an "all-girls school" may or may not have only females participating.

Elements like race and ethnicity may be more important in some countries than others, and authors will need to make the determination based on their cultures whether or not these should be reported. Socio-economic status of participants is also a sensitive topic, but one that is important for providing context. When reporting issues of socio-economic level, it is important not to make assumptions about reader's knowledge of locality or the socio-economic breakdown of a community.

We recommend that authors indicate the previous level of exposure the participants had to computing as accurately and specifically as possible. Indicate any courses students may have taken at the school previously, any exposure through school activities and clubs, and if possible, the length of that previous exposure.

It is important to provide information about the instructor(s) who led the activity, including (at a minimum) gender, race, level of experience in computing and level of experience leading the

Table 5: Student Prior Experience

Defined	Count	%	Sample terms
Unspecified	52	42.9%	n/a
Vague	7	7.7%	"Wide range", "Varied greatly", "Minimal"
Moderate	18	19.8%	"General technology usage", "Little to none", "few had very little experience"
Explicit	14	15.4%	"30% had worked with Scratch 50% had worked with Alice and Lego Robotics", "Programming (17% Yes a lot, 33% Yes a little, 33% Unsure, 17% No), with 33% having taken a programming course before. 42% had experience sketching/drawing/painting, and 75% had experience using a digital tool to draw. 83% (10 students) worked in a group on a project before."

particular type of activity. If more than one instructor is leading the activity or there are teaching assistants or lab assistants present, indicate demographic information for those individuals as well. If the instructor is one of the researchers or authors of the paper, indicate that in the reporting.

When reporting on activity components, it is important to note if the activity was an elective or required. Explain when it occurred (i.e. after school or weekends), duration of each session and how long it took to complete all of the sessions (e.g., three 2-hour after school sessions each week for ten weeks from September to December).

We recommend describing the activity in detail, including concepts that were taught, tools and languages used, the style of teaching employed (e.g. pair programming), and any additional tools and supplies used. Provide enough information for readers to understand the facilities in which the activity took place. Readers should also be aware if the intervention required a highly-specialized environment as well as any costs incurred by students or the host for conducting the activity (i.e. software licenses, equipment).

Within the U.S., the Computer Science Teachers Association (CSTA) has provided a set of categories and levels for teaching K-12 curriculum, and many activities can also be classified using this curriculum. We encourage authors to report these classification levels as well or their country's equivalent, in order to promote understanding of the targeted learning objectives and potentially provide an additional criteria that other instructors can use to find activities that might suit their needs.

It is important as a community to discuss accommodations for learners with disabilities, both physical and learning. We recommend reporting on steps taken to ensure accessibility and to ensure students with learning disabilities were accommodated.

5 CONCLUSIONS

We find that even basic program elements are often overlooked in reporting about pre-college computing activities. This makes it challenging, if not impossible, for activity instructors to replicate it at their own camp or after-school club and for researchers to replicate any associated studies. Lack of a clearly defined data set also makes it difficult to compare activities to determine which might be most appropriate for a given learning scenario and to compare the impact of those activities on learners.

These guidelines are a significant step in identifying program elements that are necessary for addressing those challenges. We encourage authors and researchers to consider collecting and publishing more details about these activities in future publications. By so doing, the data collected will be a more useful and practical resource for others. It may also serve as another step forward in improving the quality of reporting on activities and quantity due to increased replicability.

Future analysis on the data collected will include a review of what was measured and how it was measured, including an examination of the methodology used and the data analysis employed. We also intend to increase the set of venues to include a variety of venues, including IEEE venues and independent journals. The data collected will be included in repository to be released to the public.

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Table 6: Recommendations for Reporting Pre-College Computing Activities (Version 1.0)

Category	As applicable, provide:	Example
Student Demographics	Ages and grade levels	"grades 4-5 (ages 9-11)"; "15 in grade 6 (ages 10-12), 26 in grade 7 (ages 11-13)"; avoid locale-specific terms ("middle school")
	Number of students	"24 students participated"; "3 sections of 15 students each"
	Gender	"all female students"; "4 male and 16 female"; "both male and female students"
	Specific locations, including city, state, and country	"activity was held at University in AnyTown, State/Region, Country"
	Prior CS education	"students had no prior computing courses"; "15% of students had taken an introductory computing course prior to the activity";
	Prior CS experience (informal curriculum, out of school activities)	"20% of students had participated in hour of code last academic year"; "16% of students were involved in after school robotics club"
	Race/ethnicity of students	"20% of students were Caucasian, 18% African-American, 20% Hispanic, and 42% did not specify"
	Socio-economic status of students	"5% of population (U.S.) receive free/reduced lunch"
Instructor Demographics	Number of instructors	"activity was led by 2 instructors who took turns teaching and helping students, along with 3 teaching assistants to assist during lab"
	Who taught the activity	"activity was taught by the researcher"; "activity was taught by a school teacher"; "activity was taught by a second-year undergraduate Computer Science major"
	Prior experience of instructors	"instructor taught summer camps for 15 years and taught in the computing department of a university for 20 years"
	Gender	"instructors were both male"; "there were 2 male instructors and 3 female teaching assistants"
	Race/ethnicity of instructors	"instructors were white"; "one instructor was African American and one was Hispanic"
Activity Components	Clearly defined learning objectives (specific skills/knowledge activity to be taught or attitudes to be changed)	"By the end of the activity, students were expected to be able to program proficiently with Prolog and demonstrate that knowledge through a series of short group demonstrations to the class"; "the activity was designed to increase student interest in technology careers"
	Type of activity	"this one-on-one tutoring activity"; "the activity was a competition designed to..."
	Required or elective	"this was an elective activity"; "this activity was required of all 6th grade students"
	When activity was offered	"this was a summer camp"; "club met after school"; "activity was held during the school day"
	Curriculum used	"curriculum was created by instructor"; "CS for Students materials were used"; "materials from the Scratch website were used (give URL)"
	Teaching Method	"pair programming was used"; "students worked in teams"; "students listened to presenters"
	Tool/language used	"projects were completed in Scratch"; "projects were completed using Arduino boards"
	Duration of activity, including contact hours	"workshop ran 3 days for 45 minutes each day"; "club met after school twice a month for one hour each meeting for the entire school year (35 weeks)"
	Average # of students in each session (if multiple sessions)	"an average of 20 students per session"
	Accommodations for learners with disabilities	"students with disabilities were accommodated using their current individualized plan"; "activities were reviewed for accessibility for students with vision or hearing disabilities"
	Date of the activity	"activity ran from August 2015 to May 2016"; "the camp took place in July 2013"
	Materials/resources needed (including physical space and material costs)	"activity required use of a computer lab with the XYZ software installed (which can be downloaded as a free trial version from URL)"; "The camp required the use of a computer lab as well as facilities for lunch and snacks throughout the day. Cost per student for supplies was $50."
	Preparation time	"the instructors spent four weeks planning for the camp activities"
	CSTA Categories and Levels (or equivalent)	"this activity encompasses CSTA practices P2 and P5 and is at level 2, and includes coverage of the following subconcepts from the CS-Troubleshooting concept"