Pre-College Computing Outreach Research: Towards Improving the Practice

Adrienne Decker
Rochester Institute of Technology
2145 Golisano Hall
Rochester, NY 14623 USA
01-585-475-4653
adrienne.decker@rit.edu

Monica M. McGill
Bradley University
1501 W. Bradley Ave
Peoria, IL 61625 USA
01-309-677-4148
mmcgill@bradley.edu

ABSTRACT
Europe, Australia, and North America face two similar challenges with respect to computing--there have not been enough students matriculating to keep up with demand and the lack of diversity remains an issue. To address these challenges, private and public resources have been allocated to educate primary and secondary students in computing. Previous meta-studies on these often segregated outreach efforts within the United States indicate that research on their impact remains spotty, short-term, and inconsistent, leaving a gap in the ability to evaluate their long-term impact. Building upon previous research focused in the U.S., this study examines similarities and differences in the results of 17 formal, peer-reviewed computing education research journals and conferences across Australia, Europe, and North America during 2009-2015. Results indicate that a lacuna exists in international research, paralleling results of the more narrowly focused study of U.S. venues. The paper further defines the major issues researchers face in conducting assessment studies for outreach and recommendations for addressing this gap.

Keywords
Outreach; diversity; Effectiveness; Literature Review

1. INTRODUCTION
Europe, Australia, and North America are all regions that face two of the same challenges in computing: 1) there are not enough students studying and graduating in computing fields to keep up with the demand; and 2) men greatly outnumber women in these fields. With respect to skills shortages, the European Commission reports that there could be a shortage of over 800,000 Information and Communications Technology (ICT) professionals by 2020 [21]. Simultaneously, only 30% of ICT professionals are women, and overall women comprise only 23% of Europeans with a bachelor degree in fields related to ICT [43].

Likewise, in Australia the number of future job openings for software and applications programmers is above average, with strong growth expected in the next five years [5]. During this timeframe, the Australian Computer Society (ACS) reports that there will be an additional 100,000 jobs created in information technology (IT) [4]. Despite overall enrollment increasing nearly 12% in the last five years, the ACS report still predicts a shortage of skills in these fields. Additionally, from 2004-2014, the ratio of female undergraduate IT students in Australian universities has declined from 21.9% to 18.8%, indicating that more men are studying to fill these jobs [20].

In Canada, the government predicts a major shortage of IT workers in the next 5 years, with a need for an additional 182,000 workers by 2019 [2]. The U.S. Department of Labor predicts a need for over 1.2 million additional workers, calling out a 17.7% increase in growth for computer occupations from 2012 to 2022 [11, 12].

Globally, computing outreach programs have been created to address the current and future computing needs [3, 13, 19]. Many are specifically designed to address gender disparity by exposing participants to computing during primary and secondary education [14, 17, 39]. As computing education research matures and empirical research methods improve, evaluating these activities with their intended outcomes is important for improving their effectiveness. That is, if their outcome is to increase the number of people choosing computing as a career, then considering whether outreach activities with primary-school participants causally lead to more computing majors requires investigation.

Previous meta-reviews evaluate this relationship in a smaller subset limited to European and U.S. venues. The researchers concluded that the evaluation of the immediate impact is inconsistent and spotty and they noted that the research methods often have deficiencies that bring these results into question [20]. One limitation of the study was their narrow regional focus, with evaluation of venues nearly exclusively in the U.S. By evaluating venues specific to Australasia, Europe, and other countries, and expanding the analysis of venues in North America, the corpus of understanding expands on a more global scale. This study provides a review of such research with an emphasis on identifying best practices and variables to consider for encouraging longitudinal evaluations.

2. METHODOLOGY
To remain consistent with previous studies, the same meta-review framework was employed using identical framing of the research question, though expanded to include Australasia, Europe and additional U.S. venues [20, 29]. Nine additional venues, primarily non-U.S. [Australaisan Journal of Information Sciences (AJIS), Australian Computers in Education Conference (ACEC), Australian Journal of Education (AJE), IEEE Global Engineering Education Conference [only 2010-2015] (EDUCON), IEEE Transactions on Education (ToE), Information Systems Journal (ISJ), Journal of Research and Practice in Information Technology (JRPIT), Journal of Educational Computing Research (JECR), Koli Calling (Koli), Workshop in Primary and Secondary Computing Education [only 2012-2015] (WiPSCE)]were added to the original 6 [Technical Symposium on Computer Science Education (SIGCSE), Frontiers in Education (FIE), Innovation and Technology in Computer Science Education (ITiCSE), International Computing Education Research Workshop (ICER),

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Table 1. Original study characteristics and data collected

Original Research Question	Characteristic	Definition	Collection points
What are the similarities and differences in the reported results in formal, peer-reviewed research that has been conducted on computing outreach activities across different countries/regions?	Populations Studied	Students enrolled in computing outreach programs as defined by the article authors	• Participant characteristics (age and/or grade in school, gender, ethnicity, location) • Number of participants in study
	Intervention	Programs that exposed students to computing concepts	• Goals and facets of the program
	Study designs	Quantitative, qualitative, or mixed methods studies	• Research question • Quantitative, Qualitative, Mixed Methods, or Other • Longitudinal, cross-sectional, experimental, quasi-experimental, etc. • Type of data collected (participants' behaviors, attitudes, skills, knowledge, or dispositions)
	Outcome	Effects of the program on participants' behaviors, attitudes, skills, knowledge, or dispositions	• Study results

Taylor & Francis' Computer Science Education (CSE), Transactions on Computing Education (TOCE)].

Though the term *outreach* can be defined in many ways, each paper was first examined using the authors' definition. As papers were assimilated and further reviewed, *outreach* was defined as any pre-college computing activity designed to expose students to computing as a discipline in and of itself.

The previous studies manually evaluated titles and abstracts with one or more of the following criteria: K-12, outreach, computer/computing club, elementary school, high school, secondary school, after school clubs, primary school, or summer camp [20]. The same method for identifying the citations (3,949) reported in earlier studies was followed for this review, resulting inthe identification of 3,316 additional articles, for a total of 7,265. Upon manual review, these 3,316 additional citations were reduced to 36 articles, which were then examined for the same collection points as the previous studies (Table 1). Only 18 of these articles met the criteria, bringing the total number of papers represented by both studies to 98.

3. RESULTS

A summary of the remaining 98 articles focused on venue and year, country, and variables evaluated. Table 3 shows number of articles by venue and year (results from previous studies shaded), while Table 4 shows the country where the interventions took place. U.S. interventions dominated the results (63 of 98). Note that in table 4, one intervention took place in multiple countries and is counted in each country where there were participants.

A common theme found in U.S. outreach was the goal of broadening participation in computing through gender or ethnic diversity. For U.S studies, 52% indicated that a goal was to increase gender diversity and 38% to increase ethnic diversity. While no studies outside the U.S. stated that the a goal was to increase ethnic diversity, 13 of 35 (37%) indicated a goal was to increase gender diversity, with those studies in Argentina, Australia, Canada, Finland, Ireland, Saudi Arabia, and South Africa.

The number of participants in the interventions ranged from 2 to 10,200. Figure 1 compares the number of U.S. and non-U.S. studies as well as the total number of studies that reported participant numbers in each category. The largest number of studies (11) had between 10-19 participants or 20-29 participants.

Participant gender was reported by 73% (72) of the studies. There were interventions that were single gender (22, 22% all female and 1, 1% all male) and interventions that were both genders (49, 50%). The remaining 26 studies (26.5%) did not report participant gender.

Table 3. Articles found by venue and year

	Number of articles meeting criteria							
	'09	'10	'11	'12	'13	'14	'15	Total
SIGCSE	10	5	3	4	7	5	3	37
FIE	2	3	2	3			5	15
ITiCSE	3	2	2		2	1	2	12
ICER				1		2	3	6
CSE			1	1	2			4
TOCE			9	1		1		11
AJIS						1		1
ACEC								0
AJE								0
EDUCON	n/a		3		1	1		5
ToE		3						3
ISJ				1				1
JRPIT								0
JECR							1	1
Koli								0
WiPSCE	n/a	n/a	n/a		1	1		2
Totals	15	13	20	11	13	12	14	98

Table 4. Number of Interventions by Country

Countries	# of Interventions
United States	63
Finland	5
Australia	4
Argentina, Israel, Scotland	3
Hong Kong, Ireland, Saudi Arabia	2
Canada, England, Germany, Italy, Japan, Poland, Portugal, Qatar, South Africa, Switzerland, New Zealand	1

Table 5 breaks down the different types of data collected by the studies and the number of studies that collected this type of data. Computer science, information technology, and related disciplines are coded as "computing" for purposes of distinguishing the field. Many of the studies collected data on multiple variables, so the studies were coded for each variable that was collected and reported. The first column in the table represents the percentage of the overall studies that collected the particular piece of data. The second and third columns give the total number of studies in the

U.S. and outside the U.S. that collected that particular data. The percentages are within groups, that is, what percent of the U.S. studies collected that particular piece of data.

The studies (short-term or longitudinal) all reported positive or neutral findings. There were no reports of negative findings for the outreach initiatives. The most frequent data collected overall was interest in future study of computing and/or interest in pursuing a career in computing (30% of studies). Participant attitudes toward computing (29% of studies) was also frequently collected.

Longitudinal data was only reported by 9 (9%) of the studies in the literature review. The durations of the longitudinal study were 3 months to 10 years. Two of these longitudinal studies were based outside the U.S. In Finland, participants in a game programming course were followed for 2 years to determine its impact on the participants [30]. They report that the student's background did not influence their continued participation in programming and that almost all (> 90%) were still programming two years later and 65% had made more games or edited source code during that time.

One Canadian study surveyed participants three months after the intervention to determine if participants' career goals had been impacted [17]. Post-survey data collected immediately after the intervention showed that computing as a career was 2nd in responses (as opposed to 6th in pre-survey). In the three-month follow-up, it had slipped to 3rd for the participants. Though not capturing a particularly long duration of time, it demonstrates the value in collecting data longitudinally.

4. DISCUSSION

This meta-study sought to determine the similarities and differences in the reported results of formal, peer-reviewed research of the impact of computing outreach on a more international scale. This literature review, however, is built upon previous work reported in different studies—as such, the quality of this review is, in part, dependent on the quality of the research previously conducted. Further, there may have been venues and articles that may have been missed, including those outside of these venues. During the evaluation of the articles, there is also the possibility that classification of the components of the methodology or the variables reported may have been misinterpreted or missed.

Despite these limitations, the findings present a representative sample of the quantity and quality of research being published in Australia, Europe, and the U.S.

4.1 Computing Outreach Research

There is little longitudinal evidence on the impact of these activities on the participants. Only 9% of the total articles reflected a long-term study, and only two were from a non-U.S. intervention.

Over half (52%) of the total studies indicated that they were designed to increase gender diversity of the field of computing. For non-U.S. interventions, this number was only 37% of the overall studies. Within the U.S., there are studies that indicate their goal is to increase the ethnic diversity in computing. This sentiment is not expressed in non-U.S. studies.

The number of participants in the studies varied greatly, but over half had less than 100 participants, and 41 (42%) had less than 50 participants. This is not surprising given the nature of these activities as summer camps or after school programs. The number of students corresponds to a typical size of a class/cohort or

Table 5. Summary of types of data collected by studies

	Number (%) of activities collecting		
Type of Data Collected	**Total**	**U.S.**	**Non-U.S.**
Interest in future study of computing and/or interest in pursuing a career in computing	29 (30%)	18 (29%)	11 (31%)
Attitudes towards computing	28 (29%)	19 (30%)	9 (26%)
Assessment of computing (programming) skills	23 (23%)	18 (29%)	5 (14%)
Perception of the field of computing	21 (21%)	11 (17%)	10 (29%)
Enjoyment of intervention	19 (19%)	8 (12%)	11 (31%)
General interest in computing	12 (12%)	9 (14%)	3 (9%)
Self-reported abilities with computing concepts	10 (10%)	8 (13%)	2 (6%)
Self-efficacy	10 (10%)	7 (11%)	3 (9%)
Engagement (general)	5 (5%)	3 (5%)	2 (6%)
Number of majors in computing at university	5 (5%)	4 (6%)	1 (3%)
How material presented in intervention related to participants or the real world	4 (4%)	4 (6%)	0 (0%)
Relevance of computing	4 (4%)	3 (5%)	1 (3%)
Ability to express creativity with computing	3 (3%)	3 (5%)	0 (0%)
Completion of assigned task	3 (3%)	1 (1.5%)	2 (6%)
Engagement with tools beyond the scope of the assigned task	3 (3%)	1 (1.5%)	2 (6%)
Motivation/persistence	3 (3%)	1 (1.5%)	2 (6%)
Assessment of spatial reasoning ability	2 (2%)	2 (3%)	0 (0%)
Assessment of other STEM skills	2 (2%)	1 (2%)	1 (3%)
Participant GPA	2 (2%)	2 (3%)	0 (0%)
Participant drop rate from computing program	1 (1%)	1 (1.5%)	0 (0%)
Identity within computing	1 (1%)	1 (1.5%)	0 (0%)
Belonging within computing	1 (1%)	1 (1.5%)	0 (0%)
Future enrollment in computing course	1 (1%)	1 (1.5%)	0 (0%)
Achieving academic possible selves	1 (1%)	1 (1.5%)	0 (0%)

perhaps up to two classes. However, such small numbers and the lack of repetition of the intervention lead to problems for generalization of the activity's impact and effectiveness.

The measures of effectiveness varied across studies. Potential further study of computing, interest in computing careers, and participant attitudes about computing, dominated the studies. Another highly measured outcome (23% of studies) was participant knowledge about computing concepts, particularly programming constructs. When comparing data from U.S. and non-U.S. studies, knowledge of programming constructs was twice as likely be assessed within a U.S. study. Participant enjoyment in the intervention was 2.5 times more likely to be collected in non-U.S. studies as opposed to U.S. studies. It is not clear why these differences exist, but given that there is not a consistently uniform set of data that is collected by each of these interventions, it is difficult to draw any conclusions about these differences.

The original search criteria as defined in section 2 was solely focused on data associated with a particular outreach activity. However, other studies have been published that evaluate the impact of outreach activities recollectively [25, 33, 34, 35, 44].

Four of these are particularly noteworthy. In a 2010 study by McLachlan, Craig, and Coldwell, 681 Australian university students in their first and second year of studies were asked to recall experiences from secondary school. Computer usage, intentions of career choice, influences on career choice, understanding of computing terms, and attitudes about ICT were gauged. The authors found that of those that were interested in studying senior ICT subjects, there were only a few differences in opinions among the males and females. Of those not studying in the ICT field, participants indicated that it was due to lack of interest. The authors note that "…factors influencing students' decision to not continue with ICT studies seem to be coming from areas other than those explored in this research." [35, p. 134]

In a 2015 study, a team of researchers at Google surveyed 1,739 U.S. high school students and recent college graduates to determine the differences between factors that influence male and females to choose to study in a computing field [44]. They found that women who chose to study computing were influenced more by encouragement and exposure to computing. They note the role that family plays in both encouragement and exposure, suggesting that efforts should focus on ways to engage parents as well as students.

A 2012 recollective study of undergraduates in the U.S. examined why students chose not to major in a computing related field [25]. The results identified factors influencing this decision, including 1) lack of interest in the type of work that a computing major leads to; 2) lack of interest in the subject matter; 3) lack of enjoyment from computing courses; 4) lack of confidence in their ability to succeed in computing; and 5) feeling that they didn't "fit in".

A fourth recollective study performed in 2014 surveyed 770 male and female U.S. undergraduate students and found differences between the groups. Involvement in computing activities before college impacted the choice of a technology major, but that impact differed across gender and ethnicities [33, 34]. Additionally, for those who did not choose to ultimately pursue a computing degree, there were differences in perceptions among males and females of the activities and their place in technology.

Craig (2015) has theorized about the need for more formal evaluations in gender and computing interventions [16]. Her work is a major step in proposing a framework to identify the "who, what, why, and how" of intervention programs in order to create an understanding of the programs that are (and are not) effective. By contextualizing the programs within a theoretical framework, researchers can identify, replicate, and improve upon interventions that are most effective.

4.2 Challenges of Longitudinal Research

It is challenging to measure any meaningful impact of outreach, and more so for measuring long-term impact [15, 31]. Several factors may be contributing to this dearth of research.

4.2.1 Lack of reward, particularly for women

There is an increased emphasis by agencies such as the National Science Foundation on computing in K-12, and unique pressures are being placed on faculty to balance the "seemingly disparate responsibilities of research, teaching, and outreach" [6, p. 89]. There is an increased emphasis placed on different aspects and types of scholarship, with a new demand for the scholarship of engagement, where the university works with the community-at-large to solve pressing problems [9, 10]. This type of scholarship also serves as a way for the university community to become more engaged with the community and disseminate the research being conducted inside the ivory tower.

While it may be the case that these ideas are being used by some to define the new professoriate [28] and a quick web search produces several university sites about tenure and promotion that cite this model [7, 37, 42], it is unclear that it is fully embraced at all levels.

However, in the case of STEM practices, scientists view outreach as volunteer work, auxiliary to their other responsibilities, not valued by their home departments, and not money-making for the university and, therefore, of lesser value [1]. Ecklund, James, and Lincoln found that scientists perceive that there is little reward for science outreach work, especially in the tenure process [22]. The authors voice a concern that the task of outreach may be viewed by some as a feminine task, since more women are involved with outreach than men. This further decreases the legitimacy of this pursuit, particularly at top research universities, as outreach is cast into a "pink collar" job.

4.2.2 Time Commitment

The time it takes to sufficiently define data collection and to analyze data can be prohibitive [32]. Longitudinal research often includes multi-phase evaluations at various pre-defined times [18]. For a 5-year study, for example, the researchers might be immersed in structuring the study as either trend, cohort, or panel, tracking the participants, presenters, and/or organizers, monitoring collection of data, and making notes of any changes to independent variables that may affect the outcome of the study [18].

If the study were experimental in nature, then a control group will also need to be tracked, similar to a 2007 longitudinal study that tracked the middle school engineering outreach program for girls and a 2002 study evaluating the impact of a two-week summer camp on its participants [24, 27]. This only adds to the time needed to limit the variables in the study and track additional participants.

4.2.3 Tracking Participants

Tracking participants can be time-consuming. Since many outreach initiatives involve K-12 students, the amount of growth and changes that can occur in the population studied can be immense. Families move, students often to do not have permanent means of contact, and parents and students do not have much incentive for staying in contact (particularly through moves or changes of school) or responding to update requests from researchers.

It may be possible with the increased use of social media to track down participants using common social media sites. However, that process is time consuming and many researchers may lack the resources to conduct such searches for participants' post-activity. This process may also raise ethical questions and may not be approved by the researcher's institutional review board.

4.2.4 Difficulty defining methodologies and variables

The amount of time across multiple years that researchers put into this process also increases the risk to the researchers' careers. If the methodology is flawed, or if there is a failure in tracking participants during the specified period of time for data collection, then the entire study could be in jeopardy, and the time spent researching could be essentially of little value. Often, the goals and outcomes of outreach are poorly defined and it can even be time-consuming and challenging to define "outreach" [8, 32, 38].

Conflicting agendas exist, with practitioners, governmental agencies, researchers, and educators often having different views of what should be measured. Defining the methodology is a time-consuming, tedious process and attention to detail is essential.

Evaluation frameworks are spotty and "…rarely include baseline, longitudinal, or experiential data collection" [32, p. 3]. Often they focus on sociocultural or psychological outcomes, such as having fun or feeling comfortable in the group. In general, from an educational research perspective, these evaluations demonstrate a lack of maturity in the educational research field and, as a whole, indicate early stages of evaluation research processes [32].

For a complete picture of the programs, all components and participants of the activities must exist somewhere in the research literature. Various participants of such activities are often overlooked, with focus being on the K-12 participants, rather than how the program affects the presenters, organizers, or practitioners (if involved). The Science Festival Alliance, for example, considers the impact on practitioners who participate in events. One example of a post-event survey posed is "Follow up with someone you met at the conference for the first time to obtain (or share) information or resources," which aligns with the networking outcome for the events [32, p. 23]. Thus, evaluation frameworks can be comprehensive in nature and prompt the researcher to consider a variety of ways in which the program can impact anyone involved.

4.2.5 Confounding variables

Confounding variables outside of the activities, like news or popular media, may influence participants [44]. It may be possible to design a study to account for these variables; however, it may be impossible to determine what types of news or media images will be the latest "headlines" during the long duration of the study.

Further, analysis of the data provides an additional challenge with the identification of variables across series of times from multiple interventions and no comparative control group [36, 40]. This and other challenges in such analysis persists, and the research community can begin to address these challenges, such as accounting for issues with respondent recall, difficulties tracking participants, and pooling cross-sectional versus time-based data.

4.3 Improving the Research Practice

Given the above, is not surprising to find a dearth of long-term and rigorous studies. To overcome some of the challenges of longitudinal research, steps can be taken within the research community. This process includes the discussion within the broader community to change the perception that outreach is of less value than other forms of research and practice. Incentivizing faculty to engage in longitudinal research with outreach is a critical step. Other sciences have recognized the value of outreach by involved faculty [23]. If this is not valued by the academy, then it makes sense that faculty seeking to advance their career would wisely choose to pursue research that yields a more immediate return on investment for the tenure and promotion process (see Figure 1).

Many view longitudinal research as requiring the researcher to gather data across decades; however, researchers must take into account the goals of the study and the continual improvement and overall contribution of the research to the field. In the case of computing outreach, collecting data in smaller intervals (3- or 6-months post-event) is rare, even though it could provide more useful data than a stand-alone post-activity survey conducted immediately after an activity [17]. It reduces the time commitment involved and reduces the problems tracking participants over the longer-term, making it lower risk for the researchers.

Evaluation frameworks, as Craig asserts, is an essential step in streamlining and formalizing the process and reducing the risk of a failed study [16]. Solid frameworks can be promoted within the research community to encourage researchers to use these vetted models, similar to those found in other sciences [38]. This lowers researcher risk, since a framework can provide methods for tracking participants, defining the methodologies to use and the data to be collected for pre-defined variables. It can also provide best practices in evaluating the data [36, 38, 40].

To aide researchers, tools and validated instruments that support frameworks can be defined and promoted within the community [26]. A standardized computing attitudes survey, such as the one adapted and validated by Tew, Dorn, and Schneider for measuring attitudes towards computing and the Computer Science Attitudes Survey developed by Weibe, Williams, Yang, and Miller are available [41, 45]. If used to assess multiple interventions, the results can be compared. A list of tools in one central location could provide researchers with the means for collecting sound data that can be more easily compared and presented in aggregate.

Community support to promote these frameworks and resources can be effective. Workshops, panels, and special sessions at conferences, such as SIGCSE, can be instrumental in providing resources to the wider community and encouraging researchers to consider post-event follow-ups. Even with these recommendations, the largest component to changing the culture is to incentivize the researchers by considering outreach and subsequent longitudinal research as a valid path towards tenure and promotion.

5. CONCLUSION

There is a significant number of outreach programs that are reported in the literature that impact a variety of different constituents across ages, countries, ethnicities, and gender. Research on these activities report the impact on the participants through various metrics that are overwhelmingly positive. However, there is insufficient meta-evidence to conclude that, as a whole, computing outreach activities are effective.

This is in part due to the fact that many reports lack formal methodologies that are vital to effectively study outreach efforts on a broader scale. Researchers can conduct such studies to collect data that can be compared across programs. Researchers can also track participants beyond the end of the activity. Though one-time activities can often provide a boost to a participants' self-efficacy or beliefs about computing, these can radically change over two years, two months, or even two days' time. By tracking longer periods, the results become more meaningful and will aid researchers in identifying practices that have higher success rates.

Generating a useful dataset of influencing factors, formalizing the evaluation process, and conducting long-term evaluative studies are critical to identifying activities that are more effective than others. Clearly, given the lack of research, there is a need to continue to studying pre-college computing education, particularly for outreach activities, by creating and implementing standard processes for evaluating the short-term and long-term impact of pre-college computing activities on the participants.

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