Outreach in K-12 Programming: A Systematic Literature Review on Audience and Purpose

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Abstract: Outreach Programs are informal educational initiatives that schools and universities, as well as companies and associations, promote: they represent a significant variety of courses and camps for learners, whether students or teachers. In this paper we provide an overview of the publications on Outreach Programs in K-12 Programming, in the last decade 2011-2021. The survey methodology adopted is the Systematic Literature Review: we classified the papers around two different axis, the audience and purpose of the Outreach Programs.

1 INTRODUCTION

Although in literature there is not a global unique definition of what K-12 Outreach Programs (OP) are, we can include among them every informal, non-curricular initiative that implement or enrich the students' school curriculum or the Teachers' Professional Development (TPD). OP promote a different point of view, a given methodology, or a new technology that can have an impact on learners' future choices towards Computer Science (CS). The pedagogy adopted is non-formal and boosts learners' self-directed learning, creativity, collaboration and peer mentoring while removing social and emotional barriers. These programs are informal initiatives, both promoted by schools and universities or private companies and associations, conducted in parallel to ordinary CS school planning.

Sometimes we can find a definition of OP in national or regional initiatives, designed by governments through their educational agencies or ministries, that massively address a whole segment of school population in a country. The realization of the OP is an important action to promote Computing Education (CED) in schools and to increase the motivation to choose CS careers during the transition to higher education. Often, universities and colleges establish an outreach office and a responsible to ensure the OP quality and a connection to the stakeholders.

Programming is a very popular topic in OP, as it motivates kids in getting closer to STEM (Science, technology, Engineering, and Mathematics) disciplines (Kafai and Burke, 2014) and, having Computational Thinking as its theoretical framework (Resnick and Silverman, 2005; Weintrop and Wilensky, 2015; Weintrop et al., 2016), can also foster students in pursuing a CS career during their transition from school to University. Even if these programs are mainly designed for students, there are also complementary outreach programs that target school teachers and their professional development. Whether they are novices or majors in programming, these courses seem to support educators in motivating students in CS.

Related Works. In spite of their diffusion, in Computer Science Education research OP are not considered as a specific topic per se (Decker et al., 2016), but rather part of the research on CED and primarily on introductory programming. The studies on how novices learn computing, and teachers teach them how to, introduce single aspects of these initiatives as, for example, their audiences and targets, or topics, or languages and tools, or educational approaches and impact. (Begel and Ko, 2019). The most extensive review (Luxton-Reilly et al., 2018) is a broad analysis on a huge corpus of publications on introductory programming and shows the educational trends emerging in the fifteen years until 2017. Another Systematic Literature Review (SLR) is also focused on introductory programming and outreach in schools from 2003 to 2017 (Szabo et al., 2019). It reports many initiatives to engage K-12 students in CS and to boost their interest and motivation in programming languages, tools and programs, both in the curricu-

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lum or in the outreach learning contexts. A third SLR (Becker and Quille, 2019) is focused on CS1, a specific course and curriculum on introductory programming, along fifty years of research on the topic. It offers a classification of the initiatives and methodologies. Besides these reviews, our survey returned 12 overviews of the research on OP. These papers are mainly SLRs or, at times, small surveys concerning a single audience group, both an audience and a topic, or the educational purpose and the impact of interventions. In the considered decade, the first survey (Ladner and VanDeGrift, 2011) helped us in classifying by audience/target, school level, educational approach and students' perceptions. Two works from 2014 concern OP addressing the audience of novice and prospective students and they are both from the Australasian research area (Falkner et al., 2014; Bell et al., 2014). In 2015 a survey (Seiter, 2015) on learning outcomes puts the accent on the impact of these initiatives. Another couple of papers from 2016 considers OP as a way to engage students in computing. The first one is on female students' perceptions (McGill et al., 2016) and the second one on gender equity in computing (Hamilton et al., 2016). In 2017 we find a very important paper on pre-college computing activities to broaden participation in CS (Decker and McGill, 2017). Another 2019 SLR describes specifically a group of OP for K-12 underrepresented groups. (Cummings et al., 2019) A 2020 article concerns an experiment conducted with freshmen and near-peer tutors chosen among CS students. While analyzing the impact of the outreach workshops on participants, the authors give also a SLR on the programs (Jin et al., 2020).

Research Questions. The audience of the courses appears to be the main purpose in the design of the OP.

These initiatives, despite their informal learning environment, identify a variety of target groups according to their age, school level, gender, social identity.

Concerning this point, we came up with three research questions:

- RQ1 - Which audiences do OP address?
- RQ2 - Which audiences are less represented in the literature?
- RQ3 - Which are the purpose planned for each OP audience?

RQ1 means to express an overview of the findings in literature, and then a classification of papers based on the targets of the programs.

While RQ1 appears all-encompassing and settles the state of the review, with RQ2 we intend to go in depth and define the less represented groups and, if possible, suggest a reason of their minor presence in the SLR.

Finally, RQ3 aims to identify the different OP purposes, given that some initiatives are designed on a well defined purpose and others on a motivational action or expected impact on learners' attitudes towards computing.

2 METHODOLOGY

SLR. The survey on the OP that promote programming at the K-12 school stage is conducted under the methodology of the Systematic Literature Review. It includes studies on both categories of learners, students and teachers, excluding incoherent results, like OP for professionals.

The survey is made through the ACM Digital Library search engine, both the Full-Text Collection (FTC) and the Guide to Computing Literature (GCL). After a certain number of attempts, the combined search phrase:

"outreach programs" AND "programming" AND ("K-12" OR "students" OR "teachers" OR "school")

returned 155 results from the FTC and 175 results form the GCL.

Time Range. The publication dates range from 1985 to 2021, but the trend increases significantly from 2011 on. So we decided to consider and analyze the last decade (2011-2021), that is a total number of 134 papers on FTC and 145 papers on GCL. Except 2 excluded results (not relevant to our search), we defined a total set of 143 papers coherent with the search query. The survey returned data on the publication trend by year in the decade, then we also classified papers in two main classes by audience/target and purpose.

2.1 Audience

The audience label is attributed to each paper or initiative whose purpose refers to a group that benefits from the outreach in relation to an educational or social affinity, or even gender or cultural belonging.

We classified the total number of 143 papers as follows:

- Novice students in CED, 60 results;
- Prospective students in CS, 33 results;

- Girls and women, 23 results;
- Underrepresented (by ethnicity, gender, both) groups, 20 results.
- Rural area groups, 4 results;
- Physically impaired students, 3 results.

The first group of papers concerns OP designed for **novices**, meaning all those learners who approach computing principles, languages and tools for the first time. In this audience we also included the teachers actively involved in a TPD, both novices and those who already teach CS but need to upgrade (Crow et al., 2019), because of their common intention to improve their computing competences (Chipman et al., 2019).

While novices approach computing for the first time, we denominated as **prospective** students those who intend to choose, or are selected as target, to embrace a CS career.

Another significant group of papers refers to OP designed for **girls and women**, to motivate them in approaching CS and to overcome cultural misconceptions about their own role in the technology field. The main objective of these OP is to fill the gender gap in the access to STEM, and to break cultural inequalities and stereotypes about women.

In our classification women are considered as a distinct audience, although we found their presence overlapping in other programs, designed for different groups and collectively gathered with **underrepresented** students (social disadvantaged or ethnic minorities groups). The reason is that these OP declare an educational and social resolution to guarantee equal access to CS and to remove misconceptions on computing and computer scientists.

A **target** label is attributed to each paper that clearly indicates a group of people who benefits from the outreach, in relation to age and education level.

The target addressed is mainly the school students population, and papers often include 2 or 3 school levels at once; however, among the total we can identify initiatives specifically and exclusively designed for elementary (25 results), middle (45 results) high school (69 results). There are OP for the TPD (20 results until 2019) and others for undergraduate students (36 results), often related to the mentoring activity they practice with middle and high school students. The total number of 143 papers comprehends 34 studies that overlap on two or three different targets at once. This indicates that some programs, even if designed for different targets, maintain the same educational purpose and reshape the activities according to the school level and competences.

2.2 Purpose

The papers are classified also by purpose of the OP. Often, it indicates also the main topic addressed by the outreach, setting aside a possible overlapping with secondary ones. While some topics are directly CS sub-fields or a specific technology adopted, some others show strategies for the engagement of the participants, analyze their behaviour and motivation in addressing the discipline, clarify their perceptions/misconceptions on CS. The papers are divided in the following purposes:

- Programming, 41 results;
- Motivational, 37 results;
- Computational Thinking, 25 results;
- Perceptions, 11 results;
- Robotics, 8 results;
- Game development, 5 results;
- Unplugged coding, 4 results;
- Networks, 4 results;
- Microcontrollers, 3 results;
- Accessibility, 2 results.
- Cybersecurity, 2 results;
- High Performance Computing, 1 result.

The **Programming** purpose gathers the OP on introductory or advanced programming. The audience of the first topic, largely predictable, are mostly novices because it represents the very initial approach to CS. This group is followed by women, as the researchers try to enhance female motivation and perseverance in CS and to promote their transition to STEM degrees with creative and collaborative activities. Beside this group we can find substantially related OP on **CT**, **unplugged coding** and **game development**. A group of activities concern physical computing, as working on **robotics** or with **microcontrollers**, or specific aspects of computing, like the **accessibility** or the **cybersecurity** issues, the networks or the HPC.

Other programs are principally designed to boost behavioral aspects of CED and offer **motivational** sparks to pursue CS careers; some analyze the students' **perceptions** on this field and on the role of computer scientists; both these OP attempt to remove learners misconceptions, to enhance learners' self-efficacy and to promote positive attitudes towards the discipline.

3 RESULTS AND DISCUSSION

The analysis of the papers is described in this section; the results are shown in Table 2 and graphically summarized in Figure 1.

Women. The survey found 23 papers related to girls and women. The publications increase in 2016 when we register 6 articles, 2 of which are SLR about gender equity and female participation. The target addressed is mostly from high school (12 results), followed by middle (7 results) and elementary (5 results) schools. The initiatives are mainly small-scale (e.g. under 100 participants, 11 results) but there is also a certain number (8 results) of large-scale programs, for instance those addressing a whole college female target. The most frequent topic addressed in these OP is programming (11 results). This audience group does not report the initiatives in which women are considered together with social and ethnic minorities as underrepresented groups.

These OP are mainly designed to foster women participation in Computer Science. The researchers suggest that the female motivation towards CS and STEM disciplines is more effective when raised early, e.g. addressed to a K-12 audience and when programs are offered at a young age (Assiter and Wiseman, 2016; Chipman et al., 2018; Tsan et al., 2016). However, the most recent studies underline also the existing link between the actions needed in school and in university: to guarantee the female engagement in CS, the OP involve undergraduate students in mentoring high school students (Geller and Chun, 2021; McDonald and Dillon, 2021; Molnar et al., 2021). These programs have often a positive impact, ensuring the girls' appreciation for programming and consequently their choice of a CS career during the transition from high school to college (Lang et al., 2016; Lawlor et al., 2020). Some papers report studies on girls' motivation in CS and how to foster it (Sabin et al., 2015), others point on the perceptions women have (Lang et al., 2016), on how to overcome both their misconceptions in CS and the cultural bias on the role and gender of the computer scientist (Rheingans et al., 2018). The SLR report the initiatives to achieve digital gender equity and to increase female participation in CS (McGill et al., 2016; Hamilton et al., 2016).

Novice. The audience of novice students in CS concerns 60 papers. The time distribution of publications is generally constant, with two peaks in 2012 (8 results) and 2014 (11 results). The largest target addressed is the school one, with high (22 results), middle (21 results) and elementary (12 results), but there is a significant part (16 results) on Teachers' Professional Development (TPD) initiatives. The outreach are small-scale programs (26 results) and large-scale (23 results), with a little number of regional OP (6 results), covering national programs in US, NZ and Europe (2014 and 2019). The subjects addressed are mainly programming (19 results) and Computational Thinking (CT) (16 results), with increasing results in 2014; a few papers on unplugged coding (4 results, until 2016 and no results from 2017 on), robotics (2 results until 2015) and game development (3 results until 2020), give place in 2021 to accessibility (2 results) and cybersecurity (1 result).

The subjects addressed, as the OP are intended for novice learners, concentrate on programming and Computational Thinking: probably, the amount of results in 2014 correspond to the emerging global initiatives of CS divulgation as CoderDojo, Code.org, CS4all, etc. These programs and platforms and the huge participation they got and currently get, generated a literature that describe and analyze the informal approaches to teaching and learning CS. The presence of TPD initiatives highlights the importance of a systemic approach in designing programs. Students and teachers are key players of the same educational system, and they act in a complementary way (Hampton et al., 2019; Roberts et al., 2018). The continuing education of teachers increase the impact on pupils' awareness: students and teachers must be equally motivated to undertake CS and to get aware of the role of technology in studying and teaching (Chipman et al., 2019), but also in their digital citizenship. For this reason, besides some reviews on the state of novice programming teaching and learning, we can also find advises on curriculum design, educational strategies, assessment of the activities and competences acquired (Catete et al., 2018), in addition to some reflections on myths and misconceptions about CS.

Prospective. The survey regards 33 papers. The time distribution of publications registers a peak in 2011 (9 results), a progressive decreasing from 2012, a significant reduction from 2016 to 2021 and there are no results for the years 2015 and 2017. The target addressed is mostly the high school students (22 results); few papers for middle (9 results), elementary (6 results), TPD (3 results), and undergraduate (8 results). Small- and large scale programs equal (14 results each), while a little number of regional OP (3 results) report national massive programs in Australia and Europe in the last two years (2020 and 2021).

The purposes addressed concentrate on the students' perceptions (6 results) of what CS and who a computer scientist is (Lakanen and Kärkkäinen, 2019;

Table 1: The papers analyzed by audience and target.

	Women	Novice	Prospec.	Underrep.	Impaired	Rural	Total
Elementary	5	12	6	-	-	2	**25**
Middle	7	21	9	6	1	1	**45**
High School	12	22	22	8	3	2	**69**
Teacher Professional Dev.	-	16	3	-	-	1	**20**
Undergraduate	9	9	8	9	1	-	**36**
Total	**23**	**60**	**33**	**20**	**3**	**4**	**143**

Table 2: The papers analyzed by audience and topics.

	Women	Novice	Prospec.	Underrep.	Impaired	Rural	Total
Programming	11	19	4	4	2	1	**41**
Motivational	7	9	11	9	-	1	**37**
Computational thinking	1	16	5	2	-	1	**25**
Perceptions	3	1	6	1	-	-	**11**
Robotics	-	2	3	1	1	1	**8**
Gamedev	-	3	2	-	-	-	**5**
Unplugged	-	4	-	-	-	-	**4**
Networks	-	3	1	-	-	-	**4**
Microcontrollers	1	-	-	2	-	-	**3**
Accessibility	-	2	-	-	-	-	**2**
Cybersecurity	-	1	1	-	-	-	**2**
High Performance Comp.	-	-	-	1	-	-	**1**
Total	**23**	**60**	**33**	**20**	**3**	**4**	**143**

Kallback-Rose et al., 2012; Stone, 2019), and design motivational initiatives (11 results) to engage learners in pursuing CS careers. Besides these topics, some OP promote programming (4 results), CT (5 results), robotics (3 results), game development (2 results), cybersecurity and networks (1 result each).

The audience of prospective students in CS is considered as the target that can be motivated in computing in view of a transition from school to a CS degree. Considering the undergraduate, we can find some analysis of the motivation and the strategies to retain students in CS.

Underrepresented. The survey returned 20 papers. The time distribution of publications registers a peak in 2011 (6 results) and a progressive decreasing from 2013 to 2021; no results for the year 2012. The target addressed is mostly from high (8 results) and middle schools (6 results); a significant group of papers address the undergraduate population (9 results). Small- and large scale programs are the majority (7 and 10 results respectively), and just 1 result for regional OP. The purposes addressed are mainly the students' perceptions about CS (9 results) and the role of the computer scientist in our society (DeWitt et al., 2017) to promote CS role models as a key to overcome misconceptions and remove cultural barriers. Besides these topics, we can also find programming (4 results), CT and microcontrollers (2 results each), robotics and HPC (1 result each).

The audience of underrepresented categories in CS is vast and comprehend social and ethnic minorities, as well as women from the same groups. This target needs specific strategies to be involved and motivated in computing (Camp et al., 2020), because they are often living at the boundaries of our society. These OP promote diversity and inclusion in CS, removing barriers to access computing education and university careers (Garcia et al., 2020). For this target we can register initiatives aiming to motivate and retain students in CS, by providing equitable access and critical thinking skills.

Impaired. Our survey found only 4 papers on impaired audience in OP. The time distribution of publications registers only two years of publication, 2011 and 2020, with 2 results each. The target addressed is mostly from high schools (3 results); 1 result is for higher education. Small - scale programs are the absolute majority (4 results). The subjects addressed concentrate mostly on programming (2 results) and robotics (1 result).

The audience of impaired students in OP is fully occupied by visually impaired and blind people. This target needs specific strategies and technologies to access computing, for example in robotics (Ludi et al., 2014), and researchers design the programs to remove barriers to easily access CED and university careers (Shinohara et al., 2020). We register initiatives that aim to motivate and retain students in CS and to guar-

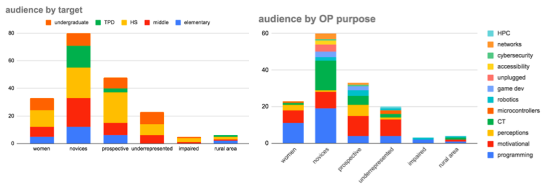

Figure 1: Targets and purposes chosen for each audience.

antee an equitable access. The choice to realize small - scale programs demonstrates how complex is to design and conduct these initiatives and, at the same time (Ludi et al., 2011), to gather a class of the same target students.

Rural area - The OP for students that come from rural areas are a little number (4 results), generally addressed to elementary and high schools (2 results each); 1 program regards also the TPD in the same schools. The time distribution of publications starts in 2015 and reaches 2021, but no results are found for the years 2016, 2017 and 2019. Small - scale programs are the majority (2 results). The subjects addressed vary from robotics to programming, from CT to motivational OP (1 result each).

These audiences, students and teachers, are reached by specific social strategies in order to access computing; the initiatives are designed to remove cultural barriers and to promote the choice of future careers in computing. The choice of small - scale programs demonstrates the complexity in designing these initiatives (Bell et al., 2018; Fasy et al., 2020), as students often have logistic problems like reaching the venue in autonomy; researchers face issues to create a class of the same target.

4 CONCLUSIONS

Although focused on programming, the survey returned a wider overview on K-12 CED and its stakeholders. It revealed a variety of audiences, among which novice students are the most addressed by outreach agents. This feature matches to the informal nature of these camps, ideal learning environments for introducing CS concepts while working collaboratively. Female targets have a considerable presence, too, and these programs mark the necessity to break cultural stereotypes and to boost women's participation in STEM, while confirming a political and research trend towards inclusion topics.

On the other hand, the few results on outreach for rural area and impaired groups marks the difficulty to design and perform these programs with specific audiences, with a sum of issues ranging from logistics (physical spaces easy to reach, transports, routes) to adapting languages and tools to the different disabilities and impairments, from infrastructures (Internet access, laboratories) to the complexity of recruiting a significant number of participants, from accessibility to social inclusion issues.

Among purposes, programming is the most common and overlaps with other goals selected by the OP designers, as robotics or game development activities. These camps are relatively easy to conceive and organize also by private companies or associations and can benefit from the huge amount of platforms, languages and tools specifically intended for educational scope. Computational thinking, chosen mainly for novices, is another appealing topic that highlights how important are reasoning and solving problems while learning to program (Lin and Weintrop, 2021). Conversely, the few results for game development, unplugged coding, accessibility and cybersecurity could suggest less interest or research commitment on these topics, except for sporadic OP addressed to novice and prospective students.

Physically impaired students (blind, deaf, Autism Spectrum Disorders -ASD) or with learning disorders (dyslexia, dyscalculia, dysgraphia, Attention-Deficit / Hyperactivity Disorder - ADHD) are often excluded from CS in school because of their impairments but they can take advantage from dedicated OP, where operators can also boost and adapt methodologies, languages, technologies and tools to their needs. As a future direction, it would be very challenging, but rewarding in terms of societal impact, to delve deeper and analyze which factors and in what measure affect the design of these experiences, in order to promote initiatives directly aimed at those less represented audiences.

Adhering to the paradigm of Open Science, we will share the results of the SLR by publishing the whole dataset/bibliography (in the final version), with an open licence, on GitHub and Zenodo. The repository is meant to facilitate scholars with a classification and to stimulate further work or design on OP. As we encountered other aspects in addition to audience and purpose of the OP, we also consider to expand the analysis and to employ more elaborate statistical tools and methodologies to explain and comprehend these elements and their relations to others.

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