Educational Initiatives to Increase Diversity in CS1 Courses: A Literature Mapping of U.S. efforts

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***Abstract*—Full paper. Introductory programming courses such as Computer Science 1 (CS1) are challenging for undergraduate students. Additional obstacles to attracting and retaining students from groups underrepresented in Computer Science majors (such as women, African-Americans, Latinx/Hispanic, and Native Americans) motivated several CS1 educational initiatives aiming at better support for students from these groups. In the context of broadening participation in computing, our paper aims to answer the following question: What does the literature tell us about educational initiatives in CS1 courses that focus on underrepresented minority groups in the United States? To answer this question, we deployed a systematic literature mapping process covering the last twelve years (2009-2020) using four academic databases: Scopus, Web of Science, IEEExplore, and ACM Digital Library. We found 67 academic documents published in conferences and journals, covering activities such as modifications to lesson plans, implementation of pedagogical changes, assessment of student sentiment, the establishment of learning communities, and mentoring events targeting to increase inclusion in CS1 courses.**

***Index Terms*—Introductory programming courses, CS1, minority underrepresented minority, URM**

I. Introduction

The lack of diversity in gender and race/ethnicity in Computer Science majors is a widely acknowledged challenge [1]. The first programming course, Computer Science 1 (CS1), has been a central topic in computing education research [2]. Introductory programming courses often exhibit a high failure rate. Robins [3] presents the failure ratio at different institutions around the world, showing it as close to 30% in many U.S. institutions. A high failure rate may push students away from CS majors, exacerbating the difficulties in attracting more students from groups underrepresented in computing, such as women, African Americans, Latinx/Hispanic, and Native Americans [4].

Three recent literature reviews addressed CS1 courses. The first paper, "Introductory Programming: A Systematic Literature Review" [5] is a report by an ITiCSE[1] working group that presents an extensive literature review covering 1,666 papers, with only 25 of those focusing on women and minority groups. The second literature review paper, "50 Years of CS1 at SIGCSE: A Review of the Evolution of Introductory Programming Education Research" [6], presents a view of the evolutionary trend of introductory programming course research reported at SIGCSE[2] conferences. It covered 481 papers, although only 12 of these had a *gender, diversity, inclusion & accessibility* focus. Finally, the paper "A Systematic Literature Review on Teaching and Learning Introductory Programming in Higher Education" [7] covers 89 papers, however only one of these addresses gender and none focuses on race/ethnicity.

Differently from those literature review articles covering CS1 courses in general, our methodology looked at papers targeting underrepresented minority (URM) student groups and addressing diversity. We then selected the relevant documents with a focus on CS1 courses. This approach resulted in a higher number of papers that include both CS1 courses and URM undergraduate students than other literature reviews that focus primarily on introductory programming courses in general.

This paper aims to answer the research question: What does the literature tell us about educational initiatives in CS1 courses that focus on URM groups in the United States? We investigate these questions through a systematic review process of documents from conferences and journals indexed by the academic databases Scopus, Web of Science, ACM Digital Library, and IEEExplore. We found 67 papers and present a literature mapping of the educational papers with a focus on CS1 courses and underrepresented minority undergraduates.

This paper is organized as follows: Section II describes the methodology; Section III present our findings answering the

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[1]Innovation and Technology in Computer Science Education (ITiCSE)
[2]ACM Special Interest Group in Computer Science Education

research question; Section IV describes some important observations based on the results; Section V presents the limitations of our paper; and Section VI reports our conclusions.

II. Methodology

This paper followed a systematic literature review based on [8] and composed of four steps: *i)* define the research questions, *ii)* find the relevant documents, *iii)* analyze the documents, and *iv)* report the results.

The first step, define the research questions, we create three research questions based on the main research question (RQ), "What does the literature tell us about educational initiatives in CS1 courses that focus on underrepresented minority groups in the United States?":

- RQ1 - What types of publications are there (conference, journal, year, states and colleges)?
- RQ2 - Which educational interventions focus on underrepresented groups in CS1 courses?
- RQ3 - What are the factors that influence underrepresented undergraduates in CS1 courses?

The "find the relevant documents" step was composed of: define the search string, specify the inclusion/exclusion criteria, choose the digital libraries, and select the documents. Our search string was divided into three parts, CS majors, URM groups, and higher education: *("computer science" OR computing) AND (urm OR hispanic* OR minorit* OR underrepresented OR "african american?" OR diversit* OR ethnic* OR race OR latin* OR wom?n OR gender OR girl* OR femal* OR black OR "native american?" OR hawaii* OR alaska OR "people of color") AND (student* OR graduate* OR undergraduate* OR doctor* OR phd)*. The search string does not include "CS1 related keywords" because this search string is part of the bigger research about diversity in CS majors. The search string was improved using VOSviewer [73], and it was adapted to each academic database. VOSviewer is a software tool used to build a visual representation of bibliometric networks.

We used four academic databases, Scopus, Web of Science, ACM Digital Library, and IEEExplore, which have the most important conferences and journals in the Computer Science Education field, and most of the documents are peer-reviewed.

The process of selecting the documents was composed of three cycles as shown in Figure 1. In Cycle 1, we found 5,111 papers, the inclusion criteria were: documents published in a conference or journal; documents published in the period 2009-2020; Computer and Education areas. For each academic databases a few modifications were necessary in the original search string. In Cycle 2, the inclusion criteria were: documents focusing on underrepresented minority groups, specifically women, African American, and Latinx/Hispanic; and papers for undergraduate level. The exclusion criteria were: documents with less than 4 pages (an attempt to map only full papers); documents in a language other than English; the educational institutions are outside of the U.S.; and papers focusing on the K-12 system. In Cycle 2, we found 465 papers. In Cycle 3, the inclusion criterion was papers focusing on CS1 courses; and the exclusion criterion was papers without educational initiatives. In the last cycle, we found 67 papers.

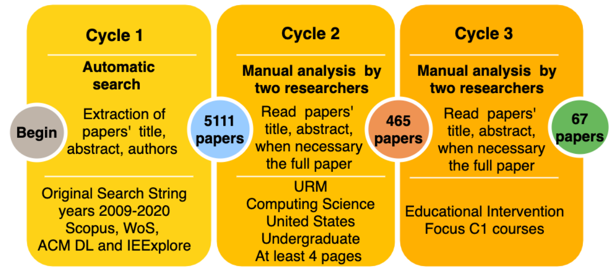

Fig. 1. Cycles of the Selection of the Relevant Papers.

The third and fourth steps, "analyze the documents"; and, "report the results", are described in the following sections.

III. Findings

The aim of this section is to answer the three research questions, in the three next subsections.

A. Answering RQ1 - What types of publications are there (conference, journal, year, states and colleges)?

We found 67 papers with a focus on CS1 courses in the last twelve years in the U.S., 57 (85.1%) from conferences, and 10 (14.9%) from journals. Figure 2 presents the distribution of those documents by year. The number of papers peaked in 2015 and the average yearly output is 7.4 papers. Our last update was in January of the 2021, some 2020 papers had not been indexed in the academic databases.

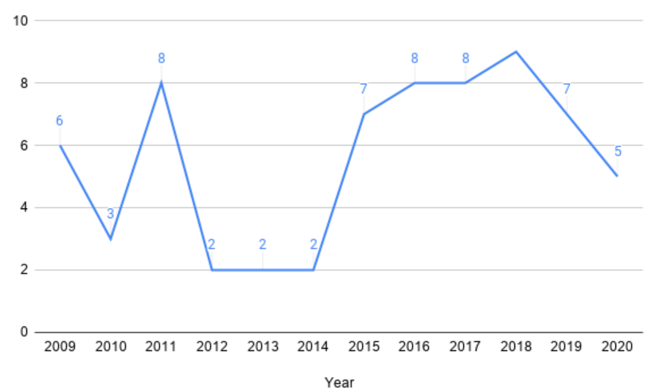

Fig. 2. Distribution of the Documents by Year.

Figure 3 presents the 17 conferences (Table I) where we found documents. Of the 57 papers from conferences, 29 (50.9%) were at the ACM SIGCSE (18) and IEEE FIE (11). The remaining papers were distributed among the conferences as shown – ASEE(7), ITiCSE (4), RESPECT (4), ICER (2) and SIGITE (2). The other conferences have one document each.

We found ten articles in six different journals. Table II presents the number of articles published in each journal and

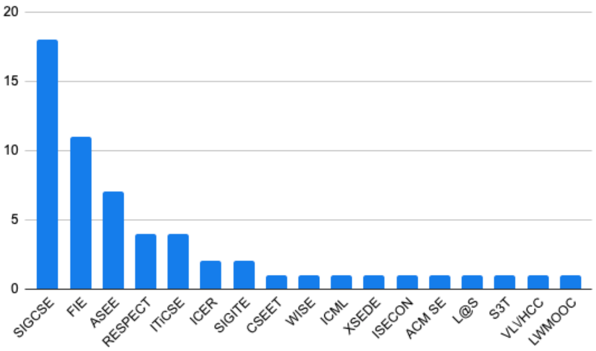

Fig. 3. Distribution of the Documents by Conference.

TABLE I
CONFERENCES WITH ITS ABBREVIATIONS.

Abbreviation	Name
SIGCSE	ACM Special Interest Group on CS Education
FIE	IEEE Frontiers in Education Conference
ASEE	American Society for Engineering Education
RESPECT	IEEE Research in Equity and Sustained Participation in Engineering, Computing, and Technology
ITiCSE	ACM Innovation and Technology in CS Education
ICER	ACM International Computing Education Research
SIGITE	Special Interest Group of Information Technology Education
CSEET	IEEE Conference on Software Engineering Education and Training
WISE	Web Information Systems Engineering
ICML	Interactive Mobile Communication Technologies and Learning
XSEDE	Extreme Science and Engineering Discovery Environment
ISECON	Information Systems Education Conference
ACM SE	ACM Southeast Regional Conference
L@S	ACM Conference on Learning at Scale
S3T	International Conference on Software, Services and Semantic Technologies
VLHCC	IEEE Symposium on Visual Languages and Human Centric Computing
LWMOOC	IEEE Learning With MOOCS

their h-index. The Journal of Computing Sciences in Colleges contains the conference proceedings for each of the regional conferences sponsored by CCSC (Consortium for Computing Sciences in Colleges), and we decided to classify it as a journal because the papers are published as journals with volume and issue numbers.

TABLE II
DISTRIBUTION OF ARTICLES BY JOURNAL.

Journal	h-index	N. articles
Journal of Comp. Sciences in Colleges	12	5
Computer Science Education	18	1
Digital Creativity	12	1
Research on Educational Effectiveness	28	1
Social Sciences	24	1
Tech Trends	33	1

Figure 4 presents the distribution of the documents in 22 states: California (11), New Jersey (7), New York (6), Texas (6), Colorado (5), Georgia (5), North Carolina (5), Virginia (4), Maryland (3), Pennsylvania (3), Florida (2), Illinois (2), Massachusetts (2), Alabama (2), Iowa (2), Michigan (2), Indiana (1), Mississippi (1), Oklahoma (1), Oregon (1), Wisconsin (1) and Utah (1).

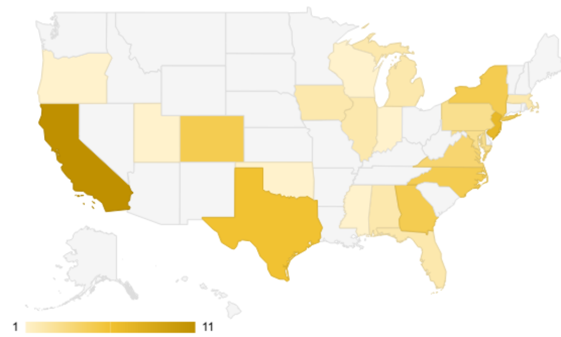

Fig. 4. Distribution of the Documents by State.

The documents were distributed among 52 higher education institutions, mainly HSI (Hispanic Serving Institution) and HBCU (Historically Black College and University). The Ramapo College of New Jersey (7), University of California at Los Angeles (UCLA) (5), University of Colorado at Boulder (5), Georgia Institute of Technology (3), University of North Carolina at Charlote (3), and the University of Texas at El Paso (3). The remaining institutions have three, two or one documents. Table III presents a list of members of the Association of American Universities (AAU) [54] with documents, and the number of documents related to each one.

TABLE III
AAU MEMBER UNIVERSITIES WITH DOCUMENTS.

College	No.of Doc.	Type
University of California, Los Angeles	5	Public
University of Colorado, Boulder	5	Public
Georgia Institute of Technology	3	Public
University of California, Santa Cruz	2	Public
University of Virginia	2	Public
Iowa State University	1	Public
Michigan State University	1	Public
New York University	1	Private
Pennsylvania State University	1	Public
University of California, Berkeley	1	Public
University of California, San Diego	1	Public
University of Texas at Austin	1	Public
University at Buffalo	1	Public
University of Iowa	1	Public
University of Michigan	1	Public
University of Southern California	1	Private

B. Answering RQ2 - Which educational interventions focus on under-represented groups in CS1 courses?

The main strategies to increase the representation of URM groups undergraduate students in CS1 were (Figure 5): teaching changes, curriculum changes, and support to students. Table IV shows the documents. The following subsections present details of these strategies.

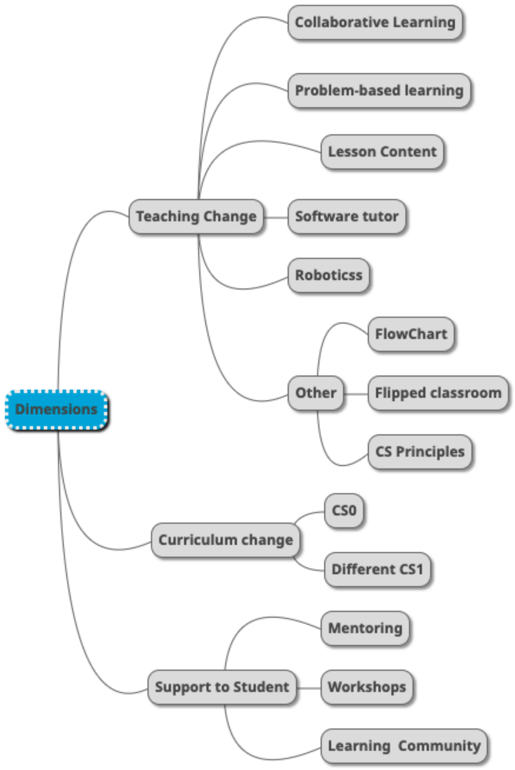

Fig. 5. Distribution of the Documents by Educational Strategies.

TABLE IV
STRATEGIES × DOCUMENTS.

Strategies	Documents
Teaching changes	[24] [12] [9] [17] [36] [35] [61] [49] [69] [34] [70] [68] [28] [13] [60] [71] [79] [29] [39] [10] [32] [48] [45] [46] [47]
Curriculum changes	[62] [23] [42] [74] [35] [27] [34] [30] [18] [75] [52] [56]
Support to Student	[53] [24] [57] [79] [33] [28] [66] [67] [37] [38]

1) Teaching changes: Table V presents the main changes in teaching used to include more URM groups in CS1. These are: Problem-based learning, Collaborative learning, Lesson Content, Software tutors, Robotics, Flowchart, Flipped classroom, and others. The use of Problem-based learning (PBL) is based on real-world problems and uses the social community of the students (student-centered problem), and Collaborative Learning in which the traditional lectures are replaced with classroom activities for groups of students, pair programming and peer reviews.

Table VI presents the documents that have a CS1 with lesson content based on different subjects. In [29] a CS1 using a creative achievement questionnaire [21] is presented. This is based on Introduction to Computing and Programming with Java: A Multimedia Approach Book [31]. In [60], the CS1 is based on the Security Injections@Towson project [41] which includes cybersecurity conception for the CS1 course and other courses in cybersecurity education. [61] presents the introductory CS course, It's All in the Mix, based on food recipes and focuses on the reaction of female African American students to this bridge between algorithms and everyday activities in the context of CS. [68] presents an adaptation to EarSketch for undergraduate in non-majors. EarSketch is a curriculum and learning environment designed to combine introductory computing courses with popular music. [10] presents "Critical CS1," a pedagogical proposal to teach CS through feminist and critical race theory, while simultaneously teaching programming concepts, Python techniques, and socio-political critique.

TABLE V
TEACHING CHANGES BY DOCUMENT.

Strategies	Document
Problem-based learning	[70] [13] [79] [35] [34] [9] [32]
Collaborative learning	[28] [79] [35] [24] [36] [16] [25]
Lesson content	[29] [60] [61] [68] [10] [78] [26]
Software tutors	[48] [45] [46] [47]
Robotics	[76] [19] [20]
Flipped classroom	[69] [49]
Flowchart	[17] [71]
Other	[12] [39]

TABLE VI
LESSON CONTENT BY YEAR.

Document	Year	Content
[29]	2009	Diversity
[26]	2009	Media
[29]	2010	Media
[60]	2015	Cybersecurity
[61]	2016	Food
[68]	2018	Music
[10]	2019	Diversity

[45] [46] [47] [48] present the Problet (problets.org) software tutor (Intelligent Tutoring Systems - ITS) for teaching C++, Java, C# and Visual basic programming in CS1 courses, and an analysis based on gender and race/ethnicity of the application of this tutor in different colleges.

Documents classified as Other are as follows. [12] describes how, in order to include more diversity and creativity, the University of Colorado Boulder used the CS principles for non-CS major undergraduate students. They designed the CS1 course to introduce students to the central ideas of CS and the principles and practices of Computational Thinking, promote programming literacy, and engage students who had no previous programming experience. [39] presents the CS1 MOOC (Massive Open Online Courses) for credit to on-campus students. They found the online course popular with older students, from URM groups, who had previously failed a CS class. The academic performance of the online students was similar to that of traditional courses.

2) Curriculum changes: The most common curriculum changes were to create a preparatory pre-course CS0 before the CS1 course or to create different types of CS1 courses. Most of the documents emphasize the teaching of computational thinking before CS1 for students without previous programming skills. The use of the visual programming tools in CS0 provides the abstraction of the programming language, as well as computational thinking and creativity for students who have no prior programming experience. Table VII presents the ten documents found on CS0. There is a variety of languages used: Scratch, Snap!, Alice, Google Android Platform, Robotics with Lego Mindstorm, Java, Python, and unplugged activities. Some of the documents are described below.

TABLE VII
LANGUAGE/TOOL AND DOCUMENTS.

Language/Tool	Document
Scratch	[34] [62]
Snap!	[52]
Python	[34] [74]
Java	[27]
Lego	[30]
Unplugged Activities	[56]
Google Android platform	[2]
3D Alice platform	[18]

3) Support to Students: This subsection is divided into three strategies: mentoring programs, community learning and workshops. Each strategy is detailed below.

Mentoring programs are reported as essential support for URM undergraduate students in CS1 courses. Table VIII presents the documents with mentoring programs: the classroom column describes if the mentoring process is "IN" (during classroom) and/or "OUT" (extracurricular activity); the team is the number of mentors by students; the diversity on selection means that the program uses diversity, race/ethnicity or gender, for the selection process. [33] presents activities in the classroom, [79] extra classes activities, and [24] [28] [53] have the in/out classroom activities. [53] and [57] present the selection criteria of gender and race diversity in their programs. In [33], one of the factors for low participation was the students lack of spare time after class to participate in the activities. The paper presents the MPP (Mentored Pair Programming), which includes three strategies: pair programming in the lab classes; peer-led team learning (PLTL), the mentor helps the teams; and the closed laboratory, where the lab is composed of three parts, pre-lab (read in-home), bridge-exercise (exercises to prepare the students for labs) and in-lab (hands-on work). With this new model, the programming is successful on different campuses. [53] presents the mentoring programming, over 13 academic years. The college created a new staff position, Student Mentor Coordinator, to manage a student mentoring program.

[66] and [67] present the learning community from DePaul University in Chicago, in addition to solving problems and being introduced to Python, students attend extra-curricular activities, including an open house, study sessions for the midterm and final exams, a midterm gaming celebration, employer visits, and tours of their colleges.

[37] and [38] present workshops. [38] reports on the near-Peer Led Workshops on Game Development, from Georgia Gwinnett College, in which students are grouped into teams of three, and the peer leader assists the groups. [37] from St. Mary's College of Maryland presents the Treisman-style

TABLE VIII
MENTORING PROGRAM.

Document	Class	Team - M (Mentor) S (Student)	Selection
[33]	IN	N.I.	N.I.
[28]	IN/OUT	N.I.	N.I.
[79]	OUT	N.I.	Recomm. letter GPA, Application
[53]	IN/OUT	N.I.	background and gender
[24]	IN/OUT	1 M / 20 S	N.I.
[57]	OUT	1 M / 9 S	Race/ethnicity and gender

Workshops in Introductory Computer Science, the program was based on [72], where the focus is on how to solve problems, and not only programming language.

C. RQ3 - What are the factors that influence under-represented undergraduates in CS1 courses?

We found 16 papers about factors that influence under-represented undergraduate groups in CS1 courses. Figure 6 presents the words in the paper abstract. Main factors reports were: sense of belonging [59] [15]; self-efficacy and self-confidence [63] [44] [51] [15] [55] [65] [58]; student-student interaction [22] [65] [11] [77]; prior experience of programming [50] [58]; leadership abilities [14]. Online courses are reported on [40] and [59]. Finally [43] presents factors related to interaction in a homogeneous group.

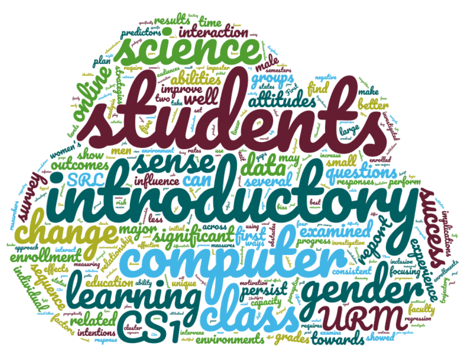

Fig. 6. Word Cloud with Abstract of the Papers.

IV. DISCUSSION

As can be seen, there are educational interventions in several U.S. states, and different colleges. HBCU and HSI universities have several proposals, but we also find proposals among the members of the AAU.

The main interventions to include more underrepresented minority undergraduate students involve changing the curriculum, changing teaching, and support for students. The inclusion of a CS0 before CS1 for students without prior experience in programming is an important change in the curriculum. As regards changes in teaching, collaborative learning and problem-based learning are the most reported strategies. Mentoring is an important intervention to support the minority group undergraduate students.

Finally, a sense of belonging, self-efficacy, self-confidence were important factors reported in the papers. Universities needs to create environment to enhance this feeling for un-represented minority group undergraduate students.

V. Limitations

This paper presents initiatives related to broadening representation in CS majors (women, African-Americans, Latinx/Hispanic, and Native Americans) in the U.S.. However, the review used full papers available in conferences or journals, and we have therefore potentially missed initiatives that there were not available in those academic databases, as well as, those initiatives not reported in papers. Important conferences, such as ACM TAPIA and Grace Hopper Celebration, have not published full papers on diversity in Computing.

VI. Conclusion

This paper presented a literature mapping based on a systematic protocol on educational interventions in the teaching of the first programming discipline specifically for groups that are underrepresented in CS1 courses. Our study involved women, African Americans and Latinx/Hispanic and Native Americans.

Diversity in CS1 courses, which is a prominent topic, has been addressed by means of several initiatives in the last twelve years (2009-2020). These aim to reduce the lack of diversity in these courses, and to increase the participation of minority groups in this area of Computer Science. In addition, all documents presented had a positive impact for that objective. Although this study was in Computer Science undergraduate courses, the activities can be applied in other courses that have the first programming discipline.

As future work: in general, all 67 documents (RQ1) had a positive impact on increasing diversity in the CS1 course; however, we want to analyze the effect of each educational initiative (teaching changes, mentoring, and others) and compare these educational strategies to those for all students.

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