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Towards a Personalized Learning Approach to BroadenParticipation in Computer Science and Promote Computational Thinking

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Abstract

Computational devices are an integral part of our daily lives that underpin our social, political, and economic livelihood. The field of computer science has the potential to be an equalizing force if all members of society have the opportunity to participate in it. For example, there is a growing influence of automation, specifically technologies that involve artificial intelligence (AI) and machine learning (ML), on transforming the way we live and work. Reflecting this growing influence, there is also an increased demand for individuals with skills and knowledge to navigate an AI/ML-enhanced workplace. However, there remains a disparity between those able to benefit from such changes in workforce demands. As such, finding ways to address this disparity is not only an imperative towards a more diverse and representative workforce, but also has the potential to foster untapped talent in engineering and other STEM fields. In an effort to fulfill this need, Curated Pathway to Innovation (CPI) has been designed to develop and maintain students' interest and engagement in computer science and programming through a personalized online educational platform powered by machine learning. Data collected thus far from CPI users suggests an increase in attitudes towards computer programming after one year of using the platform which did not vary between users based on demographic factors. The benefits and challenges of addressing issues related to equity, diversity, inclusion, and belonging in the computing sector through a platform such as CPI are further considered.

Introduction

Over the past several decades, there has been exponential growth in both the capability of computing as well as its influence in several fields[1 2]. This growth in computing has made it easier for computers to do more and solidify their ubiquitous use. We see computing in healthcare being used to speed up the development of drug discovery[3 4], in the classroom and outside of the classroom to teach students a wide range of skills[5 6]. Examples of this include the proliferation of massively open online courses (MOOCs). With the growing influence of computing, the field has the potential to be a an equalizing force if all members of society have an equal opportunity to participate in it.

As technologies like artificial intelligence (AI) become more prevalent in society, there is growing need to ensure that these technologies do not further exacerbate social inequities, specifically for members of society who come from underprivileged communities[7]. Furthermore, there is growing disparity in who is able to take advantage of these opportunities given that not all members of society are equally equipped with the skills and expertise necessary to contribute to these fields[8]. For example, although African Americans make up 13% of the U.S. population, they only represent 6% of the computing workforce and this number gets even lower the more a field requires advanced degrees[9]. Given the growing demand for computing positions, by 2026, the total projected U.S. employment in the science, technology, engineering, mathematics, and computing (STEM+C) workforce will be 9.2 million, of which 4.4 million will be computing jobs, it is imperative that we find ways to address this growing disparity[10].

Numerous programs such as code2040, Management Leadership for Tomorrow (MLT), and a number of other non-profits are looking to address this need by providing access to careers in technology for African American and Hispanic/Latinx students. Although these solutions may be great approaches for addressing the lack of diversity in the technology sector, most African Americans/Blacks, Hispanic/Latinx, and Native Americans/Alaskan Natives (AHN[1]) students are likely to have lost interest in computing by the time these programs finally reach them. Past research suggests that students begin to form interests and identities that predict their career path as early as middle school[11,12]. To have the biggest impact on addressing issues in equity, diversity, inclusion, and belonging in the computing workforce, effective programs and interventions should consider addressing emerging disparities in middle school youth and provide a means to maintain interests throughout high school. Curated Pathways to Innovation, an online educational platform, has been developed with this mission in mind. In the sections that follow, we highlight some of the issues surrounding equity, diversity, inclusion, and belonging in the STEM+C workforce, some of the strengths of current programs designed around this issue, and introduce the approach CPI uses to promote and broaden participation in STEM+C learning and interest development.

Broadening Participation in Computing

The problem of broadening participation in computing is not new and a number of solutions have been proposed to address the lack of AHN students in the field of computing[13]. The need to address this problem is important for more than one reason. As highlighted by the National Academies of Sciences, Engineering, and Medicine, in order for the U.S. to remain a leader in innovation, it must continue to develop the technical acumen of its citizens. These problems must be inclusive and engage the entire population. Especially, communities that have historically been underrepresented in the field of computing. In addition to this, there is growing concern of systemic bias in computing systems[7].

One approach to addressing these problems is to ensure that all members of society have an opportunity to gain the necessary skills that allow them to be active contributors in defining the future of computing. This can only be done through efforts to broaden participation in the field. Various programs and approaches have been developed to address this concern. Programs looking to promote diversity typically fall within the pre-college[14,15,16], college or early career

[1]The term AHN is based on the thoughtful critiques of the ”URM” terminology provided by Tiffani L. Williams: https://cacm.acm.org/blogs/blog-cacm/245710-underrepresented-minority-considered-harmful-racist-language/fulltext

professionals[17] category. These programs vary based on the target audience as well as the goal. Typically pre-college programs are geared towards PreK-12 with the goal of developing interest in computing as well as ensuring students are college ready. Some programs include NSBE Seek, a summer program ran by the National Society of Black Engineers[18], Girls who Code[19], Digital Divas[16] in addition to many others. These programs typically introduce students to the concept of computational thinking as well as programming and programming languages. At the collegiate level, these programs are focused on preparing students for either graduate school or to enter the workforce. Initiatives like the McNair Scholars[20] and various National Science Foundation-funded Research Experience for Undergraduate programs[21] have been developed specifically to prepare students to pursue graduate degrees in STEM. This is done by offering students the ability to conduct cutting-edge research either throughout the school year or during the summer. Students also participate in workshops to gain a better understanding of what it takes to gain admissions into graduate school, receive funding and standardize test prep. One of the most well known of these programs is the Meyerhoff scholars program at the University of Maryland, Baltimore County[22]. In addition to preparing students to attend graduate school, other programs are geared towards helping students find jobs in the computing field. Programs such as Code040[17], the Management Leadership for Tomorrow program and AI for All, help students by providing professional development as well as connecting students to corporate partners for internships and work experience.

Strengths and Limitations for Current Programs

Numerous solutions have been proposed to address issues around equity, diversity, inclusion, and belonging in computing. There are programs geared towards early intervention which focuses on building students' interest and ensuring they persist in the field. These early interventions are geared towards students in elementary, middle, and high school[16,17,19]. Other programs focus on collegiate students and the goal is to either provide opportunities for students to gain experience or to bolster their chances of obtaining an advanced degree or employment opportunities.

There are several benefits and limitations of these existing programs. For example, many of the early intervention programs tend to be very community-focused. They are often implemented towards a specific community and run through non-profit organizations in a certain geographic location. The challenge that often occurs with this approach is that the results do not translate well to other communities. As such, it may be difficult to determine whether a program that works in a metropolitan environment such as Los Angeles will also work in New York, let alone a more rural environment.

More recent intervention programs may provide career readiness training for students who are already pursuing computing majors. These programs provide internships, opportunities for students to learn about different career paths as well as networking and professional development to help students land their dream careers. These solutions are important and needed now more than ever. Although these solutions may be great approaches for addressing the lack of diversity in the technology sector, the issue is most AHN students are likely to have lost interest in computing by the time these programs finally reach them[23]. Past research suggests that students begin to form interests and identities that predict their career path as early as middle school[11,12], and possibly even sooner[24]. To have the biggest impact on addressing issues in equity, diversity, inclusion, and belonging in the computing workforce, effective programs and interventions should consider developing interest in computing as early as middle school and provide a means to maintain interests throughout high school as these are the critical years that students develop their interest in computing.

Curated Pathways to Innovation

In an effort to fulfill this need, the Curated Pathways to Innovation (CPI) platform provides a personalized learning experience for each student to develop and sustain an interest in computing. The CPI platform has been designed to develop and maintain students' interest and engagement in computer science and programming through a personalized online learning platform. Leveraging machine learning, CPI selects and curates educational content from a wide range of online resources that align with learners' interests and learning objectives. This content is developmentally appropriate for children and adolescents, culturally relevant to learners of all backgrounds, aligned with educational standards in K-12 computer science curriculum, and has been curated for inclusion by educators in the CPI platform. The CPI platform may be particularly beneficial for AHN learners because the content is specifically selected such that it includes representation of successful individuals of AHN backgrounds. In addition, the content is curated to align with students' interests and thus assumes a more personalized approach. Content is continuously added to provide the widest possible selection of activities for learners. Furthermore, a platform such as CPI is scalable - requiring minimal training from teachers or staff to implement.

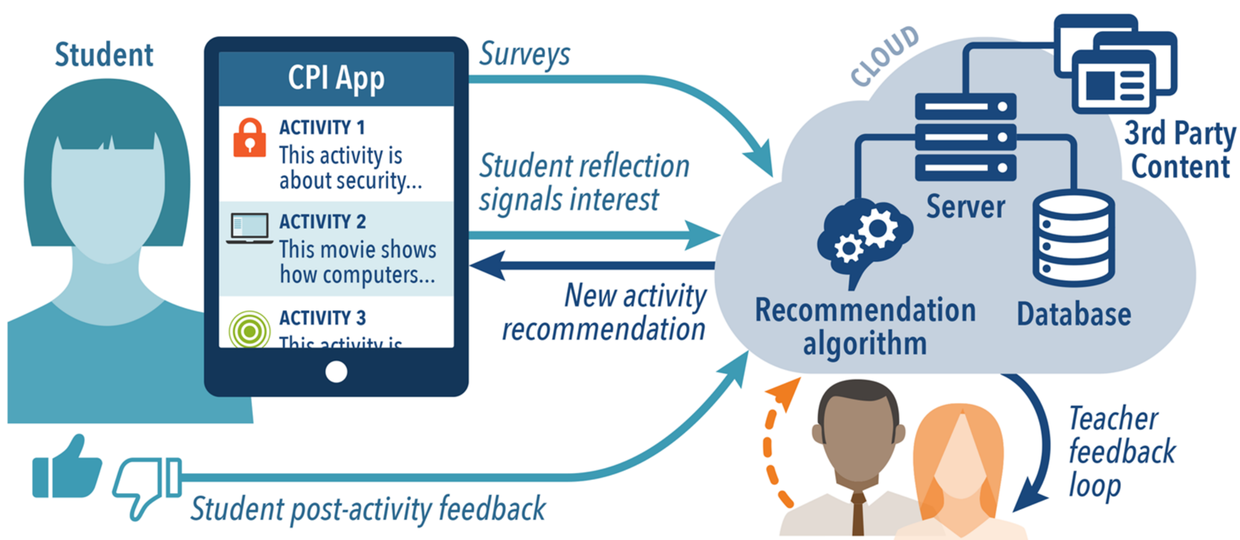
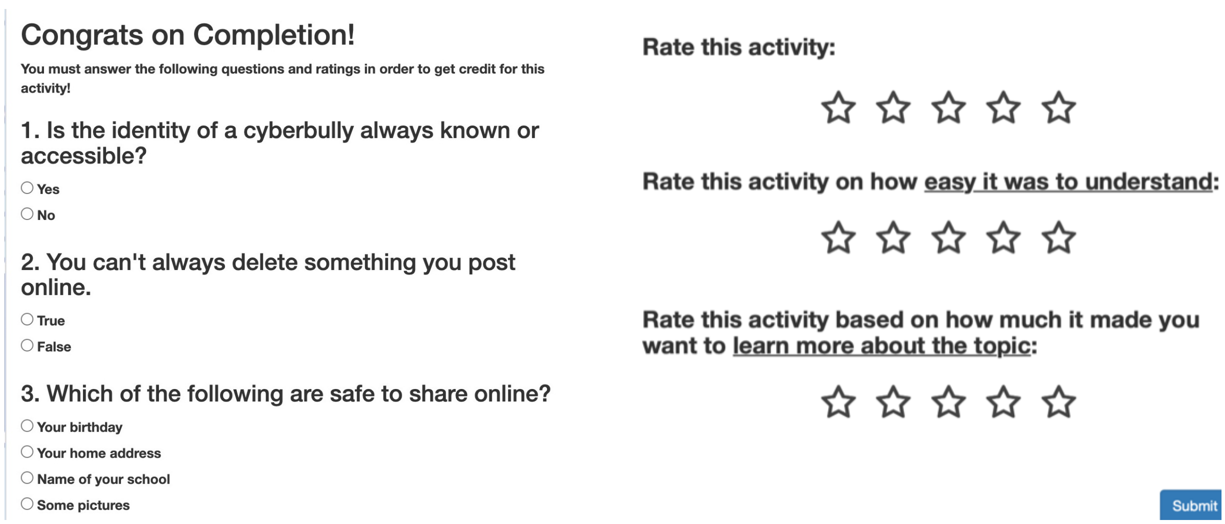


Figure 1: CPI data and platform architecture

Curation of High-Quality Educational Content

The CPI platform is effective because it makes high-quality and personally salient educational content accessible to student users. Content experts are involved in querying the Internet for high quality, freely available content useful for teaching STEM+C concepts and skills. The content experts vet this content to ensure it is appropriate for students on the platform as well as the quality of the activity. Once this content has been vetted, a set of comprehension questions are created to test students' understanding of the selected content. The comprehension questions are presented to students at the completion of each activity. Figure 2a provides an example of a comprehension question. Students also rate the activity and this information is later used as input in the ML-enabled recommender algorithm in identifying content for future users. Figure 2b shows an example of the activity rating that is provided at the completion of each activity.

In this example, a student completed the cyber squad activities that focus on teaching students how to be safe online. Thus, the comprehension question is assessing an understanding of digital safety. This content, both the link to the activity as well as comprehension questions, are categorized based on the subject matter it is teaching and placed in the content library. Content available through CPI is organized according to activities and badges. Each badge consists of a collection of activities. In order to earn a badge, students must complete a number of activities. Some activities have prerequisites while others do not.



(a) Comprehension Questions (b) Rating of Activity

Figure 2: End of activity comprehension questions and rating survey.

Personalized Learning

The "one-size fits all" model of education does not work well for students, especially for AHN. Therefore, educational resources intended to broaden participation in STEM+C should provide and present personalized content that takes the student's interests into consideration to be most effective. The CPI platform is designed with a keen awareness of this need and thus it provides each student a customized learning path based on their interests and background. One of the challenges which curated unique learning paths for students is finding a balance between the content that students must learn and the content students want to learn. For example, a student may want to learn about artificial intelligence and how to build these types of systems but may not want to take calculus. The CPI platform addresses this by generating a recommendation that includes both required and optional courses. Upon logging onto the platform, each student must take a survey to assess who they are and their interests. These survey questions are intended to gain a baseline as to the student's interest as well as experience in computing. This information and the comprehension questions are fed to the student model who then recommends a learning pathway for students. This recommendation system uses machine learning to generate this content.

Current Impact of CPI

Over the past several years, CPI has engaged over 5,000 middle and high school students (40.8% female, 33.6% Hispanic/Latinx, 16.2% White/European American, 16.1% Asian/Asian American and Pacific Islander, 6.9% Black/African American, 21.1% Other, 6.1% Did not respond). Teachers who have used CPI in the past have spoken highly of the activities as tools for triggering students' career interest in STEM, with one recently commenting, "My ultimate goal is to expose students to STEM+C so they start to consider a STEM career at an early age; CPI helps me achieve this goal through the interactive activities." Another teacher noted, "It gives students an idea of paths they may take and careers they are interested in all while having fun and earning badges." As noted previously, given that it requires minimal training on the part of educators and students, CPI is highly scalable. With an eye toward expansion under the current leadership, the team has already begun working with partners to get students to access existing high quality and engaging activities within CPI's curation, including a library's mobile maker lab, a community college's summer camps, a tech company's mentorship program, among other programs.

Preliminary results are additionally promising. Recently, CPI researchers examined growth in computer programming attitudes among middle school CPI users (N=610; $Mean_{Age}$ = 12.07 years, SD_{Age} = .77 years, %female = 37.2%; 68.3% Hispanic/Latinx, 16.3% Asian/Asian American, 4.9% Hawaiian or Pacific Islander, 4.7% White/European American, 3.5% American Indian or Alaskan Native, 2.0% Black/African American, 20.1% Other category) enrolled in either the 2017-2018 or 2018-2019 academic year in minority-serving schools[25]. Even when accounting for existing differences in students' math attitudes, there was an initial and sustained improvement in awareness, self-efficacy, interest, and career aspirations in computer programming, which did not differ based whether or not the student was from an AHN group. Given these promising findings, the CPI project leadership is now developing partnerships in multiple regions throughout the U.S. By promoting the awareness and interest in computing fields, particularly among AHN students who are underrepresented in STEM+C, use of the CPI platform may help to promote engagement in engineering fields in the future.

Conclusion and Discussion

There is a need to promote diversity, equity, inclusion, and belonging in the computing workforce. It is both a societal imperative and a need driven by changing workforce demands in the face of a rapid shift towards automation. Providing high quality and personalized learning experiences to historically underserved students, especially AHN students, is one means of achieving this aim. The CPI platform is designed specifically with this goal in mind. Results over the past several years show that not only are students exposed to new career opportunities and the skills necessary to gain access to these careers, but the CPI model makes the process of introducing students to

STEM+C more scalable and provides a streamlined approach to engaging both teachers and students in the development of these skills. As we grow CPI, one of our goals is to increase the representation of Black/African American students on the platform. Currently, we have a limited number of such students on the platform due to the low enrollment at the schools where the program was initially piloted. In the year ahead, we are expanding regions throughout the U.S. and aim to ensure that Black/African American students are equally represented on the platform.

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