Understanding and Expanding College Students' Perceptions of Computing's Social Impact

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***Abstract*—Research has found that college students who believe that computing can benefit society tend to report a higher sense of belonging. This is additionally true for students who endorse the goal of helping society; students who identify as first-generation college students, women, Black/African American, Hispanic/Latinx/Latin*, and/or Asian are more likely to endorse this goal. People from these groups are also more likely to endorse the goal of wanting to collaborate. To better understand how students decide if computing can be used to benefit society and whether it involves collaboration, we conducted interviews with 29 college students. Contrary to previous research, our participants universally expressed the belief that computing can help society and cited the ubiquitous impact of computing as evidence. However, students were also wary that profit is the primary motivator of many large technology companies. Our participants generally also believed that computing involves collaboration, which may be the result of most of our participants attending an institution that emphasizes collaboration. We propose that educators provide examples of positive social impact beyond computing's contribution to modern conveniences as a way to expand students' perceptions of the work possible in the field. Towards that goal, we provide 12 examples. Influencing students' perception of computing as having positive social impact and collaboration may be an effective initiative to broaden participation and promote belonging. That is, interventions to shift students' perception of computing may complement additional efforts to address structural inequality and discrimination that limit participation in computing.**

***Index Terms*—communal goals, goal congruity theory, broadening participation in computing, social impact**

I. Introduction

Our research seeks to understand what shapes students' perceptions of whether computing provides opportunities to work with and to the benefit of others. Previous work has shown that there is a common perception that computer science (CS)[1] does not offer opportunities to engage in work that will be beneficial to society [1]–[3]. Students who identify as first-generation college students[2], women, Black/African American, Hispanic/Latinx/Latin* [4], and/or Asian[3] are more likely to endorse the goal of working with and to the benefit of others [5]. Diekman suggests that a belief that computing will not help them achieve their goals might be one of the reasons people from groups underrepresented in computing[4] are turning away from the field [6]. Diekman refers to the hypothesis that individuals are less likely to pursue science, technology, engineering, and math (STEM) roles if they do not perceive them as enabling the achievement of their valued goals as *goal congruity theory*.

In response to the evidence in support of goal congruity theory as an explanation for patterns of underrepresentation in CS [5], [6], we are interested in designing and evaluating interventions to convince students that CS provides opportunities to benefit society and work with others. However, it is unclear what sources of information students use to determine if computing provides social value or involves collaboration. To address this gap, we address the following research questions:

- **RQ1:** What are students' perceptions of whether CS can benefit society and what shapes those beliefs?
- **RQ2:** What are students' perceptions of whether CS involves working with others and what shapes those beliefs?

We interviewed 29 students from two U.S. colleges about

[1]We use computer science and computing interchangeably. Our interviews referred to "CS," which was the title of the computing major at our two recruitment sites.

[2]The term "first-generation college students" refers to students who do not have a parent or guardian that has completed a four-year college degree.

[3]There is significant overlap between the groups of people more likely to endorse the goals of working with and to the benefit of others and the groups of people unrepresented in computing, but an important distinction is that students identifying as Asian fit only in the former category. While Asian students are not identified as underrepresented in computing, the term "Asian" includes people from a wide variety of ethnicities and backgrounds who may experience underrepresentation and explicit and implicit discrimination. Asian students may also benefit from interventions emphasizing that computing can provide opportunities to work with and to the benefit of others.

[4]In the U.S., people from groups underrepresented in computing include people who identify as women, Black/African American, Hispanic/Latinx/Latin*, Native American, Native Alaskan, Native Hawaiian, Pacific Islander and/or disabled.

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their perception of computing as being able to benefit society, and as involving collaborative work. Our work was exploratory and used thematic analysis [7] to address our research questions. Overall, our participants expressed the belief that computing can help society and cited the ubiquitous impact of computing as evidence. However, many students were also wary of large technology companies. Additionally, many of our participants expressed the belief that CS is a collaborative field and cited the frequency of group work in CS courses at their school as evidence.

A key limitation of our dataset was that students did not provide specific examples that led them to believe that CS can be used for social good, which may be due to the ubiquity of computing and technology. As our long-term goal is to design interventions to showcase these affordances in the computing field, we have developed and included within the paper 12 examples that could be presented in an intervention designed to convince students that CS can indeed benefit society.

Our work builds towards an intervention that could alter students' current perceptions of computing as lacking opportunities to benefit society. Influencing students' perception of computing as having positive social impact and opportunities for collaboration may be an effective way to broaden participation in computing. That is, interventions to shift students' perception of computing may complement existing efforts to address structural inequality and discrimination that limit participation in computing [8]–[18].

II. Previous Work

A. Communal vs. Agentic Goals

When it comes to career goals, individuals can be motivated by communion and/or agency [19], [20]. Communal goals have been defined by scholars as working with or for the betterment of others [6], [19], [20]. This includes working with a team, rather than alone, as well as working on projects that have a meaningful long-term impact on society [21]. This is in contrast to agentic goals, which relate to achievement and self-promotion [19].

Although communal goals are usually understood to mean both wanting to help society and valuing a collaborative environment, the term has not been consistently operationalized. First, it is not a given that students who place a high value on helping society will necessarily also have goals for collaboration. Additionally, students may have a preference for social impact (i.e., providing direct help to other people) or societal impact (i.e., higher-level benefits to society as a whole). A limitation of prior work is that these different aspects of communal goals need to be disentangled.

There is substantial evidence that people who identify as women, Asian, Black/African American, Hispanic/Latinx/Latin*, and/or first-generation college students are more likely to be motivated by communion rather than agency, and place a higher value on opportunities to contribute to society within their career than their peers who identify as men and/or White [6], [21], [22].

B. Goal Congruity Theory within STEM

The belief that there are relatively more opportunities to achieve communal goals in a particular career field can be restated as the belief that the field has "communal goal affordances." Diekman and colleagues' *goal congruity theory* explains that individuals with communal goals will not be motivated to pursue careers in STEM fields if they perceive STEM as lacking communal goal affordances [6]. Students' career goals and their perceptions of future careers as having communal affordance therefore relates to recruiting and retention efforts in STEM. Since people from groups underrepresented in computing are more often motivated by communion rather than agency, goal congruity theory may offer a valuable hypothesis for increasing interest in STEM fields amongst these individuals by shifting their perspective on STEM's communal goal affordances. While goal congruity theory was constructed on the base of gender (i.e., because women more often than men endorse communal goals [6]), the perspective has been used in previous studies to help explain low retention rates in science for first generation college students [22]. Additionally, goal congruity theory has been expanded to students who identify as Native American [23], Black/African American, Hispanic/Latinx, and Asian [5].

Allen et al. looked at the relationship between first-generation students' perception of the communal goal affordance of science and their interest in pursuing science [22]. They found that first-generation students showed greater interest when science was seen as having a pro-social communal goal affordance, which is when science is believed to positively impact society [22].

Diekman et al. found that women were more likely than men to endorse communal goals [6]. In comparison to other fields, careers in STEM were generally perceived to have less communal goal affordance [6]. Furthermore, they found that when STEM careers were described as collaborative and including elements of mentoring, people who endorsed communal goals reported a more positive perception of the field [6]. Their model suggests that students' belief in the communal affordances of STEM and educational environments that signal communal goal fulfillment could increase the participation of women and other communally-oriented individuals [6]. In their work, when presenting STEM careers as highly communal, students who did not endorse communal goals did not report lower levels of interest [6], meaning these changes did not appear to have an adverse effect on students who do not value communal goals.

C. Goal Congruity Theory within CS

It is a common misconception that CS will not facilitate communal opportunities [1], [2]. Given this misconception, and the tendency of groups underrepresented in computing to endorse communal goals, this perception may be obstructing a diverse population from pursuing computing careers [6], [21], [22], [24]–[26]. A study using nationwide survey data from 1971 to 2011 found that "The fact that women placed greater value on social activism (i.e., helping others in difficulty and influencing social values) explained 6.6% to 9.5% of the gender gap in computer science" [27].

Lewis et al. [5] tested goal congruity theory as a predictor of computing majors' sense of belonging, which has been shown to be a strong predictor of student retention [28]. In this previous research [5], 5,821 computing majors responded to the question "In your opinion, to what extent would a career in computing allow you to serve humanity?" on the following scale: (1) not at all, (2) a little, (3) somewhat, (4) quite a bit, (5) very much. The resulting average was 3.64 with a standard deviation of 0.99. The authors found that people from groups underrepresented in computing were both more likely to have communal goals as well as report a weaker sense of belonging in computing [5]. A perception of computing as having communal affordances, whether or not the student endorsed communal goals, was a significant positive predictor of sense of belonging when controlling for race, gender, first-generation college status, and institution. The average perception of computing as having relatively high communal goal affordances (i.e. average of 3.64 on a scale of 1-5) is in accordance with a study that has found that STEM careers are believed across all ages to be fairly likely to afford societal impact [29].

Work that predates the introduction of goal congruity theory [6] provides additional support for the theory. A survey conducted by Biggers et al. showed that a theme among people who left CS to pursue another field was the perception that their new chosen field had a more relevant connection to the real world than CS [3]. There were also findings that indicate many left CS due to a lack of quality human interaction [3]. Biggers et al. suggest, based on their survey, that students who leave CS have "an overwhelming perception that CS is an asocial, coding-only field with little connection to the outside world" [3]. Over 60% of CS leavers departed by the end of their first year of undergraduate CS curriculum. This suggests that introductory exposure renders many students skeptical that computing can fulfill their particular goals.

Contrary to the perceptions uncovered in these studies, computing does offer opportunities to accomplish communal goals (see section VII). However, many undergraduate CS curricula do not facilitate exposure to these affordances. Undergraduate computing students could benefit from explicit interventions aimed at dispelling the perception that computing careers do not intersect with opportunities to help society. Based upon prior work [5], a change in the ways students view computing may lead to an increased sense of belonging in computing. Importantly, this could additionally increase a sense of belonging for students from groups underrepresented in computing since they are more likely to endorse communal goals [5].

D. Communal Goals Interventions

To resolve this misconception of CS as a field lacking in real-world relevance, several institutions have made adjustments to their introductory CS courses, and implemented interventions throughout CS departments and curricula in ways that may change perceptions of computing careers [3], [21], [30], [31].

Biggers et al. [3] addressed a specific disconnect between the perceptions of CS for those who stay in their programs to completion and those who leave. When asked to define CS, the responses from recent CS graduates were at times exact opposites of responses from CS leavers (e.g. "Writing programs...to solve problems facing our world" versus "Coding/debugging in front of a computer screen all day"). The researchers list challenges and corresponding action plans for retaining students in CS departments, and many are specifically directed at changing the perception of communal goal affordances. They advocate for "highly interactive hands-on introductory CS courses that provide a broader overview of potential CS careers" [3] as the key to retaining student interest. For example, to combat the notion that "coursework was lacking in relevancy," Biggers et al. suggest that CS educators "contextualize the assignments and courses and use real world issues even when teaching the basics" [3]. They state that the Peer Led Team Learning [32] workshops they hold, which promote collaboration and use well-contextualized assignments, have improved retention and performance in introductory CS courses, especially for women [3]. Overall, the action plans emphasize that successful interventions to change the perception of CS and give CS students a vision of a broader dream require early and on-going action [3].

Several researchers have designed curricular changes aimed at changing student perceptions of computing. For instance, Van Wart, Vakil, and Parikh provide a case study of a 24-hour course "Apps for Social Justice" [33], which sought to apply innovative integration of students' interests and identities used in mathematics instruction [34], [35]. Buckley et al. [31] described two on-going curricular experiments in line with the goals of expanding "socially relevant computing." Goldweber et al. [36] proposed a framework for conveying computing's societal impact affordances within the curriculum. They include 14 introductory computing projects assignments that are contextualized around social good and partially address the need for graduates to be prepared to contribute to social good outcomes.

Outside the classroom, Brinkman et al. found that a more diverse pool of applicants applied and were admitted to a computing scholarship program that emphasized and was based around communal goals (like collaboration and computing-related community service activities) compared to industry standard programs [21].

Beyond the field of computing, Brown et al. similarly make a case for exposing students to the scope of "communal utility value" in a discipline in order to increase interest in the discipline [37]. For example, Brown et al. found that believing biomedical research has communal goal affordance provides a long-term increase in motivation to continue in the field for biomedical students, even for those who were already interested in biomedical research [37].

These communal goals interventions also relate to a broader set of interventions focused on culturally responsive pedagogy [38] and culturally responsive computing [33], [39]–[41].

III. Methods

A. Interview Participants

We recruited participants from two private colleges in the U.S., one a STEM-focused school, and the other a liberal arts school. Recruitment occurred through in-person and email announcements. Interviews were conducted in-person and participants were compensated with $10.

We interviewed 18 participants from the STEM-focused college and 11 participants from the liberal arts college. All 18 participants from the STEM-focused college were majoring in or thinking about majoring in a STEM field. Seven of them were majoring or thinking of majoring in CS. All 11 participants from the liberal arts college were majoring in or thinking about majoring in a humanities field.

Interviews were recorded and the audio recording labeled with a number and the participant's institution. For example, participants from the STEM-focused college are identified as *STEM_01* through *STEM_18*. Participants from the liberal arts college are identified as *LA_01* through *LA_11*. Interviews lasted between 10 and 15 minutes.

B. Interview Protocol

We sought to understand the content and sources of information that shape students' perceptions of the communal affordances of computing. That is, whether computing involves working with and for the betterment of others. Participants were asked the questions given in the following list in a semi-structured interview. The first four questions provided context about the interview participant (i.e., year, major, and major selection process). The fifth through seventh questions focused on one key element of communal goals: benefiting society. The eighth question provides additional context about the interview participant (i.e., their endorsement of communal goals). The ninth, tenth, and eleventh questions focus on the other key element of communal goals: working with others. The twelfth question provides additional context about the interview participant, but was unfortunately not asked of all participants.

1) What is your year in college?
2) What is your major or intended major?
3) How did you decide to major in that?
4) Did you ever consider majoring in CS? Why or why not?
5) Do you think that computer science can be used to benefit society?
6) What do you think has shaped that perception?
7) Are there other [non-CS] fields that you think can be used to benefit society?
8) How important do you think it is to find a career that helps you contribute to society?
9) Do you think that computer science is something where you work with others?
10) What do you think has shaped that perception?
11) How important do you think it is to find a career that allows you to work with others?
12) Anything else you would like to add?

C. Analysis of Interviews

The research was intentionally exploratory and was designed to create hypotheses about the content and sources of information students use to determine if computing has communal affordances. The methods were not designed for generalizability and recruitment at two private colleges was a known limitation to generalizability. Additionally, although this work aims to contribute to broadening participation in computing, the participants were not asked to provide their demographic information.

Audio files were professionally transcribed. Transcript files were checked for accuracy and corrected by the research team. Filler words like "um," "uh," and "like" have been removed from participant quotes for readability. Square brackets are used to clarify ambiguous referents in the quotations. Two forward slashes are used to indicate interrupted speech and ellipses are used to indicate removed text.

As a first analysis step, the research team conducted an open coding pass of the data [42] using the qualitative coding software Saturate app (saturateapp.com). The researchers also created summaries for all participants' responses to each question. Based upon these passes through the full dataset, common themes and patterns found in students' answers were noted. We developed a thematic analysis [7] of participants' perceptions of CS in order to extract general trends among their opinions and experiences.

Participants' responses to many of the interview questions did not directly relate to our questions of interest. For example, participants' explanations for their choice of major and reasons for not choosing CS related to their self-assessed ability within CS. While this corroborates previous research [43], their responses to these questions did not provide additional insights into how students perceived the nature and societal benefit of CS work. There were ways in which our interview questions and follow-up questions could have been improved to address our questions of interest. Unfortunately, contrary to best practice [42], it was not feasible for us to engage in ongoing analysis throughout data collection.

To understand how students decide if computing can be used to benefit society, we focused our analysis on the fifth through seventh questions above. To understand how students decide if computing involves collaboration, we focused our analysis on the ninth and tenth questions above. As a result of focusing on a subset of the interview questions, many of our initial codes and themes are not included.

IV. RQ1: Perceptions of Whether CS Can Benefit Society

A. Agreement that CS Can Benefit Society

All of our participants agreed that CS *can* benefit society. A common response to whether CS can be used to benefit society was some form of "yes" or "definitely." Our interview question, which used the word "can", appears to have been interpreted generously. For example, when asked what other fields can be used to benefit society participants said *"I mean, almost all of them." (STEM_04)* and *"Um, I feel like there's potential in everything." (STEM_07)*.

Towards our goal of understanding the content and sources of information that shape students' perception of computing as benefiting society, the universal agreement among our participants that computing can benefit society was somewhat unexpected and a limitation.

B. Ubiquity of Computing and Computing Innovation

An apparent cause of participants' beliefs about computing's benefit to society is the ubiquity of computing and a broad interpretation of both computing and helping society. For example, when asked what gives them the perception CS can benefit society, participant replies included:

- *"I think that as a society, we're just moving towards more and more and more technological advancement, and we've already done so much. And I think that computer science is, I guess, obviously so involved in that." (LA_09).*
- *"We're pretty much already in a technology-based world and everything that we do and depend on is a product of technology, so I think it's a huge part of it and definitely benefits it." (LA_10)*
- *"Um, computers and com// and, like, computer systems are used ubiquitously. I mean you're recording [the interview] on a computer....I mean they've completely changed the world, so yes." (STEM_09).*

The most hesitant response was *"Um, not on the surface, but I do think there's probably // it makes sense that it could. But it's not the first thing I think when I hear computer science. But if I think about it for a couple minutes, I'm like 'well yeah I could see how there could be benefits.'" (LA_02)*. When asked to elaborate on what the first thing they think of when they hear CS, they replied, *"I literally don't even know, like, coding?" (LA_02)*. This aligns with previous research that students often believe that career prospects are limited to "only coding" [3].

C. Wariness of Technology Companies

The perception that CS could benefit society did not preclude the idea that it could also have negative consequences. For example, when explaining why they thought CS could be used to benefit society, a student said *"Um, there's just, like, a lot of repetitive tasks that can easily be replaced by computer science. I mean, the social side of all the jobs that would displace is another thing. But if used correctly, it can definitely be a good tool." (STEM_04)*.

Related to the potential negative impact of CS was our participants' overall wariness of big technology companies. This was primarily expressed when participants were asked if they perceived CS to be a field that could positively impact society. One student expressed their reluctance to give too much credit to technology companies: *"I don't really know what impact a lot of the tech companies in the world have" (STEM_02)*. Another mentioned how although they think that technology can definitely positively impact society, that a lot of technology companies in the U.S. currently seem to be focused on profit: *"We get a little carried away trying to just make money" (STEM_12)*.

This wariness of big technology companies is actually a growing trend. A 2019 survey done by the Pew Research Center showed that the percentage of Americans who believed that technological companies had a positive impact on society has dropped from 71 percent to 50 percent from 2015 to 2019 [44]. Additionally, college students across the U.S. have been questioning the moral compass of many top companies and hesitating to work for these companies [45]. Our examples of how computing can be used for social good (see section VII) may be one way to show students that there exist other career options besides these technology companies.

V. RQ2: Perceptions of Whether CS Involves Working with Others

A majority of students said that they perceived CS to be a collaborative field, since it involves a lot of problem solving in groups. All students from the STEM-focused college said that they perceived CS to be a collaborative field after taking the introductory CS class at the school, and getting the opportunity and encouragement to work with others in that class. One student, in response to this question, said yes, particularly *"... in the sharing of ideas or contributing towards a larger project in teams" (STEM_01)*. Similar attitudes were expressed by other participants:

- *"The more people you're working with the more it opens even more doors for you to figure out a way to to solve the problem [in CS]" (STEM_02).*
- *"I think [CS] stresses the importance of collaboration, working with others on teams" (STEM_09).*
- *"Yes, because // I don't know, you have to work with a team of people." (LA_08).*

Despite this pattern, some students did report that their initial perception of computing was as a non-collaborative, individual activity. One student said *"I think of it as a more individualistic thing where there's someone who is a programmer working on creating a program for something on their own" (LA_05)*. Another cited the portrayal of programmers in popular media for this belief: *"In the media, in movies and stuff, people who do computer science are always type casted as being nerdy and socially inept, working alone" (LA_07)*.

A limitation of this work is that the STEM-focused college's curriculum emphasizes students working together [46], and the focus on collaboration within these courses may bias students' perceptions of CS as being collaborative. However, this may simply be evidence of an effective intervention. Beyond this institution, communicating that CS involves collaboration may still remain a challenge. Much work has been done to communicate this message; for example, there have been a variety of interventions to integrate collaboration within CS, such as through the use of pair programming [47]–[49].

VI. Limitations

Our interviews did not provide clear information about the sources of information students use to determine if computing can benefit society. The ubiquity of modern conveniences that are powered by CS may lead to these perceptions. Within previous research that motivated our work [5], the average survey response reported on the question "In your opinion, to what extent would a career in computing allow you to serve humanity?" was relatively high at 3.64, falling between "somewhat" and "quite a bit" on a scale of (1) not at all, (2) a little, (3) somewhat, (4) quite a bit, (5) very much. Based upon prior work [5], communal goals interventions seem promising, but upon reflection we should have expected general agreement that computing can benefit society. However, a higher value on that question was a significant predictor of a higher sense of belonging.

An additional limitation of communal goals interventions is that college students may have difficulty pursuing jobs that provide societal benefit. Institutional support may lead students to see big technology companies as the only career option and cultural attitudes may lead students to believe that other options are not valued. Understanding how CS departments can provide and legitimize paths towards CS careers that have positive social impact is an important area for future research.

VII. Discussion

In order to mitigate the limitations discussed above, one direction future work could take is to create interventions designed to show students that not only does CS have communal affordances, but that there are also career paths in computing beyond the large technology companies they may be familiar with. To build towards our future work of designing and evaluating interventions to develop students' belief that CS can benefit society, we have developed examples related to five themes: medical diagnosis, public health, violence prevention, equitable access, and democratizing technology. We hope to pursue further research in using these examples as part of a classroom intervention and assessing its impact on students' perceptions of computing.

A. Social Impact: Medical Diagnosis

1) Improving Cancer Detection: In 2020, breast cancer was the most commonly diagnosed cancer with an estimated 2.3 million new cases [50]. With increasing availability of imaging from mammograms, it is possible to use CS to analyze these images to detect breast cancer [51], [52]. Early mammograms from individuals eventually diagnosed with breast cancer can be used to identify possible early warning signs that can be used for early detection in other patients [51], [52]. Regina Barzilay and colleagues used a type of artificial intelligence known as machine learning to aid doctors in predicting cancer and identifying appropriate treatments [51], [52].

2) Communicating Autism Spectrum Disorder Diagnostic Data: Autism spectrum disorder (ASD) is a developmental disorder that affects communication and behavior [53]. During a typical ASD screening, doctors collect data on a child's gesture, gaze, and speech behavior [54]. This complex diagnostic behavioral data is difficult for experts to analyze or explain to a child's caregiver(s) [54]. John Lee and colleagues created a program that transforms these data into an easier to understand visualization that helps tell a story [54]. The visualization shows different colors over a temporal line to represent actions the examiner takes (i.e. saying the child's name) and the behavior of the child in response.

3) Assessing Newborn Jaundice: Newborn jaundice is estimated to affect 84% of babies, making it one of the most common newborn conditions [55]. Jaundice describes the buildup of a natural bodily waste material called bilirubin [55]. While many newborns with jaundice do not progress beyond a moderate level of bilirubin buildup, extreme cases of newborn jaundice are essential to detect early to prevent brain damage or death [55]. Since current detection techniques involve specialized equipment, caregivers must rely on the visual cues of one of jaundice's symptoms, yellow skin discoloration, to monitor the condition at home [55]. Previous work has shown that even experienced healthcare providers cannot accurately estimate the severity of newborn jaundice, and so this is not a reliable way to monitor a newborn at home [55]. Lilian DeGreef and colleagues created Bilicam, a low-cost system that uses smartphone images and computer vision techniques to accurately and easily assess the severity of newborn jaundice [55]. DeGreef and colleagues used machine learning to analyze images they collected from 100 newborn participants and created a model to predict bilirubin levels.

B. Social Impact: Public Health

1) Addressing Flint, Michigan's Water Crisis: After Flint's water supply was changed to draw from the Flint River in 2014 to save money [56], the water began absorbing lead from lead pipes within the water supply. In 2014, the water supply of the city of Flint, Michigan was changed to draw from the Flint River in order to save money. The water then began absorbing lead from the lead pipes within the water supply. This led to dangerously high levels of lead in the drinking water [57]. Even though the Flint River was known to be highly corrosive, Flint officials failed to treat the water [58]. However, the city did not have records of which homes in the system had lead pipes that needed to be removed. Jacob Abernethy and colleagues used machine learning to predict which homes had lead pipes to use the city's limited funding for lead pipe removal more effectively [59], [60].

2) Slowing the Spread of COVID-19: Coronavirus (COVID-19), like other diseases transmitted through air and surfaces, can be better contained when others can be notified quickly if they have been in the presence of an infected person. For an alert system like this to be effective, it must operate on a large scale and dispatch alerts quickly, which presents challenges to maintaining individuals' privacy. To address these privacy concerns, Ran Canetti and colleagues created a system that uses short-range communication mechanisms (e.g., Bluetooth) to provide timely alerts to individuals that may have been infected without collecting or storing personal information or location history [61].

3) Teaching Reproductive Health through Games: To provide greater access to knowledge about reproductive health, Victor Guana and colleagues built UnderControl, a mobile game that educates players about contraception and sexually transmitted infection (STI) prevention [62]. The main goal of UnderControl is to learn about the use and affordances of different contraceptives (e.g., condoms, contraceptive sponges, diaphragms). At the beginning of each level, the player is provided an informational overview about the STIs and contraceptives that appear in the game. UnderControl is built such that condom usage is the most effective way to advance to the next level as an analogy for the relative effectiveness in real life.

4) Predicting Hurricanes: Tracking and predicting extreme climate events, like hurricanes, is a long-standing scientific challenge [63]. The need to reduce the impact of hurricanes has become critical; in 2017, hurricanes killed 300 people in the U.S. and cost the U.S. $267 billion in damages [64]. Researchers have used a type of machine learning known as convolutional neural networks (CNNs) to detect and classify severe weather events with high precision [63]. Extending the state of the art, Sookyung Kim and colleagues reformulated the problem in terms of regression to produce time-sequential density maps of hurricane trajectories [63]. Their model constructs density maps much closer to the observed data than the previous models.

C. Social Impact: Violence Prevention

1) Actualizing Proposed Gun Control Legislation: Gun violence takes the lives of many in the U.S., with 11,419 people killed in 2013 [65]. A registry of the sale of firearms is one important form of gun control that officials and law enforcement can use to trace guns [66]. A current U.S. Senate office is drafting a piece of legislation that proposes a voluntary U.S. gun registration system [66]. In order to enact this vision, Seny Kamara and colleagues designed a cryptographic protocol that is feasible to implement at scale while guaranteeing the confidentiality of the data in the registry.

2) Predicting Police Misconduct: Police misconduct is the U.S. is a longstanding issue that is gaining more attention in mainstream news [67], [68]. Early Intervention Systems (EISs) aimstrive to identify police officers that are more likely to be involved in an adverse public interaction so that steps can be taken to intervene. Current EISs are only based on supervisor-intuition, which can be biased. Jennifer Helsby and colleagues built an improved data-driven EIS that uses factors such as previous adverse interactions, excessive tardiness, misuse of medical leave, or a low grade on an annual performance review [68]. Machine learning techniques were used on data from the Charlotte-Mecklenburg Police Department, and preliminary results indicate a 20% reduction in false positives and a 75% increase in true positives over traditional EISs. That is, their model resulted in a decrease of officers who were incorrectly predicted to be involved in an adverse public interaction and an increase in those correctly predicted to be involved in an adverse public interaction.

D. Social Impact: Equitable Access

1) Bringing Communication to Areas with Low Connectivity: A *community cellular network* is a mobile connectivity system built "by and for" the people in contrast to traditional mobile-network operators that are controlled by corporations [69]. This model can be a viable option for many communities, especially rural areas that disproportionately lack coverage because businesses are hesitant to fund costly infrastructure in order to provide service [69]. Shaddi Hasan and colleagues developed a system called CommunityCellularManager for operating community cellular networks at scale [69]. They deployed it in the Philippines in partnership with Globe, the largest mobile-network operators in the country, providing basic communication services to over 2,000 people in 15 communities.

2) Building Robotic Walking Suit for Patients with Spinal Cord Injuries: An estimated 282,000 people in the US have a spinal cord injury [70]. Spinal cord injuries can cause complete or incomplete tetraplegia or paraplegia, which refers to loss of sensory or motor control in all limbs or two limbs [70]. Exoskeletal-assisted walking devices are beginning clinical use to rehabilitate individuals with spinal cord injuries [71]. These exoskeletons are wearable robots that a human can, by shifting their weight, use to aid their walking [72]. A randomized clinical trial with 50 participants with a spinal cord injury showed that exoskeletal-assisted walking devices can be used effectively for mobility training [71].

E. Social Impact: Democratizing Technology

1) Designing Social Media for Change: 53% of Americans engaged in some form of political or social-minded activity on social media in 2017 [73]. Using social media as a design mechanism, Noreen Kamal and colleagues designed the online social network VivoSpace to encourage health behavior change among users [74], [75]. Participants that used VivoSpace experienced positive significant changes in their attitude toward physical activity, self-efficacy in eating healthy foods, and self-efficacy in performing physical activities. Additionally, this team abstracted the theoretical foundations of VivoSpace to explore the design of social media systems that aim to change behavior in any context, such as in organizing activist activities [75].

2) Tracking U.S. Immigration and Customs Enforcement Raids: U.S. Immigration and Customs Enforcement (ICE) commonly conduct "raids" where they arrest, or attempt to arrest, one or more non-citizens. The Immigrant Defense Project non-profit advocates for the rights of these individuals, attempting to illuminate inhumane ICE practices. Using summaries of ICE raids from the past five years, Immigrant Defense Project built ICEWatch, an interactive online tool that utilizes a geographic interface to inform communities and advocates about where raids have taken place and what tactics were used by ICE, such as surveillance, warrantless entry, ruse, collateral arrest, and use of force [76].

VIII. Conclusion

The long-term goal of this work is to design and evaluate communal goals interventions that lead to an increased perception that computing has communal affordances. Based upon previous research [1]–[3], [5], [6], [22], communal goals interventions appear to be a promising avenue to increase students' interest in computing and sense of belonging in computing. Given that people who identify as Black/African American, Hispanic/Latinx/Latin*, Asian, first-generation college students, and/or women are more likely to have communal goals, this may be advantageous for efforts to broaden participation in computing and promote belonging.

The examples provided in section VII of the social impact of computing will be used in the next phase of our research to develop interventions that can be integrated into computing courses. This will involve iteratively refining the examples and validating survey questions to assess their impact on students' perception of communal goal affordance, students' interest, and students' sense of belonging. We expect that students will vary in the examples that they find most compelling. Therefore, we will ensure that we are evaluating these interventions in collaboration with students at the college and pre-college level who are from groups underrepresented in computing. And when feasible, we will disaggregate the data to take into account multiple dimensions of students' identities. To increase the potential for scaling, we plan to ensure these communal goals interventions will demand little class time and require no additional costs to integrate into existing CS courses.

It is important to acknowledge that such interventions do not address issues of structural inequality [8], [9], a lack of encouragement [10], or bias in the form of discrimination or microaggresions [11]–[18]. However, communal goals interventions may lead to low-cost, impactful strategies that contribute to a suite of efforts to recruit and retain students from groups underrepresented in computing.

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