Understanding the Motivations of Final-year Computing Undergraduates for Considering Accessibility

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We investigate the degree to which undergraduate computing students in a United States university consider accessibility several years after instruction. Prior work has found that cultural and ethical norms become ingrained early in STEM professionals' careers; so, we focus on students approaching graduation and after an internship experience, who are just getting started in their career. In semi-structured interviews, a majority of these final-year computing students (14 of 16) indicated that they were not motivated to improve their skills in accessibility, attributing this to *not being required to consider accessibility in subsequent work or classes, not seeing accessibility as an essential skill in their profession*, and *challenges due to a learn-it-on-your-own approach* in computing. Participants suggested instructional methods and topics that they believed would have better prepared them for considering accessibility. A survey of 114 additional final-year students revealed similar themes, including that students did not personally view accessibility training as essential career preparation. Prior research has largely focused on evaluating short-term changes in students' knowledge after an educational intervention. Therefore, by focusing on students several years after an intervention, this work highlights lingering barriers for university programs in promoting accessibility among rising computing professionals.

CCS Concepts: • **Social and professional topics → Computing education**;

Additional Key Words and Phrases: Accessibility, computing, education, pedagogy

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1 INTRODUCTION

With over 1B people worldwide with a disability [66], educators are seeking to prepare and motivate future computing professionals to incorporate accessibility within their work. Prior computing education research on accessibility has largely focused on students' **short-term** response to educational interventions in **individual courses**, e.g., References [30, 34, 43]. However, it is unknown whether experiencing such an intervention has a **long-lasting** impact on students, especially as they approach graduation in the final year of their computing degree program.

Other prior research has examined what influences **motivated** computing professionals to consider accessibility in their work, e.g., References [32, 45, 47]. However, research on ethics emphasizes the importance of establishing cultural and professional norms **as early as possible** in an individual's career [23, 29]. From this perspective, to provide a baseline for future research on interventions for computing professionals, it is critical to understand the perspective of individuals at the beginning of their career.

Computing university students approaching graduation with some workplace experience (e.g., through an internship) are at a key moment in their professional development. They possess a **unique perspective** as both university students and as young computing professionals—thereby presenting an exciting opportunity for researchers to investigate what topics, resources, or instructional methods they believe would have shaped their awareness and motivation in regard to accessibility.

To understand the perspectives of undergraduate students in their final year, especially in regard to their awareness and motivation to consider accessibility, the following three research questions were investigated:

Q1. To what degree do computing university students consider accessibility—several years after receiving instruction on accessibility—as they approach graduation?

Q2. What do these students believe has motivated or dissuaded them from considering accessibility?

While university students are not experts in curricular design, it can be important for educators to consider the preferences and perspectives of their students. In a prior study, Crabb et al. investigated what educational resources university-level students in the U.K. perceived to be important to create accessible technologies [14]. This study focuses on the educational resources that final-year computing students in the U.S. express interest in, as their preferences may reveal their attitudes towards accessibility. All final year students in this study also had prior full-time paid internship experiences in the computing field. Thus, our third research question regards:

Q3. What educational resources or instructional methods do students wish they would have had to better prepare them to create accessible technologies, and what does this reveal about students' attitudes and motivations about accessibility?

We conducted semi-structured interviews with 16 university students in the final year of their computing degree programs who had work experience through an internship and who had received accessibility instruction in a required course several years prior. We asked about their attitudes, understanding, and motivations in regards to accessibility, as well as any factors they believed contributed to their perspective. We also asked participants to recommend educational topics, resources, and instructional methods that they believed could have been useful in shaping their perspective. To make sense of these recommendations with a larger population, we conducted a survey with an additional 114 university students who were in the final year of their computing degree program.

We found that the majority of interview participants did not consider accessibility in their work, nor did they indicate a motivation to increase their skills in computing accessibility. Participants attributed this perspective to *not being required to consider accessibility in work or classes, not seeing accessibility as an essential skill in their profession*, and *challenges they reported when using a learn-it-on-your-own approach* in the field of computing. Although participants in the survey showed their preferences towards several of the recommended educational resources or instructional methods that arose in the interviews, they also indicated they did not believe accessibility was an essential topic that should be included in their computing degree programs.

The primary contributions of this work are threefold:

- We present findings in regard to students' self-reported accessibility knowledge and motivation several years after receiving accessibility lectures in a required human-computer interaction (HCI) course during their degree program. Our results highlight the difficulty in achieving long-lasting effects from such an educational intervention and a need for additional longitudinal research.
- These final-year computing-degree students also had internship experiences in the computing field, and from their experiences, they identified factors that limited their interest in and motivation to consider accessibility. For instance, participants indicated that they were discouraged by the lack of emphasis on accessibility requirements in their work and educational experiences. These factors suggest possible avenues for future interventions (in both educational and workplace settings) to motivate early-career computing professionals.
- We found that the participants in our interviews suggested a wide variety of accessibility topics, educational resources, and instructional methods that they believed would have been influential in shaping their views on accessibility. A subsequent survey with a larger number of final-year computing-degree students enabled us to gather judgments from a larger population, revealing students' perspectives on accessibility as it relates to their education and career. The findings from this survey may be of interest to accessibility education researchers who may consider the opinions of these students as inspiration for further research.

2 BACKGROUND AND RELATED WORK

Computing education researchers have identified various motivations for why additional training in the area of computing accessibility is needed among computing students. In addition to the 1B people worldwide with a disability [66], accessible technologies are also used by individuals with temporary and situational impairments, e.g., 8.6M people in the U.S. with sports-related injuries in 2011–2014 [51]. Furthermore, technologies originally motivated by accessibility applications (e.g., audiobooks [3], autocomplete [9], video captions [21], or voice-enabled devices [9]) have often found widespread use, beyond the original intended audience.

The need for accessibility-aware computing professionals is also driven by regulations: In the U.S. legal context, this includes the 21st Century Communications and Video Accessibility Act [18] and the Americans with Disabilities Act [60]. Amid this legislative landscape, there has also been a recent surge in litigation: Website accessibility–related lawsuits more than doubled in 2018 (2,250) in comparison to 2017 (814) [46].

Today, companies such as Google, Facebook, Microsoft, PayPal, and WordPress have formed dedicated accessibility teams to focus on the development of new technologies [7]. Several of these companies participate in initiatives (e.g., TeachAccess [56]), with the goal of encouraging universities to include more accessibility instruction in the computing curricula. In response to the need for accessibility-aware computing professionals, the ACM Joint Task Force Computing Curricula (ACC) included accessibility as a recommendation within computing curricula [2], followed by the

Accreditation Board for Engineering (ABET) in 2018, requiring software engineering curriculums to teach Engineering Design constraints with optional topics such as accessibility and ergonomics [1]. New textbooks on computer accessibility have been published, e.g., in 2019 [19]. Beyond the computing field, there are also examples of an increasing focus on accessibility, e.g., national standards in Russia have made an accessibility course mandatory for transportation-related university degree programs [19].

With this motivation outlined above, there has been an interest among computing education researchers to understand the current state of accessibility education in computing degree programs and the efficacy of various education interventions.

2.1 Evaluation of Accessibility Education Interventions

Several prior research studies have found that computing students often do not consider accessibility when they are designing or creating technologies. In a qualitative study of 236 software project reports written by teams of computing students in a Human-Computer Interaction (HCI) course, reports were found to explicitly exclude individuals with disabilities [35], despite lecture instruction on the topic of accessibility. In a study that focused on a Software Engineering course, researchers observed similar findings: Student teams did not apply accessibility knowledge to their course projects, even though they had been exposed to relevant content and had received feedback about this issue from classmates [34]. In general, researchers have found a trend whereby computing students consider accessibility or usability as an "*afterthought*" [16, 41, 44]. To address this, Buckley et al. investigated a user-centered approach for gathering project requirements to dissuade students from thinking in terms of "*coding a solution*" and instead develop customer requirements and design options [10]. In Buckley et al.'s study, students were motivated by the requirements of the course and the desire to meet end-users' expectations of the system [10]. However, no additional study was reported that assessed whether students' motivation was sustained after completing the course.

These findings are in contrast to evaluations of accessibility educational interventions highlighting the positive outcomes of instruction. For instance, Poor et al. found that shortly after students completed an HCI course with lecture instruction, they indicated a heightened interest in "*broadening the range of technology users*" [43]. Palan et al. found an increase in students' awareness and knowledge following lectures on accessibility [40]. Interactions with individuals with a disability have also been found to impact students' short-term prosocial sympathetic attitudes [35] and general knowledge of accessibility [30]. Incorporating discussion-based instruction has also been found to be effective in increasing students' short-term knowledge [12].

Despite this prior work, there is a gap in the computing education literature: The measurements of the efficacy of accessibility educational interventions among students are typically conducted shortly afterward. For instance, in some studies, the evaluation is conducted immediately after a one-time experience [12] or at the conclusion of a course (at the end of an academic semester or term), e.g., References [30, 35]. While this prior empirical work has provided insight into students' short-term attitude changes towards usability and accessibility, **it remains unknown whether accessibility instruction contributes to a long-term commitment to create accessible technologies.**

2.2 Social and Extrinsic Motivations

Since the 1930s, psychologists have developed various theories of motivation and applied those theories to education. We consider that students' motivation to learn accessibility may be based on different intrinsic or extrinsic factors rooted in personal perceptions as future professionals, as outlined in Self-Determination Theory [15]. In particular, although an altruistic desire to "do the right thing" may contribute to intrinsic motivation, it is yet unclear what extrinsic motivations (as driven by the tech industry profession, for example) may move students to become active pro-accessibility technology advocates [50].

In computing education, substantial research has examined the impact of social and extrinsic factors on students' interest in non-accessibility-related computing topics. McCarthy et al. found that computing students were motivated to apply and expand their knowledge if there was a strong peer or social influence [36]. Specifically, students were motivated to continue their learning if they "*wanted to belong*" to a group that was perceived to have already attained those skills, because they feared appearing ignorant and because they were attracted to "*hip new concepts*" that would contribute to their knowledge [36]. Similar research found that undergraduate computing students were motivated to learn programming topics if the content was associated with their career goals [26].

Research in industry settings has also revealed factors that influence **computing professionals** to consider accessibility. Computing professionals have been found to maintain a greater commitment to accessibility if there is an inclusive company culture and if top-level management emphasizes the need for accessible technologies [8, 22]. Microsoft, for instance, recently began an initiative to modify its culture and processes with the goal of creating inclusive solutions [67]. This is in contrast to measures of inclusion within university contexts, where most computing degree programs have been found to not be fully inclusive of underrepresented groups, including women and minorities [4, 65]. Furthermore, university professors have recognized that a lack of top-level support is a major barrier in teaching accessibility [53]. It is possible that if computing-degree students experience a non-inclusive educational environment, or one with little emphasis on accessibility from administration, they may be less motivated to create accessible technologies.

2.2.1 A Learn-it-on-your-own Approach in Computing. Given the rapidly changing nature of computing technologies, most students will need to acquire at least some knowledge through self-directed learning, outside of formal classroom settings [22]. Prior research has identified the need for students and computing professionals to "upskill" throughout their careers [69]. The most common source of training used by professionals is the Internet [17]. Social and extrinsic influencers have been found to impact how computing students learn new information: Students tend toward learning behaviors that are introverted [13], choosing to rely on online resources and factual technical information rather than from people [11].

There may be value in students practicing self-directed learning, since research shows that computing professionals consider this learn-it-on-your-own ability to be very important for their prospective employees [69]. However, when it comes to learning about accessibility, a lack of mentorship may increase challenges and reduce students' motivation. Current methods used by computing students to learn about accessibility include various self-directed methods such as books, research, and software applications that simulate accessibility issues [14]. However, prior work identified limitations in the efficacy of such methods, which may not successfully convey knowledge on how to maximize accessibility [14].

3 OVERVIEW OF OUR APPROACH

To investigate whether there are long-term effects from teaching accessibility topics during a required course in a computing degree program (and what factors may influence students' views on the importance of accessibility), we undertook a three-phase study over three years:

1. We included one week of accessibility lectures during a required Human-Computer Interaction (HCI) course that is near the midpoint of students' bachelor degree program. This intervention was deployed at Rochester Institute of Technology, a U.S. university with multiple computing degree programs.

2. More than two years later, we interviewed 16 students who had previously been enrolled in courses that received this accessibility-lectures intervention. These students were in the final-year of their degree program, and all had completed an internship in the computing field. We conducted a qualitative analysis of the interview transcripts to identify major themes and to gather a set of recommendations from these students about educational topics, resources, and instructional methods that they believed would have further promoted their motivation to consider accessibility in their career.
3. To understand students' preferences in regard to a diverse set of educational recommendations that emerged from the interviews, we conducted a survey of 114 additional final-year computing degree students (who had not necessarily been enrolled in the specific HCI course two years prior). Participants evaluated various topics, resources, and instructional methods, as well as indicated how important they believed accessibility skills and knowledge were to their future career. These findings provide further insight into the perspective of these students in regard to this topic.

4 PHASE 1: INTERVENTION DURING A COURSE

Although Waller et al. [62] successfully incorporated accessibility throughout multiple courses in the curriculum of a degree program in the U.K., such efforts had less traction in the U.S, as curriculum guidelines do not require instruction on accessibility [1, 44], and there are limited computing instructors that teach accessibility [53]. Incorporating accessibility throughout a curriculum in the U.S. therefore presents multiple practical challenges that may not be easily reproducible at other universities. In selecting an education intervention to examine in our work, we considered prior work that found that professors in the U.S. typically rely on lectures as a method for conveying accessibility content [53]. The use of lectures as a method for learning about accessibility is also prevalent in the U.K. [14].

As a baseline to evaluate the effectiveness of accessibility instruction, we elected to evaluate one week of lectures at Rochester Institute of Technology. This intervention was introduced within a single, required course for two major computing degree programs. As for the content, we used the same teaching materials that previous researchers had found to be effective in the short-term [35, 40]. The following topics were covered:

- ***Prevalence of disability:*** Statistics on the prevalence of disability, including diversity (e.g., difference between individuals with "low vision" who have glaucoma vs. cataracts)
- ***Physiology and senses:*** An overview of the sensory systems and the sensitivities of each (e.g., tactile system is sensitive to both pressure and heat)
- ***Accessible technologies:*** Examples of technologies used by individuals with a disability, such as screen readers, captioning, and so on. How accessible technologies benefit a broad range of users.
- ***Web technologies*:** Information about how to author accessible web pages (e.g., alt tags) and how to build accessible sites using HTML, CSS, and JavaScript. Online resources and toolkits are also provided.
- ***Simulations and automated testing resources*:** Simulations of varying disabilities (e.g., dyslexia, color blindness, glaucoma) and automated testing resources (e.g., WAVE [64], screen readers, and color invert settings) with a discussion of the limitations of such simulations and the need for actual user testing.
- ***Guidelines and regulations:*** Discussion of guidelines and regulations, e.g., the Americans with Disabilities Act and the Web Content Accessibility Guidelines.

The lectures were integrated within a required HCI course for undergraduate Software Engineering (SE) and Information Technology (IT) degree programs. Courses were held in separate sections for SE and IT students housed by their respective departments, but the one week of lecture content on accessibility topics (outlined above) was the same in both of these courses. All students took this course during their second or third year of their degrees. At Rochester Institute of Technology, students typically require four or five years to complete their computing degree program, and there is a requirement that students do at least one internship (full-time paid work in the computing field for a period of at least 12 weeks), prior to the final year of the program. Other than this HCI course, students have limited exposure to accessibility content. Throughout other courses in their degree programs, students focus equally on topics related to back-end (networking, algorithm design, etc.) and front-end (web design, usability, etc.) development. The SE curriculum adheres to the required Accreditation Board for Engineering and Technology (ABET) standards, including some coverage of computing ethics.

5 PHASE 2: SEMI-STRUCTURED INTERVIEWS

As part of the longitudinal evaluation of the addition of accessibility lectures to those courses, we conducted interviews with a subset of students who had taken the course described above. At the time of the interview, these students were in the final year of their degree program. Participants were recruited through emails and flyers. The specific inclusion criteria were: students in a Software Engineering or Information Sciences & Technology degree program, with prior internship experience (lasting three to five months), who were in the final year of their degree program, and who had been enrolled in the aforementioned HCI course with accessibility instruction. This study design allowed us to investigate how their internship experiences and the time that elapsed since the course impacted their impressions on learning the material.

These semi-structured interviews were conducted with 16 participants from October 2018 to February 2019. Three out of sixteen participants were female, consistent with the gender ratio of the university. The interview consisted of questions about students' background knowledge on computer accessibility, their exposure to diverse end users, and experiences learning about accessibility. For example, we asked participants, "*Can you recall a time when you saw someone using an accessibility feature or technology that you were not exposed to?*," "*When was the first time that you considered creating software for individuals with different abilities from your own?, What motivated you to consider the solution?*," "*What type of information would you need to feel prepared to create accessible technologies?*" Participants were also asked to describe courses, resources, or activities that furthered their knowledge in accessibility and usability. At the conclusion of the study, participants were compensated with $20 cash. All interview procedures were approved by the university's Institutional Review Board. The 45-minute interviews were audio-recorded and later transcribed for analysis.

5.1 Analysis and Findings

Following the Grounded Theory methods of Strauss and Corbin [54], three researchers conducted *in vivo* open, axial (via constant comparison method), and selective coding to qualitatively analyze the interview transcriptions, their memos, and eventually existing literature. Interview transcripts were reviewed in two to three intervals, providing the researchers multiple opportunities to discuss their labels, memos, and assumptions. Sample participant quotes, initial open codes, and axial codes are summarized in Table 1 below.

In the next two sections, we describe the findings of the interview study, focusing on the factors that dissuaded and motivated students when considering accessibility.

5.1.1 Detractors from Learning Accessibility. In this section, we describe how a *learn-it-on-your-own approach* in computing—bolstered by a perception that accessibility is ***not important for a tech-focused career*** and ***not required for computing degrees***—**dissuaded** 14 out of 16 students

Table 1. Sample Axial Codes Informed by Participants' Quotes

Sample Participant Quote	Researcher Interpretations	Combined Category Definition	Final Category
Well, I'm going to do the requirements for the class project and I'm not going to try to go super above and beyond. Like, it's not going to matter. Just as long as you get the A, a 96 or a 99, it doesn't matter either way.- P7	Not a requirement	A motivation to create accessible technologies in course projects only if it is required	**Not required to consider accessibility**
[Participant asked, "What motivated you to consider the solution?"] *It was my job.*- P14	Motivation- Job	A drive to create accessible technologies due to a job requirement	**Not required to consider accessibility**
That's not really in our cycle... The design of what it looks like isn't in our cycle... whether it's a waterfall or spiral... - P11	Software process does not consider accessibility	No accessibility considerations within software engineering development cycles	**Not required to consider accessibility**
I mean, I would say if it was a real-world project, then yes. I would be more motivated to make sure that it is accessible. - P8	Motivation- not real-world project	A lack of motivation to integrate accessibility if the project will not be used by individuals with a disability	**Not required to consider accessibility**
While they are minor implementations of accessibility within the backend, it tends to be a front-end focused discipline. At least that is my view. - P5	Minor implementation of accessibility in backend	Accessibility considerations would mainly be relevant to a career in front-end development	**Not important for career preparation**
Seeing that a lot of deaf people have potential but are limited by their English. Because of that, they are not given a shot, even though it has nothing to do with their English. This app is a way to help them to move up somehow. - P8	Personal experience-Observation	A desire to create accessible technologies due to observed experiences with individuals with disabilities	**Strong interaction with individuals with disability**
I would probably just Google it and go online to see what other people are saying or what they are doing to address it. - P7	Self-taught; Google	Rationale for using online resources due to them being more updated or more accurate	**Learn-it-on-your-own approach**
There are actually a lot of great online resources that have the hex codes for color combinations that are more usable for people who are color blind. That's what I primarily rely on. I just try to inform myself with online resources. - P9	Self-taught; online resources	Choosing to learn independently through online resources due to convenience or additional features	**Learn-it-on-your-own approach**
I think kind of the culture is that professors are very hands-off for the most part. That is how I've always seen it. Even in some experiences that I've had, it's been like, "well you can look for it on your own, I don't have the time, I don't have to tell you the solution." - P3	Professor hands-off	Perception that professors or managers are not interested in helping	**Learn-it-on-your-own approach**

from incorporating accessibility in subsequent technical projects and implementations. Only 2 out of 16 participants were self-motivated to continue improving their skills in accessibility after taking the HCI course with the accessibility-lecture intervention, as will be discussed in Section 5.1.2.

Challenges arising from the learn-it-on-your-own approach in computing: Participants described professors and managers as "*hands-off*" or whose primary role was to give requirements, and these requirements generally did not relate to accessibility. P3 explained their hesitance in approaching professors to learn more about accessibility topics due to the trend of using the *learn-it-on-your-own approach* in computing:

> *I think kind of the culture is that professors are very hands-off for the most part. That is how I've always seen it. Even in some experiences that I've had, it's been like, "well you can look for it on your own, I don't have the time, I don't have to tell you the solution." Like the solution may be somewhere that you just have not looked.*

Students relied on online resources to learn specific content required of them and expressed feeling discomfort or embarrassment in asking professors for help, such as P11:

> *I try to learn it on my [own] first … I think most of the time, I am embarrassed that I don't know it and so I try to get as much information as I can before asking professors. But whereas, with my colleagues, like my student peers, I would probably just ask them…I would Google it, and Google it, and Google it… and then maybe ask a close peer and then a professor.*

In work environments, students also relied on online resources to complete their tasks. When P16 was asked where they learned how to implement required accessibility features for their work deliverables, they mentioned the use of online sources due to their manager's unavailability:

> *Our mentor wasn't available to help us all that much, but they were like, "you have to have this done by a certain date" so, we spent a lot of time on Google.*

Participants also expressed discomfort in interacting with individuals who used accessible technologies. Students had little knowledge of what people with disabilities actually needed and how to communicate with them. This information could not be easily found in online resources, for example. P15 shared that they were interested in the communication between students who were deaf and hearing, but that doing a project on the topic would be difficult because of the unknown etiquette:

> *I don't really know how to label how deaf a person is. What do I talk to them about? How would I communicate with them?… So, kind of on that level. If I need to take out my phone to write a message to them, or if I need to mouth words, if they can read lips really well, then sometimes things like that we can work out… I guess I would want to know how comfortable the deaf or hard of hearing person would feel in that case.*

The assumption that accessibility should be learned on their own was further reinforced by the lack of accessibility requirements throughout the curriculum, as will be discussed next.

Not required to consider accessibility: Participants also held the self-expectation that accessibility should be learned on their own due to a lack of emphasis on person-centered topics (accessibility, usability, etc.) within educational and workplace settings. Participants indicated that they only considered accessibility when it was required of them, and they noted that there was no explicit mention of accessibility within any software development process (e.g., waterfall, agile), whether in coursework or in internships. Instead, there was a focus on meeting functional requirements and satisfying the needs of stakeholders. For instance, P7 indicated that they were not driven to apply accessibility in course projects when it was not required:

> *Well, I'm going to do the requirements for the class project and I'm not going to try to go super above and beyond. Like, it's not going to matter. Just as long as you get the A, a 96 or a 99, it doesn't matter either way.*

Similarly, in workplace environments, students did not create accessible technologies unless it was explicitly required. Seven out of fifteen students considered accessibility during their internship, and all of them did so because it was required of them. For example, when P14 was asked what motivated them to consider accessibility during their internship, they replied, "*It was my job,*" and that they had to follow their manager's instructions. P16 also explained how they created an accessible website during their internship because:

> *We had to create a website with 508 compliance*[1] *in mind which is like dealing with screen reader technology.*

Outside of compliance, participants mentioned that they did not tend to think about accessibility, nor did they see it as a high priority issue. P1 described how accessibility was not fundamental for the software development process:

> *Probably because we just don't really think of [accessibility]. When we are going to create those applications, it's easy to [have] tunnel vision with what you know. Like, I don't have disabilities, so I don't think about it. I feel like that is the main issue, that a lot of people don't think about the situation of others.*

In fact, P3 self-disclosed as having a disability and shared a similar view:

> *Well I know because I am color blind, like red green deficient, I do look out for those things only because it helps me also.*

Overall, the consideration of accessibility was encouraged in coursework and internship experiences. Students also did not consider accessibility-related skills as necessary for their career prospects, as we show next.

Not seeing it as important for career preparation: The third major factor that dissuaded students from learning about accessibility was the impression that accessibility was not an essential skill for a career in computing. Twelve of the sixteen participants expressed that accessibility was necessary in select "*front-end*" development roles or domains only, e.g., healthcare, government, or access services. When P5 was asked whether they thought that all their peers would be applying accessibility in their careers, they replied:

> *Probably not, only because there are a lot of people who have a strong focus on backend implementation. While there are minor implementations of accessibility within the backend, it tends to be a front-end focused discipline. At least that is my view.*

Participants also explained that accessibility would not be a priority in startup companies or industry sectors where they anticipated few users with a disability. When P3 was asked whether they foresaw themselves applying accessibility in their future career, they explained:

> *I would say yes, but only when it is specifically asked for or necessary. In terms of cost of a project, when it comes to time and how it relates to money, the core requirements are usually going to be to get the project done first, and secondary would always be the accessibility to it. If it was designed specifically for a type of user, then it would be designed to be dedicated for that specific user.*

Students who had participated in internships—even if they were required to include accessibility—conveyed similar impressions. Participants noticed that their co-workers did not have skills in accessibility, nor did they appear to place a high value in implementing it. P5 described that their co-workers did not know how to use screen readers:

> *I had to Google it because all the other coworkers on my team were like, "I don't know, we just Google it every time we need to do it too."*

[1]Section 508 pertains to the United States Rehabilitation Act of 1973, which requires Federal agencies to procure and develop accessible technologies when they are available.

Overall, participants observed that accessibility was not a necessary skill to complete many on-the-job tasks.

5.1.2 Motivators for Learning Computer Accessibility. Although most of the participants did not indicate motivation to learn about or apply accessibility concepts, 2 out of the 16 participants (*P8, P9*) mentioned experiences that motivated them to do so. Both students were motivated to continue considering accessibility due to ***strong interactions with individuals with a disability*** and ***mentorship in accessibility.***

Strong Interactions with Individuals with a Disability: Both participants were motivated by their in-depth interactions with individuals with a disability. Through observation and interactions with deaf individuals, P8 learned that a limited fluency in English contributed to some having fewer professional opportunities. P8 aimed to design an application that could help deaf individuals improve their English:

> *Seeing that a lot of deaf people have potential but are limited by their English. Because of that, they are not given a shot, even though it has nothing to do with English. This app is a way to help them to move up somehow.*

Similarly, P9 grew up around individuals with disabilities and was driven to create accessible technologies:

> *I grew up in an environment that had people from many different backgrounds and disabilities ... [T]hinking about them now, makes me want to make sure that I can account for them.*

Mentorship in Accessibility: The other major motivator for both participants was having mentorship in accessibility. P8 completed a Research Experiences for Undergraduates (REU) summer research program sponsored by the U.S. National Science Foundation (NSF) where accessibility was required. During the program, multiple computing professionals discussed the role of accessibility in their careers. The program also matched them with research mentor(s) who guided them through the process. At the conclusion of the program, P8 was provided additional support from the college to continue implementing the project, including support for pairing with other students. This additional support from the university reinforced the importance of accessibility within the computing domain. P9 was required to complete an independent-study course when they transferred into the major. They were matched with a professor who had experience in accessibility and who highlighted the role of accessibility within software development. This experience made P9 more interested in the experiences of individuals with low vision after the course:

> *I have actually tracked a few academic papers but those primarily talk about interactive Braille pad, which is still not perfected [as] far as I understood from [the] user testing... I have kept an eye on it though. I hope that it gets produced*

These findings suggest that practices that personally engage students, and run counter to the *learn-it-on-your-own* education approach, may leave a lasting impression on students (e.g., one-on-one assistance from instructors). In addition, these results highlight the role of extrinsic and social motivations in students' decision to further their skillset in accessibility (building relationships with established professionals who apply accessibility, university encouraging accessibility, etc.).

5.2 Student Preferences towards Accessibility Computing Education

During the interviews, we also asked students to reflect on their educational experiences, resources, or training on particular topics that might have contributed toward increasing their

Table 2. The 21 Recommendations on Accessibility Education Assembled from 16 Interview Transcripts

Category	Recommendation from Participants in Our Study	Related Work on this Topic
Topics for Learning Accessibility	Gathering software requirements related to accessibility	[34]
	Disability etiquette	[34]
	Incorporating accessibility in the software development cycle	[44]
	Deaf culture	[33]
	Accessibility devices	[40]
	Authoring website content	[25, 49, 63, 68]
	Testing software for accessibility	[44]
	Communication preferences of different individuals with a disability	[34]
Resources	Examples of accessible technologies or past projects	[31]
	APIs or programming frameworks with accessibility features	[57]
	Books or websites on accessibility	[24, 39, 44, 61]
	List of professors that specialize in accessibility	-
	Guest speakers with a disability	[62]
	Inclusive design and assistive technology as part of the HCI curriculum	[42, 48, 63, 68]
	Online courses or tutorials	[56]
	Organizations that support individuals with a disability	[28]
Course Structure	Add accessibility requirements within my existing coursework and classes	[38, 43, 44, 62]
	Add a required accessibility course for my degree	[19, 44]
	Create an elective course that counts towards my major	[6, 44, 52]
	Ability to take courses outside the college that count towards my major	[48]

motivation to apply and learn more about accessibility. Students provided a total of 21 recommendations: 8 ***topics for teaching accessibility,*** 9 ***resources*** for learning accessibility, and 4 ways to ***structure*** accessibility within the curriculum. These 21 recommendations also aligned with prior studies on accessibility education, as outlined in Table 2.

6 PHASE 3: SURVEYS

The 16 interview participants mentioned a variety of ***topics, resources,*** *and* ***course structures*** that they believed would have engaged them in topics of accessibility. Of course, students are not experts in designing university curricula, but educational researchers may find it useful to understand the opinions and perspectives of students about various topics or educational interventions. While our interview methodology in Phase 2 had enabled us to collect these various suggestions from a small number of participants, we believed that these findings may be more useful for the research community if we could reach out to a larger number of students who could indicate their interest in these suggestions. To investigate this, we conducted a survey of 114 additional final-year computing students. The 16 interview participants did not participate in the survey.

6.1 Methodology

Survey responses were collected from 114 undergraduate students during March and April 2019 at Rochester Institute of Technology at which the prior phases of the study had occurred. For participation, students were required to be within one year of completing their degrees. The survey participants had not necessarily been enrolled in the HCI course two years prior, but may have had other relevant experiences or other forms of instruction (e.g., online tutorials, external accessibility training), which we could not control. Participants were recruited through email and tabling events on the university campus, and participants were compensated with $10 for completing a 10-minute survey. During the tabling events, multiple laptops were made available for students to complete the survey in-person.

6.1.1 Analysis of Surveys. During six pilot studies, we found that participants ranked and scored items differently. For instance, participants would assign high scores for multiple items but only include two items within their top ranked choices. As such, our final analysis triangulates Likert-scale, ranked, and open-ended questions:

- **Likert-scale items:** We collected Likert-scale responses (range: 1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree) of agreement with the statement, "I believe this [Topic/Resource/Course structure] would be important in preparing me to create accessible technologies in my career." To minimize ordering effects, all suggestion items were randomized per participant. In analyzing these responses, we conducted three Kruskal-Wallis H Tests for each category (Topic, Resource, Course Structure). A follow-up pairwise Dunn's post hoc analysis, with a Bonferroni correction, was also conducted to isolate the items that were significantly different from one another.
- **Ranked questions:** After students assigned Likert-scale agreement responses to each item, they were asked to indicate their top three choices: "Please indicate the top three items above that you believe would best prepare you in creating accessible technologies in your career." A weighted average was calculated to identify the overall top choices among the survey respondents. The lowest ranking was assigned a weight of 1 and the highest a weight of 3. As a result, the range of possible weighted average scores was a minimum of 0 and a maximum of 3.
- **Open-ended responses:** Two researchers independently coded the open-ended responses to "Please explain why you chose the three items above" through descriptive annotations [40]. The findings were discussed and compared by the researchers to further understand students' preferences.

6.2 Results

A total of 114 students (96 male, 16 female, 2 non-binary) completed the survey. The majority of survey participants (78.9%, n = 90/114) indicated that in the past, they had an opportunity to interact with someone with a disability. The questionnaire did not ask about the strength or duration of the relationship/interaction. Of the respondents, 75 were majoring in Computer Science, 19 in Software Engineering, and 20 in Information Science & Technology. It is important to note that the backgrounds of Computer Science and Software Engineering students overlap, as 3 out of 7 core first-year courses are the same. Furthermore, the Information Science and Technology degree shares instruction on overlapping concepts to the Computer Science and Software Engineering curriculum, such as courses in object-oriented programming, web and mobile computing, and data modeling.

In an analysis of students' Likert-scale preferences, we found that all categories resulted in significant differences between at least one pair of items (Table 3). In the next subsections, we analyze students' preferences in detail.

6.2.1 Topics for Teaching Accessibility. Of the eight student suggestions for topics for teaching accessibility, the top three items were: *testing software for accessibility* ($\bar{x}$ = 1.377), *gathering*

Table 3. Kruskal-Wallis H Test Found All Categories Contained a Significant Difference between at Least Two Items ($\alpha = 0.05$)

Category	Test Statistic	p-value
Topic	$\chi^2(7) = 76.004$	p<0.001*
Resources	$\chi^2(8) = 197.740$	p<0.001*
Course Structure	$\chi^2(3) = 62.692$	p<0.001*

Table 4. Dunn's Test Indicated That the Top Four Resources Preferences Were Significantly Different from Most Lower Ranked Items ($\alpha = 0.05$)

	APIs	Examples	Guidelines	Evaluation Tools	Professors	Tutorials	Books	Speakers	Local Orgs.
APIs		p=1	p=1	p=0.208	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*
Examples			p=1	p=1	p<0.001*	p=0.516	p<0.001*	p<0.001*	p<0.001*
Guidelines				p=1	p<0.001*	p=0.163	p<0.001*	p<0.001*	p<0.001*

Tutorials were not rated as significantly different from examples and guidelines on accessibility.

software requirements related to accessibility ($\bar{x} = 1.298$), and *incorporating accessibility in the software development life cycle* ($\bar{x} = 0.833$). A Dunn's test of the Likert-scale responses indicated that there were significant differences in the satisfaction scores between *testing software for accessibility* and every Topic category except *gathering software requirements related to accessibility* ($\alpha = 0.05$). These results corroborate the interview findings, whereby students mentioned a lack of prioritization in identifying and incorporating accessibility requirements into the development process, as well as a lack of detailed guidance on what is necessary to accomplish this.

In the open-ended question, students explained that they desired "*practical learning*" tools that could be directly applied to software. Students were not as interested in reasons behind accessibility practices, instead wanting vetted tools that could be used in development. One survey participant explained:

> *As important as understanding disability background and culture is, Software Engineers need to rely on development tools to create technology that the disabled can use. It is easier to follow specifications than to understand the reasons behind the inclusion of said specifications.*

Students also explained that lower ranked Topics would be "*unnecessary and unproductive,*" because they (1) can be "*learned outside of the classroom*" and (2) would not produce more tangible results, because "*merely examining these topics without applying them to software requirements and testing would not result in better technologies for those with disabilities.*"

6.2.2 Resources for Learning about Accessibility. The top three preferred resources among students were: *APIs or programming frameworks with accessibility features* ($\bar{x} = 1.535$), *examples of accessible technologies or past projects* ($\bar{x} = 1.246$), and *accessibility guidelines and regulations* ($\bar{x} = 0.877$). The Likert scale responses supported the ranked findings, whereby there were significant differences between the three top rated choices and the five lower rated choices. As seen in Table 4, there was no significant difference between the fourth-place option, *evaluation tools*, and the top three ranked items.

The top choices were consistent with the interview findings: Students preferred resources that could support them if they had to learn content on their own. Students preferred quick solutions,

Table 5. Dunn's Test Indicated That the Top Course Structure Preference (an Elective on Accessibility) Was Significantly Different than All Other Options ($\alpha = 0.05$)

	Elective	Existing Coursework	External Course	Major
Elective		p = 0.001*	p = 0.006*	p<0.001*
Existing Coursework			p = 1	p<0.001*
External Course				p<0.001*

The second highest-ranked choices (existing coursework and an external course) were not significantly different.

such as "*built-in accessibility features*" in APIs or programming languages, "*online simulators,*" guidelines, and automated evaluation tools that would diminish the need of having "*someone [with a disability] there to evaluate it for you.*"

Some participants also viewed the lower-ranked, more human-centric, items as backup or secondary resources. They did note these resources were "*good and important to have*" but believed that *"students [would] not use them or not be as interested in them*, preferring to *learn by example and documentation, as well as having online validators."*

6.2.3 Course Structure. For the Course Structure category, the top three items were: *create an elective course on accessibility that counts towards my degree* ($\bar{x} = 2.266$), *add accessibility requirements within existing coursework and classes* ($\bar{x} = 1.706$), and *ability to take courses outside the college that will count towards my degree* ($\bar{x} = 1.422$). In the Likert-scale responses, the option for an elective course on accessibility was significantly different from all other options, as seen in Table 5 ($\alpha = 0.05$).

In the open-ended questions, participants explained that they would want to take a class on accessibility only if they were "*truly interested*" in learning more and did not want to be "*forced to learn more about it.*" Participants indicated that accessibility was "*irrelevant to their majors*" and that an elective would allow their peers to learn more if they wanted to. One participant explained:

> *Requirements get pretty iffy, personally I don't like required courses when they are absolutely irrelevant to my degree/major. However, if someone was passionate about creating accessible technologies, and it was within the scope of the field they want to work in, [then] they would "want" to take these courses.*

Another participant mentioned:

> *As important as accessibility is, not everyone is planning to work in jobs or fields that work with accessibility technologies, so I would err on the side of making the course materials an elective rather than required.*

These results are accordant with the interviews: Participants were not motivated to learn about accessibility, because they did not see accessibility as an essential skill in all computing careers.

7 DISCUSSION

In this section, we describe the results for each of our research questions (R1, R2, and R3) in the context of prior research literature.

> **R1:** ***To what degree do computing university students consider accessibility—several years after receiving instruction on accessibility, as they approach graduation?***

In interviews, we found that the degree to which students considered accessibility, several years after instruction, was low: students did not tend to think about accessibility and the only **temporary** change to this phenomenon was when accessibility was required. When accessibility was not required, students reported choosing to create technologies for individuals with similar characteristics to themselves.

There were two exception cases, however: One student worked on a project targeted at individuals who were deaf or hard of hearing, and the second student completed a project considering individuals with low vision. Although their projects were initially required for their internship or degree, both students continued their learning by collaborating with other students or researching articles online.

Our findings are consistent with prior work reporting a prevalence of computing students considering accessibility as an afterthought [10, 16, 41, 44], in addition to short-term studies where students did not apply accessibility knowledge when it was not required [34, 35]. Whereas surveys of university professors indicate that lectures are predominantly used for accessibility instruction [53], our findings suggest that these methods may not be effective at motivating students to consider accessibility **beyond satisfying compliance standards when required to do so**. Additional research is needed to ascertain how other types of educational interventions can build upon the findings from this study, such as how integrating accessibility more substantially throughout a computing degree curriculum could shift expectations among future members of the computing profession as to the need for considering accessibility in their work.

> **R2:** ***What do these students believe motivated or dissuaded them from considering accessibility?***

There were three main "detractor" factors that prevented 14 out of the 16 interview participants from considering accessibility: *challenges from the learn-it-on-your-own approach in computing, not being required to consider accessibility,* and *not seeing it as important for career preparation.* **Students did not indicate that internships on accessibility nor short-term experiences with individuals with a disability motivated them to broaden their skillset in accessibility.**

Students described an expectation that computing students and professionals needed to learn things on their own; many perceived that the primary role of professors (in an educational context) or managers (in a work context) was to give requirements. Students expressed discomfort in approaching others for help, especially professors and individuals with disabilities. Without mentorship, students sought accessibility-related information through online resources that lacked the human perspective. The use of online resources is in line with prior work on computing students' and professors' tendency towards introverted learning strategies [11, 13] and the use of Internet sources [17, 37]. Prior research indicates that relying solely on online accessibility resources can be problematic, since guidelines may provide limited insights [27, 58] and automated evaluation tools may be unreliable [59].

Students were also dissuaded from considering accessibility due to a lack of requirements and emphasis on the topic. Such discouragement has also been found in prior surveys of computing instructors, who report a lack of emphasis on accessibility in U.S. curriculums and limited support by administration [53]. Instead of focusing on user needs, computing topics are more likely to emphasize functional requirements to optimize the system [10]. The participants of our study also focused on functional requirements, prioritizing what was in the rubric without allocating additional time for accessibility features. This approach continued into internships, where participants indicated that they did not apply accessibility unless it was explicitly required.

The final major factor that dissuaded students from considering accessibility was that they did not see it as an important skill in preparing them for their careers. The participants of our study saw accessibility as a specialization that would be used in select computing sectors. Even when accessibility was required in internships, students described their co-workers placing a low value in accessibility-related tasks. Students' prioritization for learning job-related skills has also been identified in different university settings [26, 36]. Theories on engineering students' motivation further support these findings, emphasizing the importance of targeted learning for perceived career value [55].

The importance of personally engaging students in an environment where accessibility was embraced, was underscored by the experiences of the two participants who were exception cases in our study. Both students had experiences that ran counter to a learn-it-on-your-own approach: They reported having mentors with knowledge of accessibility and in-depth interactions with individuals with disabilities. Although both students were required to apply accessibility for their work, they continued to boost their knowledge in accessibility after project requirements were met. We note that their specific experiences may have facilitated a sufficient combination of extrinsic (i.e., mentor support, reinforcement of career roles [15, 32]) and intrinsic (i.e., meaningful personal interactions with disabled individuals [10]) motivators to encourage the students to keep integrating accessibility. **Whereas motivation theories indicate that extrinsic motivation may be less effective than intrinsic motivation** [5]**, our findings suggest that extrinsic factors must be addressed first** (e.g., survey participant noting *"As important as accessibility is, not everyone is planning to work in jobs or fields that work with accessibility technologies."*).

In summary, our findings suggest that the current computing profession relegates accessibility as an afterthought, and this played out in students' understanding of what was expected of them: to seek solutions on their own, working independently from others; to develop optimally performing solutions, absent human considerations. Above all, these expectations aligned with students' brief experiences of the "real world" when their internships modeled similar cultural aspects: little was expected of them to include accessibility beyond compliance, and even then, seeking accessible solutions was an isolating and ad hoc task.

> **R3:** ***What educational resources or instructional methods do students wish they would have had to better prepare them to create accessible technologies, and what does this reveal about students' attitudes and motivations about accessibility?***

From our analysis of the interview transcripts, we had observed that our 16 participants had offered a wide variety of suggestions in regard to which accessibility ***topics*** they would have liked to learn more about, to which types of information ***resources*** they would prefer, and to which ***course structures*** they preferred. To help us to make sense of these recommendations and to determine how prevalent these views might be among computing students, we had decided to reach out to a larger number of students through a survey. Although students are not experts in curriculum design and their preferences do not necessarily represent what future accessibility education should follow, asking their opinions about how accessibility should be taught can serve as a useful probe for understanding their perspective. We therefore conducted a survey of 114 senior-level students to investigate their agreement with suggestions about educational topics or resources that had been raised by the interview participants.

The results of the survey indicated students were most interested in accessibility topics that could be readily applied to software and that would support them in a learn-it-on-your own approach. The top three topics suggested by students were related to testing software for accessibility, gathering software requirements, and incorporating accessibility in the software development cycle. These results are consistent with the recent work of Crabb et al., which indicates that students in the U.K. wanted simple methods to implement accessibility, such as having accessibility "*baked* *in*" to software libraries [14]. Students were less interested in topics that were not hands-on or that focused on motivations for accessibility, as students believed those topics could be learned outside of class. Hands-on projects may be one opportunity for students to interact with individuals with disabilities, e.g., with instructors introducing end-users with a disability to students [20, 34].

After suggesting resources and topics on accessibility, survey participants indicated their opinion that accessibility should be taught as an elective course (significantly preferred by students to other options, as had been shown in Table 3). This preference for accessibility to be taught as an elective may reveal something about students' attitude toward this topic, i.e. suggesting that they did not consider accessibility as a necessary skill. In an analysis of the open-ended responses, students indicated that accessibility would not be relevant for all computing students. They explained that if accessibility were to be offered via an elective course, then a subset of their peers who wanted to specialize in accessibility would have an opportunity to study the topic.

It is important to note however, that these educational resources and instruction methods do not address the root issue. Although students (in our survey) indicated a preference for information resources for self-learning and for having accessibility as an elective course, each of these preferences actually relate to two factors identified in our interview study as **detractors** from students considering accessibility: *the learn-it-on-your-own approach in computing* and *not seeing it as important for career preparation.* This contrast between what students are asking for and what may actually positively influence their long-term views on the importance of accessibility is striking. This suggests that to engage students in instructional content on accessibility, instructors must first address social and extrinsic factors that reinforce the importance of accessibility in computing. The impact of such extrinsic factors may explain why in prior work, instructors have found accessibility lectures to be effective at imparting knowledge and skills in the short-term [26, 30, 37], but have also found instances in which students did not apply accessibility concepts without having been required to do so [30, 32]. These social and extrinsic factors may also contribute to the well-established phenomenon of students considering accessibility as an afterthought [16, 41, 44].

8 LIMITATIONS AND FUTURE WORK

One limitation of this study is that it has only been conducted at one university in the northeastern U.S., and additional research would be needed to replicate this study at other universities to determine the degree to which the findings should be generalized. In addition, while it may be interesting to consider which topics or educational interventions students express an interest in (as in our survey study), this should not be taken as a specific recommendation for instructors to follow. Instead, additional research is needed on the efficacy of these various intervention options, but future researchers may find inspiration or guidance in their selection of interventions to evaluate, based on the results of this survey.

There is also additional information that, in retrospect, we would have liked to have captured from survey participants: For instance, it may have been interesting to ask about the nature of prior internship experiences (e.g., whether it tended to focus on front-end or back-end technologies). Gathering a wider set of information about the prior experiences of respondents to the survey may have enabled an analysis of responses partitioned on sub-groups who had shared common workplace or educational experiences. In future work, a larger analysis could be conducted to better understand whether particular previous educational or internship experiences may shape the opinions of students about various accessibility educational interventions.

Although the analysis of interview data in this study revealed some extrinsic factors that may have influenced (both positively and negatively) students' motivation to consider accessibility, a future study could specifically focus on such factors. For instance, a future study may examine some of the types of experiences identified among the exception cases in our interview study (the students who reported strong motivation to consider accessibility in their work), e.g., whether participation in a project mentorship activity (e.g., NSF Research Experiences for Undergraduate Students) influences students' interest in maintaining their knowledge of accessibility.

9 CONCLUSION

In summary, this mixed-methods study investigated the degree to which university students considered accessibility, several years after completing a required Human-Computer Interaction course in their degree program. While use of accessibility lectures during a required course in this study is consistent with educational guidelines [2], ABET requirements [1], and short-term recommendations of researchers [35], our study has revealed that, in the long-term, this type of educational intervention does not motivate students to further their knowledge in accessibility. In the long-term, multiple social and extrinsic factors may dissuade students from further developing their skills in accessibility.

In addition to transferring technical skills to students, this study suggests computing degree programs should foster an environment in which accessibility and inclusion is prioritized, to engage students in the topic (e.g., through 1-1 support, requirements throughout the curriculum, exposure to computing experts on accessibility, gaining meaningful relationships with diverse populations).

Prior work has focused largely on the short-term analysis of interventions in individual courses, and the findings of this study provide a longer-term analysis of accessibility teaching methods across multiple courses, which contributes to the existing literature on accessibility in computing education. Our findings provide a baseline for future research considerations to understand how factors outside the classroom may shift students' attitudes and understanding about accessibility.

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REFERENCES

[1] Accreditation Board for Engineering Technology. 2013. Criteria for accrediting engineering programs 2014–2015. Cycle, 25. Retrieved from http://www.abet.org/Linked Documents-UPDATE/Criteria and PP/C001 08-09 CAC Criteria 11-8-07.pdf.

[2] Association for Computing Machinery (ACM) Joint Task Force on Computing Curricula and IEEE Computer Society. 2013. Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science. Association for Computing Machinery, New York, NY. DOI: https://doi.org/https://dl.acm.org/doi/book/10.1145/2534860

[3] American Foundation for the Blind. 2019. The digital talking book. American Foundation for the Blind. Retrieved from https://www.afb.org/about-afb/history/online-museums/afb-talking-book-exhibit/recording-technology-moves/digital.

[4] Lecia J. Barker, Charlie McDowell, and Kimberly Kalahar. 2009. Exploring factors that influence computer science introductory course students to persist in the major. In *Proceedings of the 40th ACM Technical Symposium on Computer Science Education (SIGCSE'09)*. ACM Press, 153–157. DOI: https://doi.org/10.1145/1508865.1508923

[5] Kenneth E. Barron and Judith M. Harackiewicz. 2000. Achievement goals and optimal motivation: A multiple goals approach. In *Intrinsic and Extrinsic Motivation*. Elsevier, 229–254. DOI: https://doi.org/10.1016/b978-012619070-0/50031-3

[6] Paul Bohman. 2012. *Teaching Accessibility and Design-for-all in the Information and Communication Technology Curriculum: Three Case Studies of Universities in the United States, England, and Austria*. Ph.D. Dissertation. Utah State University, Logan, Utah.

[7] Erin Brady and Jeffrey P. Bigham. 2014. How companies engage customers around accessibility on social media. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS'14)*. ACM Press, 51–58. DOI: https://doi.org/10.1145/2661334.2661355

[8] Marca Bristo. 2001. The Accessible Future. Washington, D.C. Retrieved from http://www.ncd.gov/publications/2001/June_2001.
[9] John Brownlee. 2016. How designing for disabled people is giving Google an edge. Retrieved from https://www.fastcompany.com/3060090/how-designing-for-the-disabled-is-giving-google-an-edge.
[10] Michael Buckley, Helene Kershner, Kris Schindler, Carl Alphonce, and Jennifer Braswell. 2004. Benefits of using socially-relevant projects in computer science and engineering education. In *Proceedings of the 35th Technical Symposium on Computer Science Education (SIGCSE'04)*. ACM Press, 482–486. DOI: https://doi.org/10.1145/971300.971463
[11] Luiz Fernando Capretz. 2003. Personality types in software engineering. *Int. J. Hum.-comput. Studies* 58, 2 (2003), 207–214. DOI: https://doi.org/10.1016/S1071-5819(02)00137-4
[12] Jim A. Carter and David W. Fourney. 2007. Techniques to assist in developing accessibility engineers. In *Proceedings of the 9th International Conference on Computers and Accessibility (ASSETS'07)*. ACM Press, 123–130. DOI: https://doi.org/10.1145/1296843.1296865
[13] Dallas K. Cecil. 2009. Personality types of IT professors. In *Proceedings of the 10th ACM Conference on Information Technology Education (SIGITE'09)*. ACM Press, 13–23. DOI: https://doi.org/10.1145/1631728.1631735
[14] Michael Crabb, Michael Heron, Rhianne Jones, Mike Armstrong, Hayley Reid, and Amy Wilson. 2019. Developing accessible services: Understanding current knowledge and areas for future support. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI'19)*. ACM, New York, NY, Paper 216, 12 pages. DOI: https://doi-org.ezproxy.rit.edu/10.1145/3290605.3300446
[15] Edward L. Deci and Richard M. Ryan. 1985. The general causality orientations scale: Self-determination in personality. *J. Res. Person.* 19, 2 (1985), 109–134. DOI: https://doi.org/10.1016/0092-6566(85)90023-6
[16] Alistair Edwards, Peter Wright, and Helen Petrie. 2006. HCI education: We are failing—why. In *Proceedings of the HCI Educators Workshop.*
[17] Enhanced Network Accessibility for the Blind and Visually Impaired. 2007. Analysis of the ENABLED Web Developer Survey. Retrieved from http://www.enabledweb.org/public_results/survey_results/analysis.html.
[18] Federal Communications Commission. 2010. 21st Century Communications and Video Accessibility Act (CVAA). Retrieved from https://www.fcc.gov/consumers/guides/21st-century-communications-and-video-accessibility-act-cvaa.
[19] Susan Gallagher, Irina Karapetyants, and Karalyn Clouser. 2019. Comparative approaches to accessibility education in the United States and Russia. In *Proceedings of the ASEE Conference & Exposition.* Retrieved from https://peer.asee.org/32523.
[20] Ed Gellenbeck. 2005. Integrating accessibility into the computer science curriculum. *J. Comput. Sci. Coll.* 21, 1 (1988), 267–273. DOI: https://doi.org/10.1080/0899340880010104
[21] Morton Ann Gernsbacher. 2015. Video captions benefit everyone. *Policy Ins. Behav. Brain Sci.* 2, 1 (2015), 195–202. DOI: http://doi.org/10.1177/2372732215602130
[22] Joy Goodman, Hua Dong, Pat M. Langdon, and John Clarkson. 2007. Factors involved in industry's response to inclusive design. In *Designing Accessible Technology* (1st ed). Springer, London, UK, Chapter 4. DOI: https://doi.org/10.1007/1-84628-365-54
[23] John D. Gould and Clayton Lewis. 1985. Designing for usability: Key principles and what designers think. *Commun. ACM* 28, 3 (1985), 300–311. DOI: https://doi.org/10.1145/3166.3170
[24] Handspeak. 1996. ASL sign language dictionary. Retrieved from https://www.handspeak.com/word/search/.
[25] Susan M. Harrison. 2005. Opening the eyes of those who can see to the world of those who can't: A case study. *SIGCSE Bull.* 37, 1 (2005), 22–26. DOI: https://doi.org/10.1145/1047124.1047368
[26] Tony Jenkins. 2001. The motivation of students of programming. In *Proceedings of the 6th Conference on Innovation and Technology in Computer Science Education (ITiCSE'01)*, ACM Press, 53–56. DOI: https://doi.org/10.1145/377435.377472
[27] Brian Kelly, David Sloan, Lawrie Phipps, Helen Petrie, and Fraser Hamilton. 2005. Forcing standardization or accommodating diversity?: A framework for applying the wcag in the real world. In *Proceedings of the International Cross-Disciplinary Workshop on Web Accessibility (W4A'05)*. 46–54. ACM Press. DOI: https://doi.org/10.1145/1061811.1061820
[28] Andrew J. Ko and Richard E. Ladner. 2016. Access computing promotes teaching accessibility. *ACM Inroads* 7, 4 (2016), 65–68. DOI: https://doi.org/10.1145/2968453
[29] Carol T. Kulik and Loriann Roberson. 2008. Common goals and golden opportunities: Evaluations of diversity education in academic and organizational settings. *Acad. Manag. Learn. Educ.* 7, 3 (2017), 309–331. DOI: https://doi.org/10.5465/amle.2008.34251670
[30] Sri H. Kurniawan, Sonia Arteaga, and Roberto Manduchi. 2010. A general education course on universal access, disability, technology, and society. In *Proceedings of the 12th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'10)*. ACM Press, 11–18. DOI: https://doi.org/10.1145/1878803.1878808

[31] Richard E. Ladner. 2010. Accessible technology and models of disability. In *Design and Use of Assistive Technology: Social, Technical, Ethical, and Economic Challenges*, Meeko Mitsuko K. Oishi, Ian M. Mitchell, and H. F. Machiel der Loos (Eds.). Springer, New York, 25–31. DOI: https://doi.org/10.1007/978-1-4419-7031-2_3

[32] Jonathan Lazar, Alfreda Dudley-Sponaugle, and Kisha-Dawn Greenidge. 2004. Improving web accessibility: A study of webmaster perceptions. *Comput. Hum. Behav.* 20, 2 (2004), 269–288. DOI: https://doi.org/10.1016/j.chb.2003.10.018

[33] ChongMin Lee and Scot A. Pott. 2018. University students' attitudes towards deaf people: Educational implications for the future. *Deaf. Educ. Int.* 20, 2 (2018), 80–99. DOI: https://doi.org/10.1080/14643154.2018.1438777

[34] Stephanie Ludi. 2007. Introducing accessibility requirements through external stakeholder utilization in an undergraduate requirements engineering course. In *Proceedings of the 29th International Conference on Software Engineering (ICSE'07)*. ACM Press, 736–743. DOI: https://doi.org/10.1109/ICSE.2007.466

[35] Stephanie Ludi, Matt Huenerfauth, Vicki Hanson, Nidhi Rajendra Palan, and Paula Garcia. 2018. Teaching inclusive thinking to undergraduate students in computing programs. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE'18)*. ACM Press, 717–722. DOI: https://doi.org/10.1145/3159450.3159512

[36] Robert McCartney, Jonas Boustedt, Anna Eckerdal, Kate Sanders, Lynda Thomas, and Carol Zander. 2016. Why computing students learn on their own: Motivation for self-directed learning of computing. *ACM Trans. Comput. Educ.* 16, 1 (2016), 2:1–2:18. DOI: https://doi.org/10.1145/2747008

[37] Robert McCartney, Anna Eckerdal, Jan Erik Moström, Kate Sanders, Lynda Thomas, and Carol Zander. 2010. Computing students learning computing informally. In *Proceedings of the 10th Koli Calling International Conference on Computing Education Research (Koli Calling'10)*. ACM Press, 43–48. DOI: https://doi.org/10.1145/1930464.1930470

[38] Rachel Menzies, Garreth W. Tigwell, Mandar Tamhane, and Annalu Waller. 2019. Weaving accessibility through an undergraduate degree. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'19)*. ACM Press, 526–529. DOI: https://doi.org/10.1145/3308561.3354611

[39] Meeko Mitsuko K. Oishi, Ian M. Mitchell, and H. F. Machiel der Loos. 2010. *Design and Use of Assistive Technology: Social, Technical, Ethical, and Economic Challenges*. Springer Science & Business Media. DOI: 10.1007/978-1-4419-7031-2.

[40] Nidhi Rajendra Palan, Vicki L. Hanson, Matt Huenerfauth, and Stephanie Ludi. 2017. Teaching inclusive thinking in undergraduate computing. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'17)*. ACM Press, 399–400. DOI: https://doi.org/10.1145/3132525.3134808

[41] Lasserre Patricia. 2011. Service learning: An HCI experiment. In *Proceedings of the 16th Western Canadian Conference on Computing Education (WCCCE'11)*. ACM Press, 12–16. DOI: https://doi.org/10.1145/1989622.1989626

[42] Helen Petrie and Alistair Edwards. 2006. Inclusive design and assistive technology as part of the HCI curriculum. In *Proceedings of HCI Educators Workshop*. 23–24.

[43] Michael Poor, Laura M. Leventhal, Julie Barnes, Duke R. Hutchings, Paul Albee, and Laura Campbell. 2012. No user left behind: Including accessibility in student projects and the impact on CS students' attitudes. *Trans. Comput. Educ.* 12, 2 (2012), 5:1–5:22. DOI: https://doi.org/10.1145/2160547.2160548

[44] Cynthia Putnam, Maria Dahman, Emma Rose, Jinghui Cheng, and Glenn Bradford. 2016. Best practices for teaching accessibility in university classrooms: Cultivating awareness, understanding, and appreciation for diverse users. *ACM Trans. Access. Comput.* 8, 4 (2016), 13:1–13:26. DOI: https://doi.org/10.1145/2831424

[45] Cynthia Putnam, Kathryn Wozniak, Mary Jo Zefeldt, Jinghui Cheng, Morgan Caputo, and Carl Duffield. 2012. How do professionals who create computing technologies consider accessibility? In *Proceedings of the 14th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'12)*. ACM Press, 87–94. DOI: https://doi.org/10.1145/2384916.2384932

[46] Sara Randazzo. 2019. Lawsuits surge over websites' access for the blind. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/lawsuits-surge-over-websites-access-for-the-blind-11550415600.

[47] Antonio Rincon. 2009. *Section 508 Adherence by Industry Professionals: Improving Universal Design through Training*. Ph.D. Dissertation. Nova Southestern University, Broward County, Florida.

[48] Brian J. Rosmaita. 2006. Accessibility first!: A new approach to web design. In *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education (SIGCSE'06)*. 270–274. DOI: https://doi.org/10.1145/1121341.1121426

[49] Brian J. Rosmaita. 2007. Making service learning accessible to computer scientists. *SIGCSE Bull.* 39, 1 (2007), 541–545. DOI: https://doi.org/10.1145/1227504.1227493

[50] Carol Sansone and Judith M. Harackiewicz. 2000. Intrinsic and extrinsic motivation: The search for optimal motivation and performance. Elsevier, 229–254. DOI: https://doi.org/10.1016/b978-012619070-0/50031-3

[51] Yahtyng Sheu, Li-Hui Chen, and Holly Hedegaard. 2016. Sports- and recreation-related injury episodes in the United States, 2011–2014. *Nat. Health Stat. Rep.* 99 (2016), 1–12.

[52] Kristen Shinohara, Cynthia L. Bennett, Jacob O. Wobbrock, and Wanda Pratt. 2017. Teaching accessibility in a technology design course. In *Proceedings of the 12th International Conference on Computer Supported Collaborative Learning (CSCL'17)*. 239–246. https://repository.isls.org//handle/1/237.

[53] Kristen Shinohara, Saba Kawas, Amy J. Ko, and Richard E. Ladner. 2018. Who teaches accessibility?: A survey of U.S. computing faculty. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE'18)*, ACM Press, 197–202. DOI: https://doi.org/10.1145/3159450.3159484

[54] Anselm Strauss and Juliet Corbin. 1990. *Basics of Qualitative Research*. Sage Publications.

[55] Marilla D. Svinicki. 2010. A guidebook on conceptual frameworks for research in engineering education. Retrieved from http://www.ce.umn.edu/~Smith/docs/RREE-Research-Frameworks Svinicki.pdf.

[56] Teach Access. 2020. Teach Access. Retrieved from http://teachaccess.org/.

[57] Tenon.io. 2019. Accessibility as a Service. Retrieved from https://tenon.io/.

[58] Mary Frances Theofanos and Janice Redish. 2003. Bridging the gap: Between accessibility and usability. *ACM Interact.* 10, 6 (2003), 36–51. DOI: https://doi.org/10.1145/947226.947227

[59] Shari Trewin, Brian Cragun, Cal Swart, Jonathan Brezin, and John Richards. 2010. Accessibility challenges and tool features: An IBM web developer perspective. In *Proceedings of the International Cross Disciplinary Conference on Web Accessibility (W4A'10)*. ACM Press, 32:1–32:10. DOI: https://doi.org/10.1145/1805986.1806029

[60] United States Department of Justice. 1991. Americans with disabilities act: Title III regulations. Retrieved from https://www.ada.gov/regs2010/titleIII_2010/titleIII_2010_regulations.pdf.

[61] W3School. 2019. How to Meet WCAG. *World Wide Web Consortium*. Retrieved from https://www.w3.org/WAI/WCAG21/quickref/.

[62] Annalu Waller, Vicki L. Hanson, and David Sloan. 2009. Including accessibility within and beyond undergraduate computing courses. In *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'09)*. ACM Press, 155–162. DOI: https://doi.org/10.1145/1639642.1639670

[63] Ye Diana Wang. 2012. A holistic and pragmatic approach to teaching web accessibility in an undergraduate web design course. In *Proceedings of the 13th Conference on Information Technology Education (SIGITE'12)*. 55–60. DOI: https://doi.org/10.1145/2380552.2380568

[64] Web Accessibility in Mind. 2019. Web Accessibility Tool. Retrieved from https://wave.webaim.org/.

[65] Telle Whitney and Valerie Taylor. 2018. Increasing women and underrepresented minorities in computing: The landscape and what you can do. *IEEE Computer*. 51, 10 (2018), 24–31. DOI: https://doi.org/10.1109/MC.2018.3971359

[66] World Health Organization. 2011. Summary: World Report on Disability 2011. Retrieved from https://apps.who.int/iris/handle/10665/70670.

[67] Mark Wilson. 2018. What you're getting wrong about inclusive design. (April 2018). Fast Company. Retrieved from https://www.fastcompany.com/90166413/what-youre-getting-wrong-about-inclusive-design.

[68] Susan A. Youngblood. 2013. Communicating web accessibility to the novice developer: From user experience to application. *J. Bus. Tech. Commun.* 27, 2 (2013), 209–232.

[69] Carol Zander, Jonas Boustedt, Anna Eckerdal, Robert McCartney, Kate Sanders, Jan E. Moström, and Lynda Thomas. 2012. Self-directed learning: Stories from Industry. In *Proceedings of the 12th Koli Calling International Conference on Computing Education Research (Koli Calling'12)*. ACM Press, 111–117. DOI: https://doi.org/10.1145/2401796.2401810

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