Contents

1 Introduction

Technology in modern society is ubiquitous, economically explosive, and culturally male. The stereotype of the young white male software developer is still the norm in information technology (IT) fields, even after decades of intervention to increase diversity in tech. According to the National Center for Women in Tech, in 2015 women made up 57% of the U.S. workforce but held just 25% of professional computing jobs; they likewise received more than half of all U.S. bachelor's degrees but only 17% of degrees in computer science, down from 37% in 1985 (National Center for Women & Information Technology, 2016). Despite the large body of research documenting the underrepresentation of women in IT, technology has not seen the same progress toward gender parity observed in the other STEM fields.

Researchers have proposed many explanations for the persistent gender imbalance in IT. Some focus on early exposure to computing, some on the importance of formal programming education, and some on hiring practices within the tech industry. The data on computer science education and technical employment support all of these interpretations, but few studies discuss more than one at a time. This project uses interactive visualization to combine these sources of data and present a holistic picture of the state of women's representation within IT.

2 Prior Work

2.1 Women in IT

Modern computing is overwhelmingly male, according to a long, robust, and surprisingly consistent literature on gender in technology. Sanders (2005) summarizes research from the 1980s through the mid-2000s to show that women and girls regularly have less exposure to computers, especially programming; that they are less confident in their own computer skills, despite often being more proficient than their male peers; and that they are uncomfortable and uninterested in stereotypically macho tech culture.

Recent research focuses on the educational and professional consequences of those attitudes. Fewer women than men study computer science, and more women switch majors or drop out of the program (Cohoon, 2006). Similarly, fewer women enter careers in computing (Bartol and Aspray, 2006), and they change careers or leave the workforce at much higher rates than women in any other career path (Glass et al., 2013). Most researchers see a causal relationship between women's low participation in computer science education and their low rates of employment in tech: fewer women study computer science, so fewer women find and keep computer science jobs. These studies employ the metaphor of a "leaky pipeline" (Camp, 1997) and suggest that recruiting girls to computer science earlier in their education is the key to diversifying the IT workforce. More recent analyses, however, highlight the many different career paths that lead to IT work, arguing that a focus on the pipeline unduly ignores these alternate paths. Both perspectives agree that the lack of women in IT is a problem both for women and for IT as a field; the following sections summarize the two views.

2.1.1 The Leaky Pipeline

In the pipeline view, women are underrepresented in technical fields because they are neither encouraged to enter them nor given the support they need to remain. Studies investigating the leaky pipeline typically explore why girls never develop a serious interest in computer science (Barker et al., 2006), why female computer science majors frequently change departments (Katz et al., 2006), or specific techniques to improve female student retention (for instance, see the large literature on pair programming, e.g., Werner et al., 2005; Porter et al., 2013).

Gendered patterns in computer use appear well before high school: middle school boys are more likely to use computers for gaming, while girls use computers primary to communicate (Barker and Aspray, 2006). Increased exposure is correlated with greater confidence and interest in computers, so boys, with more varied computer experience, typically have much higher confidence in their own skills (Frantom et al., 2002). Both gaps, in experience and in confidence, only widen as children get older (Fitzpatrick and Hardman, 2000). These patterns have been documented since home computers were fairly uncommon (Jones and Clarke, 1995), but to my knowledge have not been investigated since the advent of ubiquitous mobile computing.

Formal computing education is also predominantly male, with fewer women than men studying information technology even as other STEM fields move toward gender parity. In 2004, just 16% of high schoolers who took the Advanced Placement (AP) computer science exam were female; Physics B, the next-most disparate AP exam, had more than twice as many female test-takers at 34% (Barker and Aspray, 2006). In a national study of computer science departments, Cohoon (2006) found that women made up 24% of undergraduate computer science majors, but comprised 32% of the computer science students who switched to another major. Programs with higher female enrollment saw less-gendered attrition rates, corresponding with higher overall graduation rates and a more collaborative culture seen in departments that actively recruit and mentor female students (Margolis and Fisher, 2002).

2.1.2 Problems with the Pipeline Metaphor

Unlike work on IT education, research on women in IT careers often rejects the notion of a pipeline and highlights instead the many possible paths to a career in technology. Bartol and Aspray (2006) argue that the distinction between education and career implicit in the pipeline metaphor is rarely valid for knowledge workers, and note that jobs in IT are being created and filled much faster than traditional students are earning IT degrees. Many workers are entering IT from other pathways rather than from a computer science degree program. Women in particular are more likely to transition into tech from another field, whether by taking on more technical tasks within an existing role (Von Hellens et al., 2001), by returning to school after some time in another career (Jesse, 2006), or by receiving vocational tech training (Chapple, 2006).

2.2 Narrative Data Visualization

The most memorable data visualizations do not simply present data; they tell stories. Most iconically, Charles Minard's famous map, pictured in Figure 1, evocatively depicts Napoleon's Russian campaign of 1812 by mapping the army's journey and its size as 422,000 soldiers set out confidently, just 100,000 reach Moscow, and only a tenth of those make it home through the frigid winter weather. Many modern analysts, designers, journalists also use data to tell their stories. Established news sources like the New York Times and the BBC feature interactive, data-driven stories, as do dedicated data journalism outlets like FiveThirtyEight. Even personal correspondence can contain data stories, as with Giorgia Lupi and Stefanie Posavec's Dear Data project (Lupi and Posavec, 2016): the two sent each other weekly postcards visualizing an aspect of their lives that week, from the doors they opened in week 24 to the times they said goodbye in week 52. When they shared their project online, so many people connected with their data stories that their website now hosts mailing groups for other would-be data diarists.

Narrative visualizations combine the engagement of storytelling with the authority of data analysis, creating a distinct medium that blends the author's message with the viewer's interactions. Not all visualizations either seek or achieve this balance, as Lee et al. (2015) note; many visualizations are analytical tools that deliberately avoid narrative framing. But many visualizations are carefully crafted to illustrate the author's point. Segel and Heer (2010) identify four narrative structures commonly used to balance narrative and exploration in data stories: the checklist, which lets users explore a labeled storyboard of the interactive story; the interactive slideshow, which follows a traditional slideshow format but allows users to explore the data found on each slide; the drill-down story,

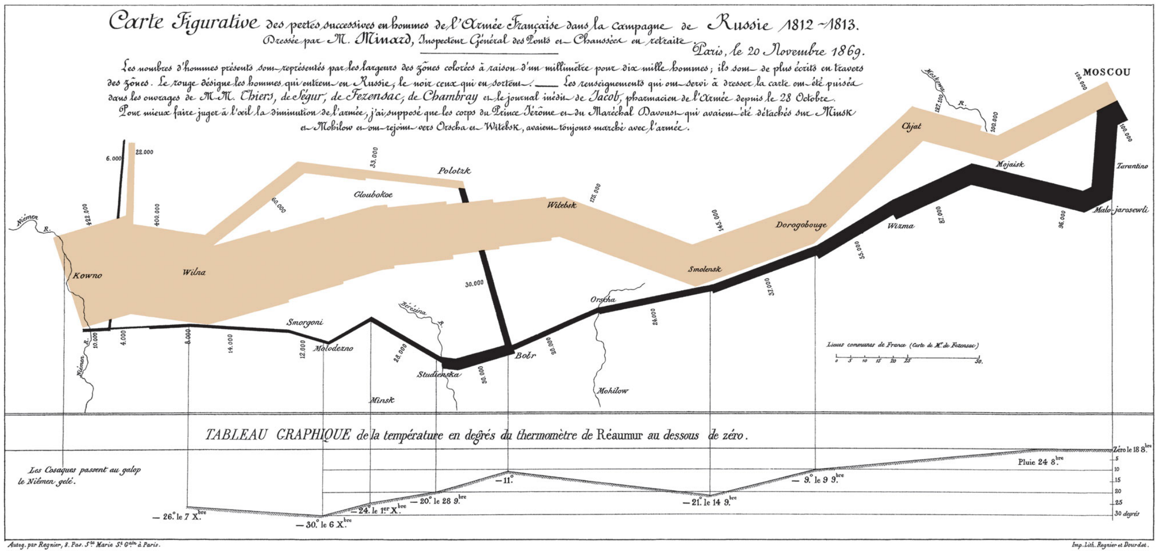


Figure 1: Charles Minard's Famous Map of Napoleon's Russian Campaign

which presents a summary graphic that illustrates the theme and lets users explore the underlying data; and the martini glass, which guides users through a tightly structured narrative before opening up into free exploration.

2.2.1 Visual Narratives as Activism

The combination of compelling story and convincing data makes visual narratives a natural tool for social or policy change. As early as the 1850s, John Snow, one of the fathers of modern epidemiology, used an annotated map to convince London officials to close a cholera-contaminated well (Johnson, 2006). In the same spirit, Michigan Public Radio (2016) published an interactive map of lead levels in 4,000 households in Flint, MI to demonstrate that the problem affected the entire city.

Persuasive narrative visualization can also provide narrative framing to connect personal decisions and attitudes to larger issues. Pandey et al. (2014) presented audiences with graphs or numerical statistics about a range of social issues; among viewers without strong prior opinions, significantly more were convinced by the simple graphics than by the numbers alone. However, Kim et al. (2010) demonstrate that visualizations without context—that is, visualizations that are not part of a narrative—do not show the same persuasive effects. They used graphical displays to encourage users to conserve energy by turning off their computers when not in use. One group saw a display of the time their computers sat idle, with no mention of energy conservation; the other saw an animation of a coral reef that got healthier as they reduced idle time. Although the coral visualization did not directly display their usage data, participants found it far more compelling than the standard idle tracker because it told a story by connecting their actions to environmental change.

With proper framing, simple visualizations can provide this narrative context as well as iconic representations like the coral reef. Zuckerman and Gal-Oz (2014) evaluate the effectiveness of two different step trackers, one that includes a game and one that simply displays the user's daily steps as a bar chart filling toward their step goal. Their bar chart is visually quite similar to Kim et al's ineffective idle time tracker, and yet it was just as effective as the game in motivating participants to walk more. The bar chart in Zuckerman and Gal-Oz's study represents progress toward the user's own goals; it represents a simple but compelling narrative that motivates users to act.

3 Project Overview

This resource uses short narrative frames and simple data visualizations to connect prior research on women's representation across IT. It combines several publicly available datasets, spanning the education pipeline from high school to employment in computing, over the last several years, allowing viewers to explore not only the current state of gender diversity in computing but recent trends across the stages of the pipeline. Short narrative explanations provide context for each visualization, suggesting features of the dataset that viewers may want to explore.

In the following sections, I discuss the design, construction, and evaluation of this tool. Section 4 begins by describing the methodology used to design and build the visualization, including data collection (§4.1), design considerations (§4.2), and development of the webpage and visualizations (§4.3). Section 5 discusses the user testing process, including changes made and future expansions inspired by user feedback. Finally, Section 6 concludes with lessons learned and a roadmap for further improvements.

4 Building the Project

The increasing role of technology in society means that the questions the project explores—namely, who gets to build our technologies and how effective the calls for diversity in tech have been—are relevant to the general public, not merely to those inside the tech world. Consequently, the project has three major goals:

1. Connect prior research by presenting data on both education and employment in tech
2. Facilitate comparison across datasets, even for those without sophisticated analytical skills
3. Provide context to highlight the importance of interesting points within the data

Data Source	Years Included	Subset	Variables
College Board AP Statistics	2010–2016	AP Computer Science Exam	Gender, Exam Score
CRA's Taulbee Survey	2010–2015	Graduate & Undergraduate degrees awarded	Gender, Program
United States Bureau of Labor Statistics Detailed Employment	2011–2015	Computing Occupations	Gender, Occupation

Table 1: Summary of Data Sources Used

This section presents the data collection, design, and development processes used to accomplish these goals.

4.1 Data

4.1.1 Data Sources

To connect earlier research and enable interested viewers to explore more thoroughly, all data used in the project is publicly available and cited in prior research and media reports. It comes from three sources, summarized in Table 1:

- The College Board's AP Computer Science test taker demographics[1]
- The annual Taulbee Survey report of diversity in computing education[2]
- The Bureau of Labor Statistics' employment report by occupation[3]

Where feasible, I collected all data going back to 2010; the Bureau of Labor Statistics changed their reporting categories in 2011, so for consistency I excluded their 2010 data. Only the College Board had released 2016 data at the time of collection. Because not all groups contain the same years' data, visualizations including multiple groups use percentage breakdowns by gender, rather than absolute numerical comparisons.

The College Board's Advanced Placement (AP) program offers high school students the opportunity to earn college credit for courses taken in high school by passing standardized exams. Each AP exam covers introductory college-level material within a single subject area. The exams are scored on a 1–5 scale, with scores 3–5 considered passing and eligible for college credit. AP exam data does not include students who are exposed to computing through other means, including the after-school

[1] AP Data available from `https://research.collegeboard.org/programs/ap/data`
[2] The Taulbee Survey available from `http://cra.org/resources/taulbee-survey/`
[3] BLS data available from `https://www.bls.gov/cps/tables.htm`

programs that are popular interventions to introduce girls to coding. However, it provides consistent national data on the students who receive a rigorous introduction to computer science while in high school, and it is commonly used as a proxy for computing education before college.

The nonprofit Computing Research Association (CRA) conducts and publishes the Taulbee Survey, an annual report on enrollment in computing programs in higher education. It reports on the number of students and faculty in computer science, computer engineering, and information departments across the United States, and gives demographic breakdowns for each education level. Because this project focuses on the traditional tech pipeline from high school to industry employment, I use the Taulbee data on bachelor's, master's, and PhD degrees awarded and exclude data on faculty and postdoctoral positions.

The United States Bureau of Labor Statistics posts detailed data by occupation in Table 11 of its Current Population Survey, broken down by gender and ethnicity. This includes a fairly granular section of "Computing Occupations", including specialties like database administration and web development.

These three sources are ideal for comparison for several reasons. First, they all have a national scope, avoiding the sample size problems of many single-department or regional case studies. Second, they are all regularly cited in existing research on diversity in tech and are publicly available for verification. Finally, they have a similar structure, with breakdowns by gender and by occupational or educational category. This makes them easy to present consistently, while allowing supplementary data to be added in the future to explore facets specific to that stage in the pipeline.

4.1.2 Data Cleaning

All three data sources are available either as spreadsheets or in PDF tables. The College Board spreadsheets include demographic information for all AP tests, broken out by gender and by exam score, so I extracted the data for the Computer Science exam and discarded the others. The Bureau of Labor Statistics similarly includes all occupations in their spreadsheet, so I extracted the data for all of the "Computer and Mathematical Occupations" as seen in the literature. The Taulbee Survey publishes its data as part of a PDF report; because the data is already aggregated (and consequently fairly small), I manually copied the data from their PDFs into a CSV file.

Both the College Board and the Taulbee Survey give the aggregated counts of male and female students for each relevant category, so the only further processing required was to format each row consistently. The Bureau of Labor Statistics, on the other hand, provides a total count of employees for each category, rounded to the nearest thousand, along with the percentage of women employed

Figure 2: Primary Personas: Gabriella Griffin & Laurie Woods

in each category. They do not provide diversity statistics for categories with fewer than 50,000 total employees, so I excluded these categories from the visualization. For the categories included, I used the percentages provided to calculate an approximate female employee count, to correspond with the data for educational stages.

4.2 Design

For this project, I used a user-centered design approach, beginning by identifying the characteristics and goals of its target audience. With those users in mind, I determined the tasks the final webpage should support—what kinds of questions it needed to answer, how much context it would provide, and what resources it should include for further exploration. These decisions guided the selection of relevant design principles, which in turn shaped the resulting designs.

4.2.1 Users

My project is intended for a general audience, not simply for women's advocates within technology. Most viewers will probably have an interest in the topic, as a woman, as someone who cares about technology, or both; but they may not have any exposure to gender diversity statistics within tech. This motivates a narrative thread throughout the page, rather than analytical visualizations presented without comment, both to provide context and to help them interpret the data visualizations.

I used two primary personas to guide my design work:

- Gabriella Griffin, 19, undergraduate psychology major
- Laurie Woods, 28, web designer/front-end developer

Together, they include both casual audiences (Gabriella) and those invested in diversity in tech (Laurie). Details for each persona are included in Figure 2.

4.2.2 Tasks

I do not assume viewers have any prior exposure to diversity statistics or to the tech industry. For users like Gabriella, the primary task the project supports is noticing the gender imbalance at all stages in the tech pipeline. Users like Laurie, who are already aware of the problem, can explore the statistics to see the extent of the problem. The project provides an overview of the data to give this high-level introduction to tech demographics, then presents each stage of the pipeline individually, allowing viewers to explore questions like:

- When do women get involved in tech? Is a computer science degree required?
- Where does the pipeline leak? Is there a stage when more women seem to drop out?
- What kinds of technical careers are open to women? What kinds are still relatively closed?
- Does exposing girls to computer science at younger ages lead to more women working in IT?

The project should also answer questions about the importance of gender diversity in tech and about the interventions used to increase women's participation in IT. This includes presenting background information from prior research and providing resources where interested viewers can learn more, from the data used in the visualizations to media coverage to company diversity policies.

To provide high-level context and allow more detailed exploration, I use an "overview first, details on demand" strategy. While this is usually used to describe individual data visuallizations, I use it to structure the webpage itself. Viewers see an overview of the pipeline first, to provide a conceptual map of the rest of the project. They are then able to choose a specific section of the pipeline to see more information immediately, or to scroll through the page to view the entire pipeline in chronological order. The detail views are designed for consistency, to facilitate comparison across stages.

4.3 Development

4.3.1 Tools

While designing the project, I used low-fidelity, analog tools to quickly generate ideas and gather feedback on them, beginning with paper- and whiteboard sketches. I used the Pencil Prototyping tool[4] to create wireframes for another round of feedback. I then constructed the actual webpage and visualizations using the D3.js JavaScript library[5] for the visualizations and HTML5/CSS3 for the page layout. The page display conforms to responsive web design principles, although the interactive aspects of the visualizations do not.

4.3.2 Process

As discussed above, the project began as a series of conceptual sketches, which allowed me to quickly try out ideas and revise them to find an appropriate design. Figure 3 shows some of these early

[4] `http://pencil.evolus.vn/Next.html`
[5] `https://d3js.org/`

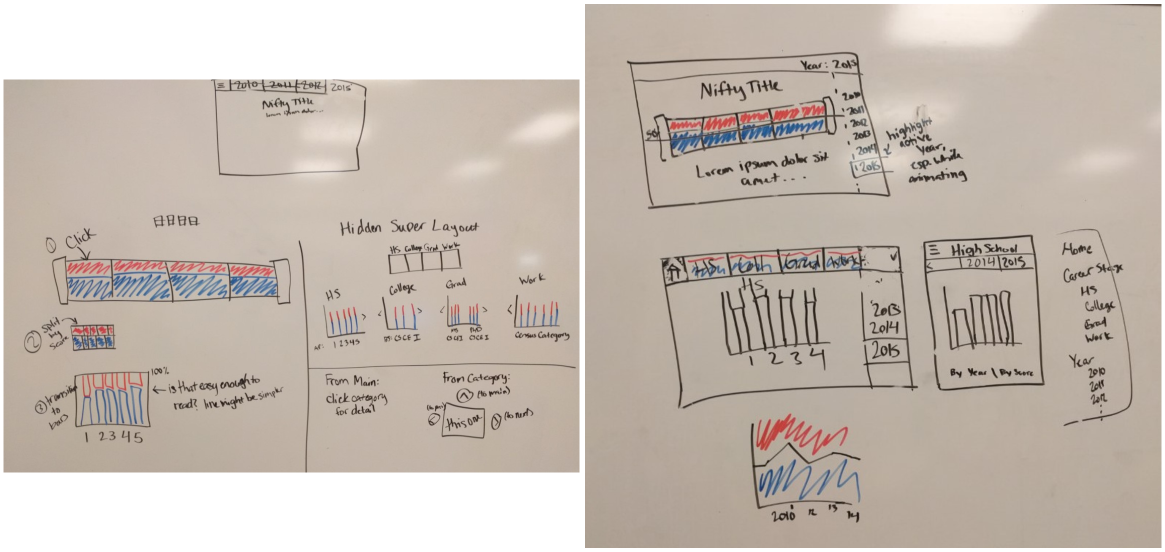


Figure 3: Early Design Sketches: data display (left) and page navigation (right)

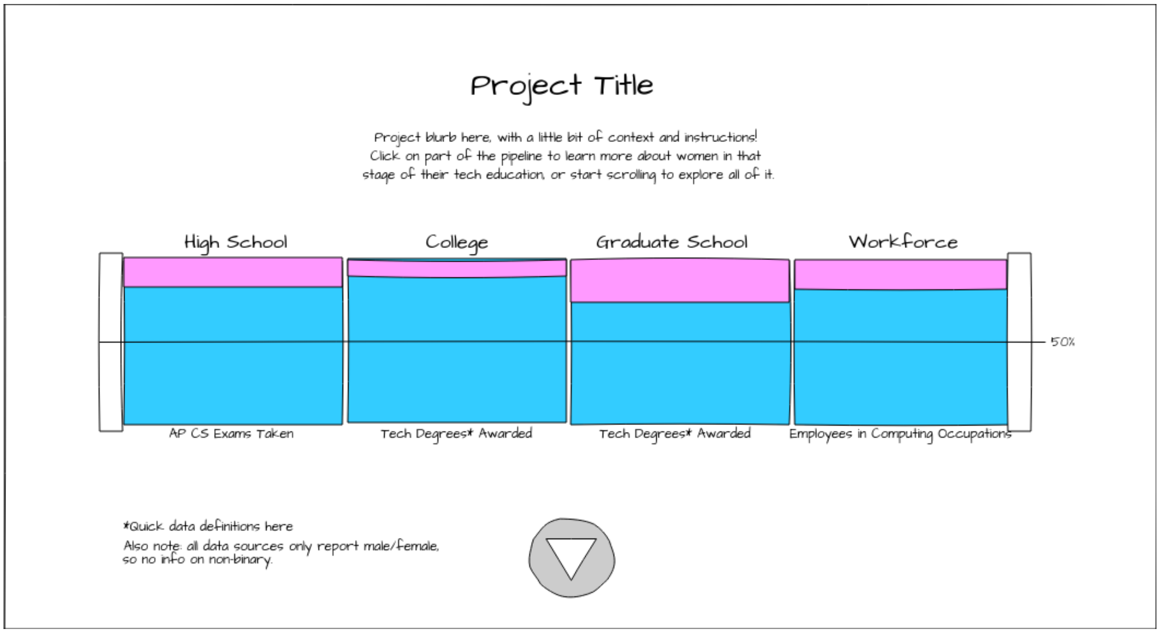
sketches, featuring ideas for page layout, navigation, and transitional animations. They also include my annotations of feedback I received: while I discuss user evaluations in Section 5, testing began at this stage and continued throughout the project.

Considering my design goals in light of that initial feedback, I decided to focus on a simple data display that is easy for a general audience to interpret. The page begins with an overview of the entire pipeline, allowing users to see all of the high-level data at once; scrolling down reveals detailed views of each stage in the pipeline. This detail view includes two bar graphs: one showing the demographic breakdown for each year of data, and one showing the number of men and women in each subgroup (degree program, occupation, or exam score). Each of those detailed views employs the same structure, so that users learn from earlier graphs how to read and interact with the later ones. A short paragraph accompanying each graph directs viewers to points of interest within that stage. Figure 4 shows wireframes of the overview and details panel.

The completed webpage, shown in Figure 5, follows essentially the same structure, adding narrative interludes between each of the detailed views to provide context without cluttering the data views. Hovering over each graph gives users a dark reference line and a numerical indicator of the percentage of women at that point on the graph, as seen in the bottom view of Figure 5.

5 User Testing

Throughout the design and development of the project, I collected feedback and incorporated it into later iterations. Two people offered feedback on the early design sketches and on the wireframes; I



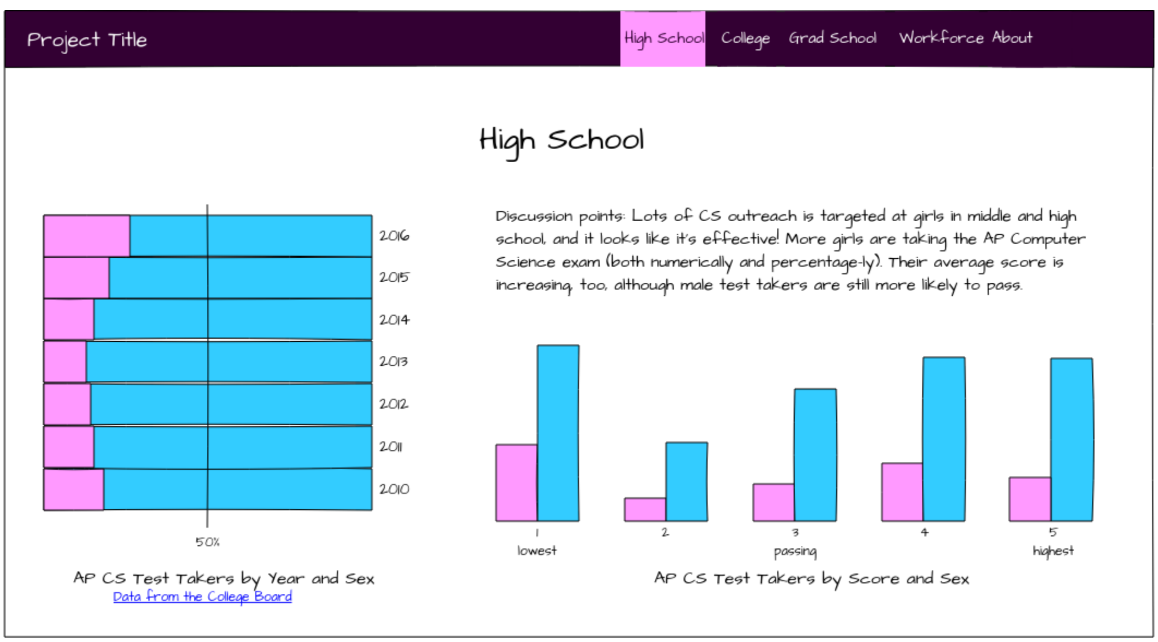


Figure 4: Wireframes: overview (top) and high school detail (bottom)

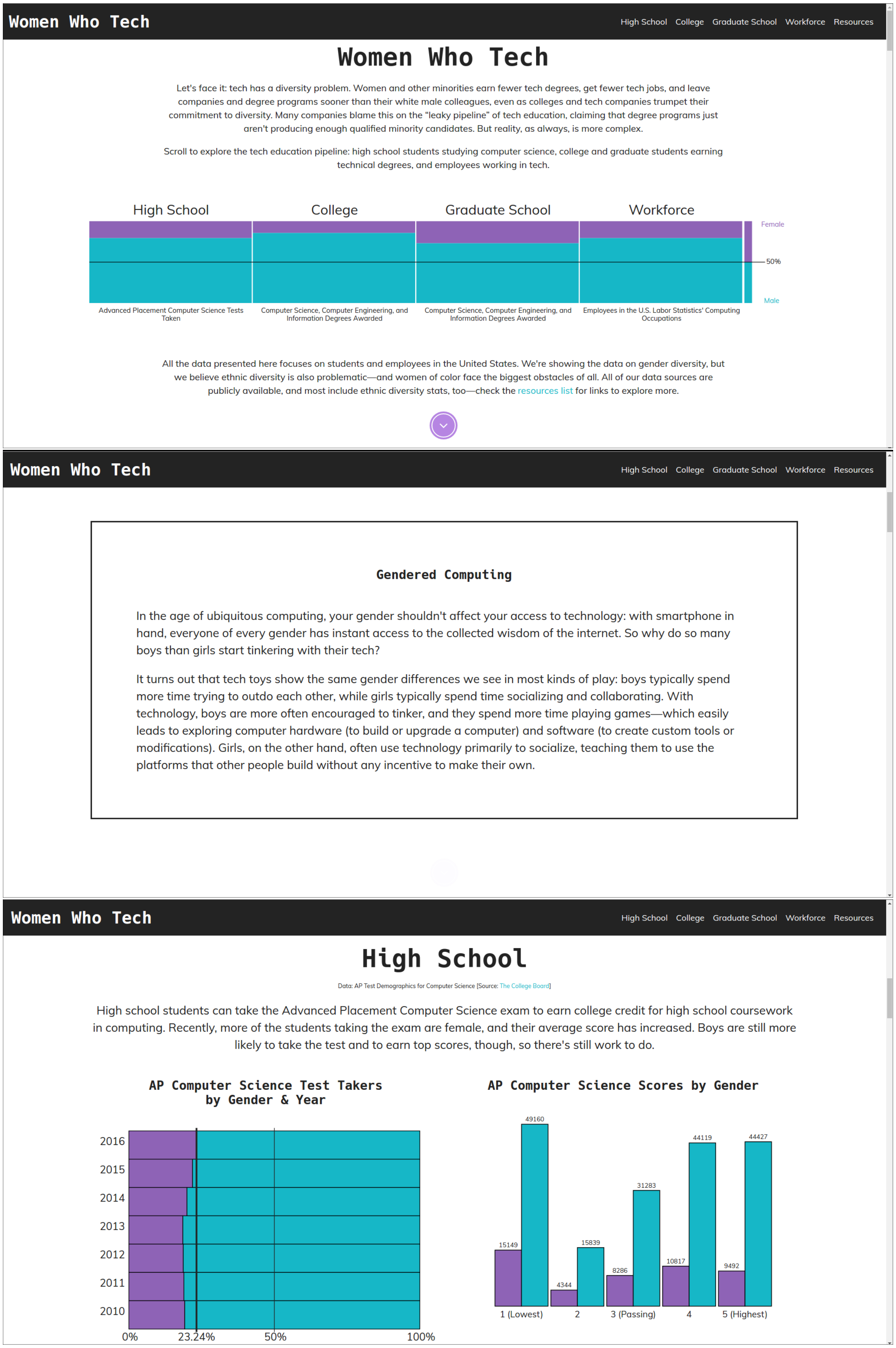


Figure 5: Screenshots: overview (top), narrative frame (middle), and high school detail (bottom)

recruited a total of eight informal testers for the actual website, four loosely corresponding to each persona, to browse the site and offer their impressions. Some of the resulting changes were based on their explicit feedback, while others were based on my observations as they browsed. This section presents the major changes introduced during this process.

5.1 Page Structure

In several early wireframes, I included annotations directing viewers to points of interest directly on the graph. However, the users who saw these wireframes said the annotations felt cluttered and were less certain, not more, how to interpret the underlying data. This led to the narrative boxes in between graphical displays, providing similar context without infringing on graph space. However, later testers noted that these narrative frames are text-heavy and may be visually uninteresting to people who engage primarily with the visualizations; they may be a good place to bring in smaller, supplementary data sets to explore.

I also rearranged the detail views so that the introductory text is above the graphs, rather than next to the year graph as in the wireframes. This alleviated problems reading the category graph when bars were too short: the increased vertical space allowed for even short bars to be clearly visible.

5.2 Navigation

The menu bar on the top of the page jumps between primary sections—the data views along the pipeline—without displaying the narrative sections in between. Because the information is all contained on a single page, users have always been able to scroll to view all of the content. However, the earliest versions of the webpage did not have an indicator besides the native scrollbar that this was an option. Consequently, two of the first testers navigated the page entirely by clicking on the menu bar and never saw the narrative frames.

After observing these tests, I added a purple downward-pointing arrow to the top panel (seen in the top screenshot of Figure 5). It clearly indicates scrollability; all later testers scrolled down the page without difficulty. When viewers reach the first narrative frame, the arrow disappears to avoid obscuring later content. This did not cause further problems with navigation, presumably because viewers had already realized that scrolling was the easiest way to navigate the page.

5.3 Future Improvements

Testing also revealed areas for improvement that have not yet been addressed. Several testers commented that they would like to see more variation between groups: because high school and employment are very different life stages, people were interested in the different ways the lack of gender parity affects high schoolers and working adults. A popular suggestion was to include stories of girls and women affected directly, while two testers asked about the kinds of interventions used at each stage. One commented that she would like to see more variety in the section layouts, with more comparison features in the overview and unique displays for each set of details.

Another common request was for more time-oriented displays. While each detail display includes a summary of the data by year, the trends for all groups are never presented in the same view. Three of the eight testers asked for a time-specific overview, while one suggested animating the existing overview to show year-by-year changes. All four of these testers expressed a strong interest in an annotated timeline, showing changes in demographics along with the dates of big tech companies' diversity policies, nonprofit events, and other related milestones.

6 Conclusion

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