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"YOU DON'T HAVE TO BE A WHITE MALE WHO WAS LEARNING HOW TO PROGRAM SINCE HE WAS FIVE" COMPUTER USE AND INTEREST FROM CHILDHOOD TO A COMPUTING DEGREE

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"YOU DON'T HAVE TO BE A WHITE MALE WHO WAS LEARNING HOW TO PROGRAM SINCE HE WAS FIVE" COMPUTER USE AND INTEREST FROM CHILDHOOD TO A COMPUTING DEGREE

A THESIS APPROVED FOR THE
SCHOOL OF COMPUTER SCIENCE

BY

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Table of Contents

Abstract

For over three decades, researchers have been trying to understand why so few women enter STEM (Science, Technology, Engineering and Mathematics) fields, and in particular the field of computing. Some answers to this question were found by Margolis and Fisher (Unlocking the Clubhouse) between 1995 and 1999. Margolis and Fisher found that boys and girls had different experiences with computers from a very young age and that these experiences influenced their desire to pursue (or not) computing. In particular, they found that boys' interest in computers start early –from the moment someone (usually the father) introduces them to computing. And boys continue to be intensely attached to computers until college where they naturally decide to study computing. On the other hand, girls' interest in computers appear later (usually in high-school) and needs reinforcement from teachers, parents or peers. The girls who decide to pursue computing in college take multiple factors into consideration, including enjoyment for the field and excitement about the career possibilities.

Today computers are more accessible than ever, yet women are still a minority in college computing majors. Studies suggest that several factors encourage or discourage women to study computing, from stereotypes to role models and cultural influences. But to our knowledge, in the past twenty years, no other study replicated Unlocking the Clubhouse (UTC), investigating the link between early computer experiences and the choice to enter computing.

Taking place in a large public Midwestern institution, this study aims to capture

how today's computer science (CS) and computer engineering (CE) majors interacted with computers throughout their childhood and adolescence. We were particularly interested in differences between men's and women's experiences. We wanted to know if the differences spotted twenty years ago in Unlocking the Clubhouse (UTC) exist today. Besides, UTC was conducted in an exceptional, highly competitive institution (Carnegie Mellon University). So we also wondered if UTC results would apply in a more typical institution.

To answer those questions, we interviewed eleven third and fourth year students who were majoring in CS or CE, including six women and five men. Our sample was otherwise predominantly White and from a middle-class background. The interviews lasted from eleven to sixty minutes. We discussed three main topics during these interviews: computers at home, computers in school, and their decision to study CS/CE.

We performed a qualitative iterative and inductive analysis of these interviews and discovered that the participants had indeed a greater access to computers and started interacting with technology at a very young age. Advanced usage of the computers, though, were reserved for a small group of people. We noticed that fathers still had a major role in buying technology, introducing advanced usage of the computer to the children and fostering an interest for computing. The father-son relationship around computers seems to still be a norm. We also found that students followed very different paths leading to CS/CE. Many students for instance did not choose CS/CE as their first major in college.

The results we obtained seem to indicate that views and attitudes are slow to change and that efforts remain to be done to recruit and retain more women into computing. Further replications of Unlocking the Clubhouse across various settings would allow researchers to better understand the background of computing students and to create better initiatives.

Chapter 1

Introduction

From the beginning of the 1980s, women's participation in Computer Science (CS) at the undergraduate level has declined [33]. And even though men's participation boomed at the end of the 1990s, women did not follow the trend [33]. In 2017, women represented 57% of all bachelor degrees holders, but earned only 18% of CS bachelor degree [30].

In 1986 Schubert had already warned about sexism in CS and gender inequality existing in CS education [34]. From there on, researchers have been concerned about gender inequality in CS and studied its foundations and consequences. Researchers have found that girls' decision to participate in CS was greatly impacted by their environment, gender stereotypes and computing stereotypes, the institutions they attend. The fact that outside factors push women away from CS is one reason why it is interesting to study those factors and ways to weaken or eradicate them. Besides, today's world is in need of engineers and computer scientists, so a higher girls' participation would only help overcome this shortage. Bringing more women into computing would also help reduce the gender wage gap, since it is partly due to the fact that women occupy less prestigious and well-paying jobs than men. Finally, when girls are given the same opportunities as boys, they are found to perform as well as them [18].

Between 1995 and 1999, Margolis and Fisher conducted a seminal study in the area of gender and computing: *Unlocking the Clubhouse (UTC)*. They examined the childhood experiences with computers of CS undergraduate students and the link between those experiences and the decision to pursue a CS degree [23]. This research has been crucial to understand the different systemic obstacles girls need to tackle to enter the field of Computer Science and the factors influencing girls to study and persevere in or drop out from CS.

But UTC also has limitations. First, UTC was conducted in an unusual, very competitive and prestigious institution: Carnegie Mellon University (CMU). CMU is one of the top universities of the country, ranked in 2018 25th in national universities and ranked first in computer science by U.S. News and World Report [41]. It is unclear whether UTC results reflect the realities of most computing students. Besides, twenty years have passed since UTC and I found no other study that has replicated their results. Since access to technology has greatly changed, we suspect that children's experiences with computers have also changed. This may impact the way students enter in the computing world as well.

For those reasons, we decided to conduct research inspired by UTC, although in a different, more typical university at a smaller scale and in a much shorter period of time. We wanted to get insight into the role of today's children's computer experiences on the pathway to computing, and if and how girls' and boys' experiences were any different. We were also interested in the impact of the institution on the students profiles and stories: particularly, if we could find differences between UTC students and these students.

In the following chapters, we will give a review of the current literature in the subject, including a summary of the UTC chapters we took inspiration from. Then we will explain our research methodology and scope. Finally, we will discuss the results of our research in comparison with UTC and other sources.

Chapter 2

Related Works

2.1 A Reference Study: *Unlocking the Clubhouse*

2.1.1 Chapter 1: “The Magnetic Attraction”

In the first chapter of their book, Margolis and Fisher expose the relationship between computers and young children. They explain that little boys and girls have completely different experiences. The boys are introduced to computers by a parent (most of the time the father) very early. Not only do they enjoy the computer as a toy, and a machine they can control but also are interested in programming and how the computer functions. The girls in the study have a smaller interest in computers. They enjoy using it but have other hobbies. Some also tinker with it, but others barely touch it.

This gender divide is reinforced by parents’ knowledge: 43% of the participants’ fathers but only 8% of their mothers were considered the family expert in computers. Children observe these differences and the roles their parents have at home and construct models from an early age. Thus seeing their father using the computer more than their mother can lead them to identify the computer as a masculine object.

Besides being the expert, the father is usually also the one buying the computer and having control over it. Fathers then pass it to their son: more than half of the boys in the study have a computer in their room (whether their personal computer or a computer shared by the whole family). Girls on the other hand have less access to computers at home. Consciously or not, parents expect their sons to like computers and their daughters not to. They perpetuate at home the gender inequalities already existing in the world.

2.1.2 Chapter 2: "Middle and High-School: A Room of His Own"

In this chapter, Margolis and Fisher state that the gender difference increases with age. They found that in middle and high-school boys continue to be passionate about computers: they take programming classes, join the computing clubs, and spend their free time in the computer lab.

Girls, on the other hand, do not naturally go towards computers. To enroll in advanced computing classes (such as AP CS), they often need encouragement from teachers or family.

Other factors keep girls away from CS. For instance, girls tend to underestimate their math abilities and CS is often linked to mathematics. The low popularity of CS has also a role.

The researchers particularly examined the role of the advanced computing classes. For one third of the females interviewed, taking a programming class in high-school help them decide to study CS.

2.1.3 Chapter 3: "Computing with a Purpose"

This chapter is devoted to the decision to pursue a computing degree. We learn that men and women consider different factors to choose their major in college. In particular, men mostly choose computing degrees for the pleasure, as a natural continuation of their childhood hobby. Women take more factors into account: enjoyment but also the relation to mathematics, the versatility of the field, the career prospects, the encouragement from parents and peers.

In fact, the most significant difference is the wish to use computing to help others or solve big problems, found in many women and a few men only. Margolis and Fisher called this desire "computing with a purpose."

2.1.4 Chapter 5: "Everyone knows so much more"

In this chapter we learn how the highly competitive environment of CMU welcomes experts but frighten off novices. Particularly, girls are more often novices and have less experience in computing than boys (38% of women and 7% of men rated themselves as beginners, 12% of women and 45% of men rated themselves as experts [23]). Although the lack of experience ultimately does not influence the success, it undermines self-confidence. And women feel discouraged when comparing themselves to their peers (in particular the men), which eventually can make them drop CS altogether.

2.2 Recent Studies

After UTC, researchers have continued studying how young people enter in computing (and in Science, Technology, Engineering and Mathematics (STEM) fields in general) and how male and female students differ. We now present a quick review of some recent studies in this field.

Like we read in UTC, chapter 3, multiple factors (sometimes gender-specific) influence the decision to study computing. Here are some that researchers have found in the last years:

- According to Eccles et al., math self-ability and a low interest in working with other people positively predict a STEM major choice. On the contrary, high value in work-family balance and an altruistic orientation negatively predict a STEM major choice. While men are more likely to hold the characteristics or beliefs associated with positive prediction of a STEM major, women are more likely to hold those negatively predicting a STEM major. [17]

- Financial prospects, risk aversion and the proportion of women in a field all influence the choice of a major and push men towards and women away from STEM fields. [1]

- According to Lewis et al., students abilities and how they see their abilities impact their interest in computer science. In particular, comparing their abilities to peers can lower students' interest and motivation in CS. [22]

- Wang et al. found in 2015 that women are still more likely to major in CS when they are encouraged to do so (like Margolis and Fisher found in UTC) and when they have previous exposure to computing experiences. Those factors influence men less [42].

- “Communal goals”, i.e. the desire to help people, do a meaningful work, give back to the community (similar to the “computing with a purpose” idea found in UTC) are goals felt to be incompatible with computer science and push women and underrepresented students away [4].

- Another study found that even students who were good at computing did not pursue CS, because of misconceptions of the field or because they have no idea what a computer scientist does in their job [8].

- Although the connection between video games and CS is often considered to be important, Disalvo et al. showed that a great interest in video games could lead people to study CS but was only part of the decision [16].

Researchers have also studied the factors that make students stay and persist in STEM fields, and in particular in CS:

- Seymour and Hewitt in the 1990s have conducted a large and seminal research called *Talking About Leaving: Why Undergraduates Leave the Sciences* and found several important results. Contrary to the popular belief, students staying in the sciences perform as well as students leaving. Several factors lead students to leave the STEM fields: loss of interest, better teaching in non-STEM fields, poor teaching in STEM, intense course load, lack of support from faculty, perceived cost exceeding the outcome. The loss of interest results from the other factors. Women and underepresented students are the first one to suffer from all these discouraging factors [35].

- Chang et al. also found that Black and Hispanic students were less persistent than White and Asian students in STEM. But pre-college experiences explain almost all racial differences. Some encouraging factors (influencing students to stay) include: studying in groups, undergraduate research, involvement in student organizations [9].

- Another model developed by Simon et al. explains that achievement goals, self-efficacy and the perceived autonomy support impact the motivations, emotions and achievement of the students which in turn predict the persistence in STEM [37].

- Unfortunately, the factors encouraging students to stay are more often seen in male students and the discouraging factors in female students. Hardin et al. showed that after one undergraduate introductory STEM class, women had a lower STEM self-efficacy and STEM interest while men felt a higher perceived support for pursuing STEM [21]

Stereotypes also play a great role –at different levels– in the students' decision to enter and stay in STEM fields and in CS. Miller et al. found in a large study involving data from 66 nations that women representation actually predicts national gender-science stereotypes [26]

Firstly, CS and gender stereotypes influence the students' interest in CS (and STEM). CS stereotypes include social isolation, brilliance, focus on technical aspects. These stereotypes attract more boys than girls. Gender stereotypes state that girls are less able than boys in mathematics and science [10]. All of the stereotypes previously cited are also found in UTC, twenty years earlier, in particular in the form of the "geek mythology". So, stereotypes are still deeply present today, as early as in the first grades of elementary school ([2, 25]). Math-gender stereotypes are also worth examining when studying stereotypes in CS, because CS is often linked with mathematics and mathematics self-efficacy influences CS major choice [33].

Stereotypes impact performance: that is what is called *stereotype threat*. Many researchers have studied this wide-spread phenomenon and showed in particular its role as a barrier for women wishing to enter in the computing world ([5, 14, 36, 39]).

Although some predictors of students' decision to major in CS have persisted throughout the years, some have evolved or disappeared. A study conducted by Sax et al. with forty years of data shows that the altruistic orientations have remained a negative predictor of students' decision to major in CS. A father in STEM and a high value on status or wealth have remained positive predictors of students' decision to major in CS. On the other hand, math self-concept (positive predictor) and artistic ability (negative predictor) are becoming weaker predictors. This is good news for women, because they tend to underestimate their math abilities and value artistic abilities more than men [33]. The fact that the factors leading to a major choice change over time justify the need to continue research on this topic.

Chapter 3

Methods

3.1 Qualitative Research

I chose to use a qualitative approach. Quantitative and qualitative methods have different goals, tools, and quality criteria. These differences are explained in this section and summarized in Figure 3.1.

Researchers using quantitative methods want to test an hypothesis [3]. They know what they are looking for and use tools to verify or refute of their hypothesis. Quantitative research designs use a sample that is large enough to represent a population, and then generalize the results found to that population. To collect data, the main tool used is surveys. The main analysis tool is statistics. Different types of statistics are used to test the influence of factors on outcomes, the dependence of multiple factors, the differences between groups or to describe a phenomenon.

In qualitative methods, the goal is to find new phenomena, new theories, and understand why a situation happen. The qualitative method is in this sense diametrically opposed to the quantitative method: whereas in the quantitative method the data confirms or refutes the theory, in qualitative methods the theory is usually created from the data (but can also be used with traditional hypothesis based research). In qualitative research, the sample can be smaller. The tools also differ: to collect data in the qualitative method, textual sources such as surveys, interviews, focus groups and observations are used. Software help the researchers analyze data but the comparisons and descriptions mostly come from the researchers themselves.

In order to measure quality, different criteria are established. For the quantitative approach, they are the following:

- validity: the tools used measure exactly what they should
- generalizability: the sample and the methods used allow the researchers to generalize their results to a whole population
- reliability: the experiences and results can be reproduced
- objectivity: the researchers try to avoid biases and direct interactions with the participants

For the qualitative approach, now:

- credibility: the results can be believed
- transferability: an extensive description of the research settings allow readers to determine whether the results can apply in a new context
- dependability: the specific context is described and considered by the researchers
- reflexivity: the researchers expose their biases

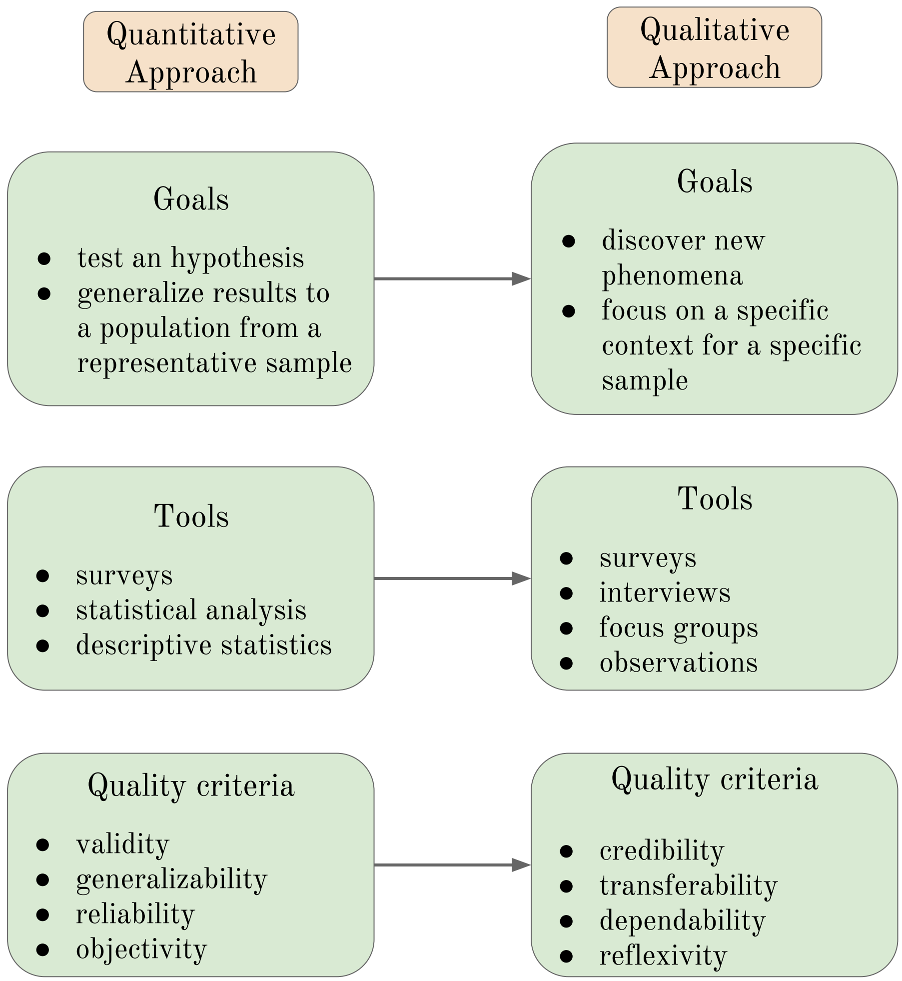

Figure 3.1: Diagram comparing the qualitative and quantitative approaches

Researchers used to conduct quantitative studies can be at first confused when faced with a qualitative approach. Instead of aiming for objectivity and detachment from the participants, researchers in qualitative studies interact directly or indirectly with participants and own their biases. The difference between genralizability and transferability is also worth noticing: with generalizability, validation is the responsibility of the researchers, with transferability the researchers provide information but the primary reponsibility lies with the reader.

Quantitative and qualitative can be combined in the same research design both in parallel or sequentially. This approach is called *mixed* methods.

Within the qualitative approach, different strategies exist [11]:

- ethnography: a study –usually long– in which the researchers observe a cultural group in its natural setting
- phenomenology: a study focusing on a single experience or phenomenon and aiming to understand the causes and context of this experience
- phenomenography: a study which analyzes the different ways people experience a particular experience or phenomenon
- grounded theory: an inductive study in which the theory is constructed from the data, the collection of data stops when saturation is reached, and the protocol evolves with the results
- case study: an in-depth study focusing on a particular example of a phenomenon
- narrative: a study analyzing individual stories
- basic interpretive: a study that do not have any special characteristic

These strategies are often combined in qualitative research [15]. My research follows the phenomenography approach. The full methodology I conducted is explained in the next section.

I decided to use a qualitative approach for several reasons. Firstly, this was the approach taken in the original study, Unlocking the Clubhouse (UTC). But most importantly, I wanted to uncover the experiences of men and women students in CS and how the situation changed since UTC. I wanted to compare today's students' experiences with those lived twenty years ago by UTC participants.

3.2 Research Design

The goal of my study was to find if and how the students' pathway to CS have changed since UTC. From the start, I chose to use phenomenography and interact with participants through interviews.

3.2.1 Setting

I found that one limitation of UTC was the environment of the study: Carnegie Mellon University is a very special institution, because of its prestige and excellence. I suspected that students in this institution were not typical CS students. So I chose to conduct my revisit in Midwestern University[1], a public institution in the Midwest. Midwestern University is a large state flagship university, with a focus on research and a modest ranking in CS. I hoped that changing the setting of the research would allow me to discover new patterns.

3.2.2 Participants

In UTC, Margolis and Fisher interviewed 127 students, including 97 students in CS. I decided to recruit students from CS and Computer Engineering (CE). CE classes focus more on the hardware side of computing. Although CE students were not included in Unlocking the Clubhouse, I considered that the two majors were sufficiently similar because at MU the two majors share several classes. The recruitment of students in an additional major allowed me to recruit participants more easily. I recruited junior and senior students (students in third or more year of Bachelor of Science degrees). These students are closer to graduation and thus they are better established in CS and CE majors, than first or second year students.

[1]Pseudonym.

When designing the study, I decided to recruit 10 to 20 participants. Although it may seem like a small size for a sample, it is sufficient for a qualitative study such as this one. Other studies with a similar sample size have succeeded before [3, 20]. Another factor that I took into consideration while choosing the number of participants was the fact that this research was part of a master's thesis. Therefore, the time was limited and the sample had to be manageable by one researcher.

While recruiting, I also wanted to oversample women. One of the goals of this study was to compare men and women experiences, and in order to do so I had to have a sufficient number of women: I aimed to recruit about 50% of women and 50% of men, although women make up 18% of CS and CE students at MU (taken from an uncited institutional FactBook to protect the anonimity of MU).

3.2.3 Recruitment

The main tool I used to recruit participants was email. I sent several emails to all CS and CE students via MU administration, between January and March 2018. In this email, I presented my research topic and invited interested students to contact us. I received 20 answers from these emails. I sent the link to my online preliminary survey to these 20 students and received 14 answers.

In an effort to recruit more women, I also gave an informal talk in a meeting of a local organization promoting women's participation in computing. There I also presented my research topic and invited interested students to contact us. At least one women was recruiting during this talk and subsequently answered the survey.

3.2.4 Survey

The preliminary questionnaire given to the participants had multiple objectives: request informed consent to participate in research, assure eligibility (by asking if the student was enrolled in any third or fourth year CS/CE classes), and collect information about the participant's social identity.

I were particularly interested in the gender of my students. I asked "Do you identify yourself as..." and the choices were: "Man", "Woman", "Other", "Do not wish to say". About half (5/11) of the participants identify themselves as man, and the other half (6/11) as woman. My goal was thus reached.

I also asked about race/ethnicity, because some racial or ethnic groups (e.g. Black, Hispanic, Native American) are underrepresented in computing. Although it was not the primary focus of my research, race/ethnicity influences the path to and experiences in computing [24]. In this question, provided the "Do not wish to say" option. I also allowed students to select multiple races/ethnicities. The aggregated results of the survey are available in Section 4.1.

I then asked about the high-school they graduated from and the academic level (e.g. completed high-school, attended college, completed college, attended graduate or professional school...) and job of their parents. With the name and state of the high-school, I found the percentage of students eligible for free and reduced priced lunch, a proxy for poverty [28]. The combination of these questions aimed to get a sense of the socioeconomic status of the participants without asking questions that are uncomfortable for many people. The proportion of free-or-reduced-price lunch in a high-school is indeed a correct (but not perfect) indicator of a high-school's poverty level and is widely used in research education to determine the economic background of the participants [38].

3.2.5 Interviews

I decided to use interviews. This was also the main tool used by Margolis and Fisher in Unlocking the Clubhouse (in combination with focus groups and surveys). It is also a very common strategy used in qualitative research to collect experiences and feelings. I first estimated the interviews to last between 30 minutes and one hour.

To construct my semi-structured interview protocol, I took inspiration from Margolis and Fisher's protocol, described in Appendix B of their book [23]. I also added new questions relevant to my context, such as: When and how did you first acquire your own personal computer? My protocol evolved several times during the data collection period. I adapted it based on the answers I received in the previous interviews. Some of this changes were minor, but I can distinguish two distinct phases of interviews. During the first phase, the questions asked were focused on *what* happened to the participants, and the length of the interviews was shorter. During the second phase, an introduction and conclusion were added, as well as more questions, and the focus shifted towards *how* things happen, *how* the participants felt and *why* they took their decisions. The last interviews were thus better than the first, but all brought me interesting insights on each participant's path to CS/CE.

All interviews were divided into four parts:

- first experience with computers: when and how it happened (UTC: Chapter 1)
- computers at home: how computers were treated at home (UTC: Chapter 1)
- computers in school: how computers were used in school (UTC: Chapter 2)
- choice to study CS/CE: why the students decided to major in CS/CE (UTC: Chapter 3 and 5)

3.2.6 Research Involving Human Subjects

This study involves human subjects, and thus had to be accepted by the Institutional Review Board (IRB) of the University of Oklahoma. The goal of this board is to protect research participants and verify that researchers respect applicable regulations and policies. In particular, the IRB checks how identifiable information about participants are used, how participants give their consent and how the risks and benefits of the study are explained to the participants. In December 2017, the OU IRB gave approval for this research.

In this study, there are minimal risks for the participants. The topics covered during the interviews do not pose more risks than a typical conversation. There are also no direct benefits for the participants.

I decided to compensate the participants for their time. Estimating that the interviews would last a maximum of one hour, I chose to compensate participants with a $10 gift card. I also stated that participants who started but did not finish their personal interview would be compensated with a $5 gift card (this case did not happen).

3.3 Analyzing Data

The following diagram shows the four analysis steps I used during this study.

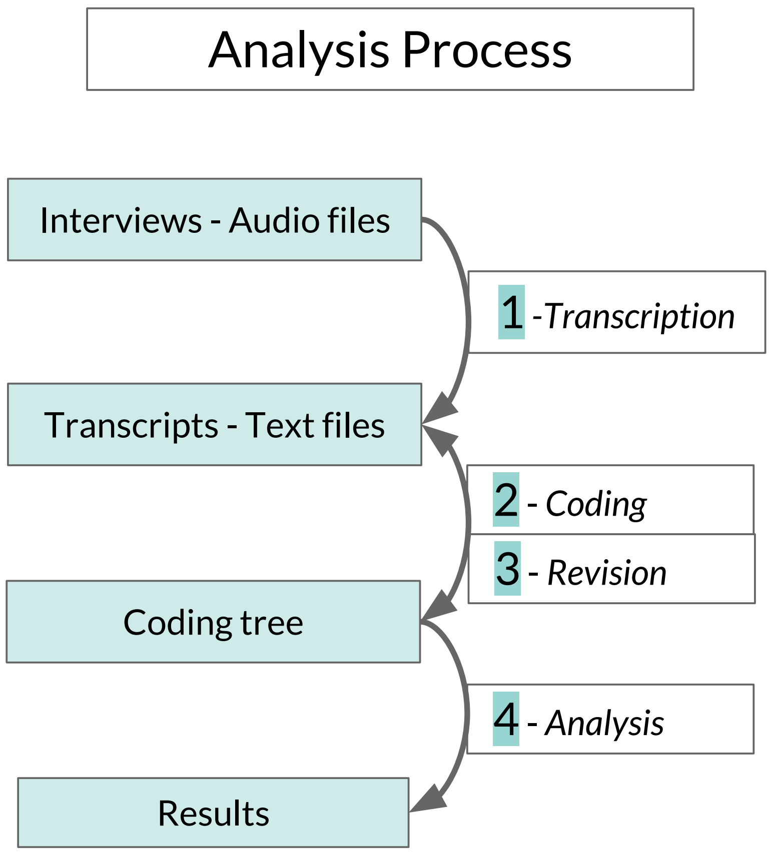

Figure 3.2: Analysis steps

3.3.1 Transcribing Interviews

The preliminary step for analysis is the transcription, i.e. the transformation of the interviews (audio files) into transcripts (text files). There exist several solutions to make this step fast and easy: for instance, using an automatic transcription tool or hiring people to do it. We decided however that I would personally and manually do the entire transcription. It is a time-consuming process (including listening to all interviews multiple times), but very useful: it allowed me to become more familiar with the stories of the participants.

3.3.2 Coding Transcripts

The second step is the coding. This step consists in grouping together pieces of interviews that are related in terms of topic. In order to do this, I read the transcripts again and searched for themes. Some themes were present in Unlocking the Clubhouse and new themes that participants talked about. Figure 3.3 below shows an example of two coding elements in an interview.

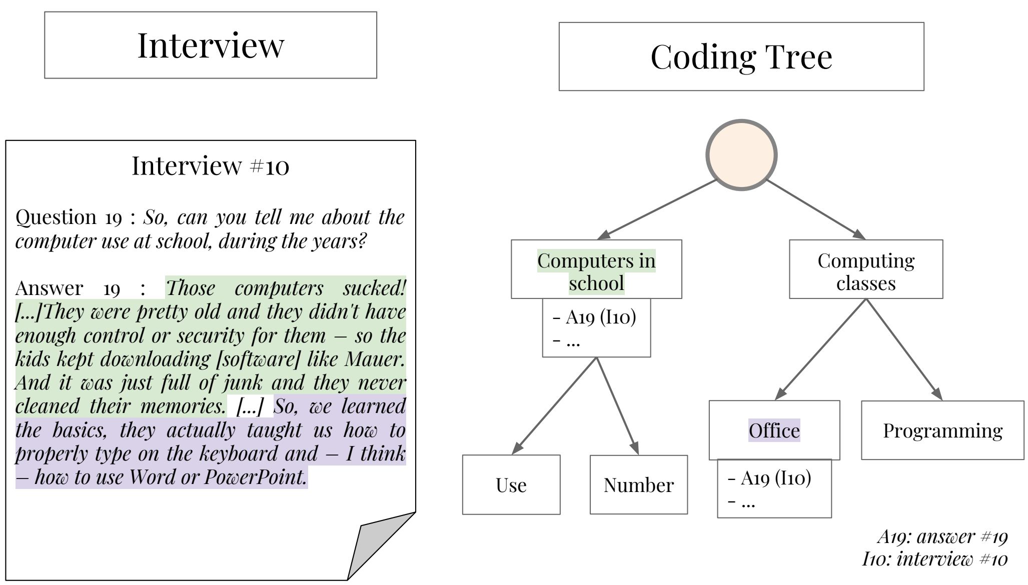

Figure 3.3: From the transcript to the coding tree

Of course, only an extract of the coding tree is represented here in this example. It shows that paragraphs can be coded at a parent or a child node, anywhere on the tree. The actual tree has three layers of nodes: in the first one there are 30 nodes, and in total more than 200. I encoded the interviews using the NVivo (11) software. NVivo is a qualitative data analysis tool widely used for qualitative research [32].

After coding the transcripts, I revised my coding. Instead of beginning with the source (the interviews), I started this second round from the target (the nodes). From the nodes' description, I created a text query in NVivo. The goal was to verify that everything that should be coded was indeed coded. The tool allow its users to specify options during the text query, and most of the time I chose to search for a word and the words similar to it (for instance when looking for "sibling", the tool showed results including "brother", "sister" or even "family"). A couple of entries were re-discovered via this step. The familiarity I had with the data, the small size of the sample, the small size of some interviews allowed me to check everything manually and be sure that coding was as complete and consistent as possible.

3.3.3 Analysis

Finally, I analyzed all the nodes previously coded. I started with themes present in Unlocking the Clubhouse and compared the results. I dissected every node, counting how many participants expressed each idea and compared the participants' experiences to those previously reported. The results of this analysis are presented and discussed in the next section. We thus used an iterative and inductive methodology.

3.3.4 Data Saturation

In many qualitative methodologies, data collection stops at data saturation. Saturation is defined as the point where more data would not lead to different nodes, in other words it is the point where all codes have been discovered.

Before analyzing the data, I decided to stop at a number of participants between 10 and 20 and recruited 11 participants. I do not claim that data saturation had occurred, but rather it had become impractical to recruit more participants.

Many authors have studied the impact of data saturation. Some have found that this is a hard point to reach in practice and that it depends greatly on the research context [31]. Some have tried to fix a number of interviews to reach saturation: in a study of 60 participants, the saturation was reached at 12 interviews [20]. But different views exist on this concept [19].

As the results show in the next section, this study has highlighted new profiles of students that were not present in Unlocking the Clubhouse. Are there even more different profiles existing? Only multiple replications of this study in various settings would answer the question. But I propose that the sample was big enough to find new patterns, and thus is satisfactory.

Chapter 4

Results and Discussion

4.1 Profile of the Participants

As I previously stated, the total number of recruited participants was eleven. Table 4.1 below shows the aggregated answers to the preliminary survey and summarizes the characteristics of the participants.

We can also see that this sample is not very diverse. Firstly, six out of eleven participants are female. The majority of participants are White (as is typical in computing at at MU) and come from middle-class families. This is not surprising, because I did not make any effort to recruit any racial/ethnic/socio-economic groups preferentially. A similar study that focuses on the experiences of racial/ethnic/socio-economic would lie a good addition to the litterature.

Eight of the participants were CS majors and only three were CE majors. This difference in proportion prevented me from finding different patterns between CS and CE students.

Table 4.1: Participants' Social Characteristics

	Number of participants
Gender	
Female	6
Male	5
Major	
CS	8
CE	3
Race/ethnicity [a]	
White	6
Hispanic or Latinx	4
Asian or Asian-American	2
Black or African-American	1
Parents' Education [b]	
Master	6
Bachelor	4
High-school	1
High-school Poverty [c] [d].	
Mid-low	5
Low	2

[a]The total is above 11 because some participants indicated multiple race/ethnicities.

[b]The is the maximum of the two parents' higher level of education.

[c]Results by participant. The total is less than 11 because some participants did not provide high-school information.

[d]The poverty is defined by the proportion of students eligible for free-or-reduced priced lunch. Low: less than 25%, mid-low: between 25.1 and 50% [29]

4.2 Childhood and Home Environment

The first part of the interviews focused on the early childhood of the participants and the use of computers at home. It corresponds to the first chapter of UTC.

4.2.1 Access to Computers at Home

All of the participants had access to a computer at home, from a very young age. As Amy stated: "I don't remember a time when we didn't have it, you know?". And many participants began using the computer at four or five years old. It was "another toy", another everyday object.

Most of them even had access to multiple machines, as showed in table 4.2 below. No gender differences were identified in terms of access to computers at home. Most of the participants (8/11) had access to a computer shared with their siblings or whole family (these results exclude participants' own personal computers, discussed in the following subsection).

In some cases, the computer was reserved for the parents and the participant had reduced access, like Daniel[1] explains: "Easy access... Hum, not at first, it was the computer that my parents would use. It was kinda... it was a special treat to use the computer at that time." In other cases, the parents and the children equally shared a computer.

In the house, computers were located in a common room most of the time. Only one participant had a computer in his room. This is very different from what was exposed in UTC. Twenty years ago, children had much less access to computers (as shown in figure 4.1). Participants of UTC did not always have a computer at home. Besides, the computer was mainly in the son's room and, which made it more ac-

[1] All names are pseudonyms.

cessible for fathers and boys. Here, the computer is accessible to the entire family, including mothers and daughters. I think that this result is partly due to the accessibility of computers today and their centrality in 21^{st} century life. The fact that most families in the sample are White and middle-class also plays a part in this shift (although participants also came from White and middle-class backgrounds in UTC).

The placement of the computer in the house can also be used for parents to control their children's access to it. I found that most participants' parents wanted to control the time their children spent on the computer or what content the children used.

Table 4.2: The Access to Computers at Home

	Participants		
	Female	Male	Total
Number of Computers			
One	2	1	3
Two	1	2	3
Three	1	0	1
Four or more	2	2	4
Computer's Owner [a]			
Children	2	1	3
Parents	2	2	4
Family	3	2	5
Location [b]			
Common room	3	2	5
Participant's Bedroom	0	1	1
Father's Office	0	1	1
Parental Control [c]			
Time Control	3	3	6
Content Control	3	1	4
No Control	2	2	4

[a] Here the total is greater than 11, because multiple computers per participant are counted, although not all participants gave this piece of information.

[b] Not all participants answered this question.

[c] Here the total is greater than 11 because some participants were controlled over both time and content.

Parents' control over the content of computer activities mainly meant "educational use only". For instance Hannah recalls how she eventually had to use the computer in secret:

> In starting high school, we really, really liked to play online, but we would get in trouble because it wasn't educational at that point in high school. So at some point it was: you would wake up really, really early to play, but we would get in trouble because our parents, if they went to the restrooms, they would see a light from downstairs and that would be "The computer is on!" and "What are you doing?"

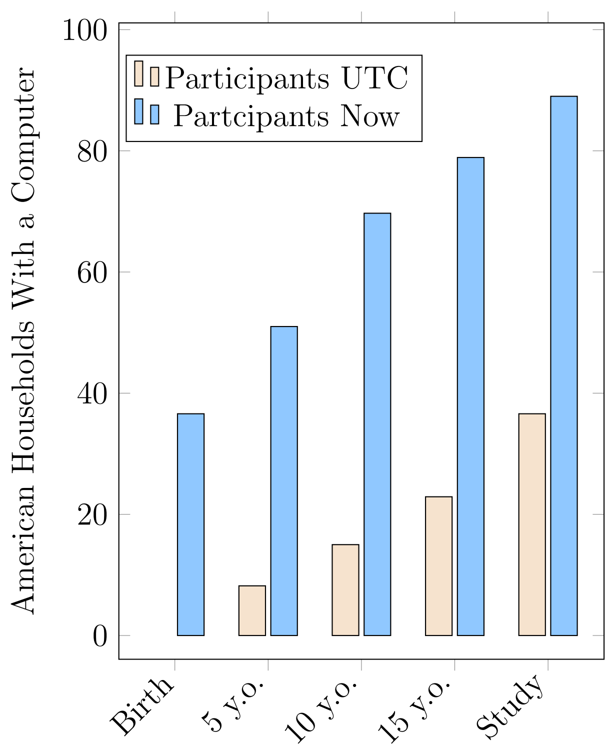

Figure 4.1: Access to Technology Over the Years [2]

[2] Data from the US Census Bureau, particularly the American Community Survey, in: UTC: 1984, 1989, 1993, 1997; now: 1997, 2000, 2007, 2012, 2016. [40] Internet access was surveyed only from 1997, the year of "Study" for UTC participants" and of "Birth" for participants in this study. I did not include Internet access data because there is not enough data to plot and compare.

Some parents included in the "no control" category in table 4.2 also wanted their children to use computers for educational purposes only, but did not control if it was the case. Lucy is such an example: "They trusted me enough, and I was already so stressed out by school, they knew all I was doing was schoolwork!"

4.2.2 Personal Computers

At the time of the study, all of the participants owned a personal computer, which is not surprising since a computer is required for students in CS and CE. Table 4.3 lists the circumstances in which they obtained their computers.

Table 4.3: Personal Computer

	Participants		
	Female	Male	Total
When			
Middle-school	1	2	3
high school	3	2	5
College	2	1	3
How			
Bought (parents)	3	1	4
Bought (themselves)	1	1	2
Built	0	2	2
Second-hand	2	0	2

Most participants had a personal computer before coming to college, some even before high school, i.e. when participants had more schoolwork to do on computers, as Amy recalls: "And so, my dad got me my own, because I was using it a lot for school and my brother only had to maybe do an assignment once a month.".

Hannah is one of the few who got her first computer in college and she explains why: "In high school, we had computer labs anyways and... it was expensive."

When it came to how participants got their first computer, the most common case was a purchase by the parents –Three participants declared that their father was actually the buyer. Only boys built their own computers, both helped by their father.

When obtaining a personal computer, some participants expressed their knowledge and interest in computer, by doing research, like Barbara did: "The one that I personally bought, and the only one that I personally bought, I did a lot of research on the type that I wanted, and I searched online (...) I wanted a specific laptop with custom specs and stuff like that." And others, like Eleanor, simply followed general school guidelines and chose their computers very differently: "I didn't do any research, or anything before (...) I looked at them all and (...) I found the one that had –it was like really cool, it had red under the keyboard– that's pretty cool."

Those results are in a way very different from what was observed in UTC, where only 17% of women had a personal computer as a child versus 40% of men. This huge gender difference seems to have disappeared.

But something that has remained the same is the role of fathers. They are still the primary buyers of technology in the house, the ones that introduce their children to computers: six out of eleven participants obtained their computer from (or with the help of) their father. The roles of the fathers will be further explored in the next section.

4.2.3 Skills and Use of the Computer in the Family

The Family Expert

The computer expert in the house is defined as the person who could fix computer problems in the house. The results of this question are summarized figure 4.2.

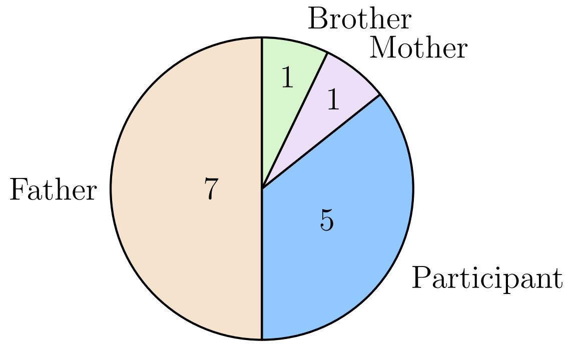

Figure 4.2: Expert in the house

As we can see, the father is the expert in most cases. But participants also became experts of the house, among them two were boys and three were girls.

We can also notice that the total is larger than the number of participants, because sometimes the father had been the expert until the participant surpassed him, like Amy: "When I was small, my dad usually fixed [the computer], (...) but it got to a point where I was 10 and I was fixing all the problems."

Another participant, Diane, explains how she fixed computer problems: "I like solving problems, I like puzzles (...) I would just sit with it, look at it, try to think, and I would do the right googling and then eventually get it fixed. So, they'd just call me."

Again through this question we see that the father has still an important role regarding technology at home. Besides being the buyer, he is also the fixer. This aspect has not changed since UTC. What has changed is the role of participants. Here I found that boys and girls learned how to fix problems on their own, thanks partly to the amount of searchable information available to them online and their access to technology –particularly a personal computer.

Participants

The participants began using computers at a very young age (four or five years old) and at the beginning, all of them mainly used it to play games. As Amy recalls:

“When I was like very small, my parents had a Macintosh computer that was the family computer and all I did on it was play.”, and Daniel too: “I remember... (...) I was probably 4 or 5 years old... (...) There was this like hot wheels, like racing type of game. I have no idea what happened to that game, but I remember playing a long time ago. It's the earliest memory that I guess that I have.”

After that, all of the participants started using the computer for schoolwork and the internet. In middle-school, many used instant messaging to communicate with their friends. Hannah is one of them, as she tells: “I guess later, when AIM [AOL Instant Messenger] was a thing, and er... internet got a little bit faster, AIM was the cool thing, instant messaging to friends and stuff like that.” and Sam too: “I know in middle-school we used instant messaging, so (...) if you wanted to talk to your friends or... the girl you're interested in, you had to... get on it and talk to them on there.”

From that point, the place of computers in the participants' life only grew. Differences in use and skills started to appear. Some began to use the computer for more advanced tasks, such as administration, fixing small issues or programming. Justin, for instance, learned some Java on his own at fourteen years old : “I learned a little bit on my own. I knew some Java going into the class, 'cause I had been messing around with it earlier. 'Cause I liked video games, I was like 'Hey, maybe you could make one!' Turns out it's really hard! [laughs]”. Like him, some participants also taught themselves web design or computer troubleshooting, while others learned from their father. Many had an interest in computing, although not all of them took a computing class or thought about computing as a career (see pathways to CS/CE).

Few of the participants had experiences related to computer hardware, and those were always introduced by a father or another male figure. Sam and Justin both built a computer with their father, whereas Barbara built one with her male cousin. For her, this activity was only a way to spend some time with her cousin, as she explains:

“We built one that he got that would change colors on the side. And, in reality at that time, I had no interest in computers, I was just building it to build it with him, but he would tell me where to put things.”

From middle-school, differences in skills and use appeared between the participants, although not necessarily by genders. Those who had an interest in computers or technology in general and had the opportunity to develop this interest (i.e a class in high school, or a relative in the field) did so and ended up studying computer science/engineering. Others took a longer path to come to CS/CE.

In Unlocking the Clubhouse, computers did not have many (or any) games to play on. The internet –when available– was too slow for instant messaging. The participants in UTC did not experience what we now think of the basic and everyday uses of the computer. They immediately began with advanced tasks, such as programming or building a computer. Most of the time, this type of advanced tasks had to be introduced by a parent or a relative –and this is still true today. Today it seems that, although basic use of the computer is popular and wide-spread, the advanced uses are still reserved to a portion of the population that already has expertise and is mostly male.

Parents role

At home, the participants’ experiences were also shaped by their parents, in particular their parents’ skills and attitudes towards computers. As are participants come form homes with one male and one female parent, my language will reflect this reality and be exclusive of other family configurations.

Six out of the eleven participants had at least one parent who was in computing for their job or hobby. Mostly fathers (six out of eight such parents) occupied this position. Besides, fathers played a greater role at home with respect to computers, as shown in the table 4.4.

Table 4.4: Parents role regarding technology at home

	Mother	Father	Both
Buyer/Owner	0	4	2
Teacher	0	7	0
Supervisor	0	0	4

I indeed heard many stories of fathers teaching their children different things on the computer, or sharing computing activities with them. For instance, Hannah's father taught her some basic administration skills:

> He taught me some, like you know the basics things of how to kill a program, or like go into the command prompt and little things like that. And see things that are running in the background, and how to system restore back to the previous day in case that, like that is the fastest way to get rid of a virus.

Sam also had a father in the computing world and he built a computer with him. An experience he remembers as being fun and instructive: "I think it was a really awesome time because... my dad had a lot of fun with it, I had a lot of fun with it, hum –It kind of gave me an insight into the box that was the computer to see it from, you know, we've got a case and okay now we've got a motherboard." Ialso heard several occurrences of the computers at home being solely bought or owned by the father.

These roles are linked to the skill level of the parents. A characteristic which I found to be unbalanced between the mothers and fathers. Mothers were typically found to be novices: Justin describes his mom as "clueless" regarding technology; according to Sam, his mother "doesn't understand technology at all"; Barbara also says "my step-mom is completely incompetent when it comes to electronics. (...) Yeah, my real mom's even worse"; and so on. On the other end of the spectrum, fathers were often described as experts or at least a person that had some knowledge about computers: Hannah's father "was pretty much an expert, especially in terms of hardware"; Chris's father "was in computer science as an undergrad"; Sam's father "is a computer scientist".

One remarkable exception stood in Eleanor's mom, the only mother expert, a computer engineer herself. She made a huge impression on Eleanor, as described in a further section.

I also found parents where neither the father nor the mother were experts: both had an average knowledge about computers.

The relation between the parents' gender and their computing skills is also described in Unlocking the Clubhouse. Families where both parents had none to few computer skills usually did not have a computer at home: computers were less common at this time. When there was an expert in the family, it was most likely to be the father. And the passion of computing was preferentially passed down from fathers to sons. In this study, I heard stories of fathers teaching their daughters, but the lessons covered only basics skills, from using Word to rebooting the Wi-Fi. The sons who learned from their fathers engaged in far more advanced activities, from programming to building a computer. This seems to indicate that the father-son connection is still used to introduce children to the computing world, to the detriment of girls.

Family use of the computer

Gender differences also appear in the use of computers by family members, especially parents (table 4.5). The biggest difference can be observed for the technical categories: software and systems, and hardware. Software and systems includes fixing software problems on the computer, downloading software and setting up a computer. Hardware includes taking apart or building a computer or changing a component. Fathers did technical tasks more than mothers: as I saw earlier, the father is usually the fixer.

I can also notice that many parents used computers in the house to work or do household related tasks. This is another witness of the centrality of computers in the family life, and maybe a reason why computers have moved from the boy's room to a common room.

Table 4.5: Computer Usage at Home

Usage	Family Member		
	Woman	Man	Total
Parents			
Work	5	5	10
Household related[a]	5	3	8
Technical: software and systems	1	7	8
Internet and social media	3	3	6
Technical: hardware	0	5	5
Entertainment	1	3	4
Other family members[b]			
Entertainment[c]	3	4	7
Internet and social media	3	2	5
Technical: software and systems	1	2	3
Art	2	1	3
Technical: hardware	0	2	2
School work	1	1	2

[a]Household related: budget, holiday plan, taxes.
[b]Other family members: siblings, cousins.
[c]Entertainment: video games (mostly), streaming videos.

Results on siblings' use show that they mostly used computers for entertainment. I did not collect many stories about siblings though, because not all participants had siblings and some siblings were (much) younger than the participants.

I still noticed that brothers were more often considered experts: four participants over the five that have a brother talked about how their brother was tech-savvy or into programming. Amy, for instance, describes him: "My brother was really into video games, and really into technology and so he was taking like a tech class at school (...). He plays video games on [his computer], he does digital art (...), he's done some programming..."

Sisters, on the other hand, tended to be described as not interested by technology or novices with computers (four out of six participants having a sister). Diane has a sister like that: "She likes using [computers]. She's not very interesting in how they function or why they do what they do or how they are capable in doing the things that they do."

Finally, several participants mentioned that their younger siblings had an even easier access to computers than they did. They reported that their siblings were comfortable using diverse devices (smartphones, tablets, computers) and had a better knowledge of technology.

4.3 Computers in School

In school, all participants had access to computers, found in different places, mostly a computer lab or the school library (figure 4.3).

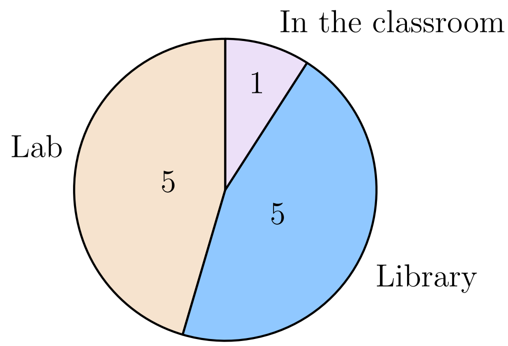

Figure 4.3: Computers in school

The participants reported using these computers for different tasks, but the main activity they did in regular classes was office-related: typing an essay on the computer, using a presentation tool or using spreadsheets. Few used the computer in more complex activities, such as art or other uses (scientific use, online activities in class). In other words, the participants mostly used computers in school to do basic office-related tasks.

Table 4.6: Use of computers in school

Accs	Participants		
	Women	Men	Total
Office	6	5	11
Online research	4	1	5
Games	2	2	4
Reading	3	0	3
Art	1	2	3
Other	2	2	4

Note that some of these tasks were asked in class but performed at home as homework. Justin explains it: "Yeah [we would use computers in regular classes], but not during the class. It would be required for most of our writing classes and stuff, like 'Hey, make sure this is typed.'"

The fact that most of the participants came from a middle-class environment and went to schools with low numbers of socio-economically disadvantaged students can explain why they used computers often and were asked to use a computer while doing their homework. Barbara moved a few times during her school years and noticed that:

> In Pistachio State (...) you had to have your papers typed out, you had to turn them in in a certain format. When I went to high school in Walnut State, they really didn't care. (...) It's because of the economy, they assumed you didn't have a computer, so computers were just kind of on the wayside.

4.3.1 Computer classes

All participants were also offered some kind of computing class throughout their school years. Again, the class that all participants had was an office class, teaching them skills from using basic functions of a computer (using an internet browser, typing with a keyboard) to office software (i.e. word processor, spreadsheets, presentation). This class was offered from primary school to high school. Lucy had it in high school: "One of [the classes] was typing –which was really kind of silly because at that point everyone knew how to do it."

Three other participants judged their office/typing class as boring or useless, Justin being another example: "From elementary school up till high school (...) the whole time we had computers, we had typing classes and I never learned a thing!"

Sometimes the "computer class" was a catch-all class: Eleanor, for instance, learned how to write a check with the baseball coach there.

Only half of the participants had also access to a programming class, most of the time AP CS or another entry-level programming class –one student had a more advanced class.

Those programming classes were all optional. Not all participants chose to take programming classes.

Table 4.7: Computing classes

	Participants		
	Women	Men	Total
Computing class			
Office	6	5	11
Programming	2	4	6
Digital Art	1	0	1
Programming classes			
Non-offered	4	1	5
Offered	2	4	6
Taken	1	3	4
Non-Taken	1	1	2

In this sample, few of the girls were offered the opportunity to take a programming class in high school. This gender imbalance may be due to the small number of participants interviewed.

When I've asked to the participants who took these classes about the proportion of girls in this class and found that girls were a minority. Sam for instance told me that:

> There was definitely more males which is sad. (...) They were efforts to bring in more women, so there was Girl Tech and some other things that were really awesome and that helped. (...) I've gone back –you know, to talk to my professors and stuff –and there's more girls now. Hum, but when I was there, there (...) maybe were 3 or 4 girls, in the class of 20.

This observation is supported by national statistics: according to the College Board, in 2012 and 2013, only 19% of AP CS test takers were female, in 2015 22% [13]. And it's not new: in 1999 (during UTC research), 17% of AP CS test takers were female [12]. As it appears, advanced computing classes in high school are still dominated by boys.

Technical clubs

Technical clubs are another entry into the world of computer science. Five out of ten participants had the opportunity to join such a club in high school. The clubs offered were robotics (3/5) and programming (2/5).

Table 4.8: Technical Clubs

	Participants		
	Women	Men	Total
Technical clubs[a]			
Non-offered	3	2	5
Offered	2	3	5
Robotics	1	2	3
Programming	1	1	2

[a]The total is equal to 10 because one participant gave an unclear report of the clubs present in her high school.

Robotics clubs are interesting because students can program a real and concrete application. But out of the three who joined the robotics clubs, two reported a poor learning environment and only one did some programming. Daniel, for instance, said to us:

> Definitely not... a good learning environment, cause the teacher didn't know anything about writing programming in C. So, actually I had to go to my dad for most of help with that, because no one else had any background knowledge

> on how to work with that. (...) It was really hard at the beginning; my dad is not a great teacher. He's good at programming, but he's really bad at explaining things... It was kind of overwhelming.

Hannah had a similar experience: her robotics club was supervised by a physics teacher who did not know how to program and the coding was done by a college student.

Poor teaching was also a characteristic of advanced computing classes or clubs in UTC. It seems that this has not improved much in the last twenty years.

Lucy, who had a programming club in high school, did not join it because it was the boys' thing. She recalls: "It was always completely dominated by males and I just didn't feel comfortable. (...) Being in an environment of males who... all they do is play video games and I didn't do that, so I didn't feel like I could connect with them very well." Another study participant, Justin, who participated in a programming club, came from the same high school as she did and described learning other programming languages (C++, PHP, Javascript) in this club. Justin did not mention video games at this point in the interview.

Her view of the club echoes the description found in UTC, where the authors explain that technical clubs (like robotics and programming) were dominated by boys who had a computer at home and liked tinkering with it.

4.4 Studying Computer Science/Engineering

4.4.1 Four pathways to CS/CE

While interviewing the participants, I realized that seven of them came from a different major and four initially chose CS or CE (see figure 4.4).

The participants came from scientific or engineering majors (electrical engineering, aerospace engineering, biology), but also from business and English. The boys all came from an engineering background while the backgrounds of the girls is more diverse.

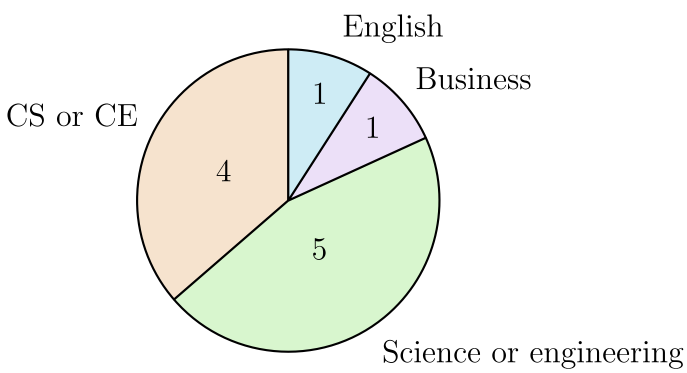

Figure 4.4: Participants' First Major

Actually, I distinguished four paths that the participants took to major in CS/CE: *the early bird*, *the late bird*, *the second-time-around* and *the legacy*.

The early bird

I called the first path the early bird, because it includes the participants who knew early on that they wanted to study CS/CE. From high school to college, they stayed on the path. They typically took a programming class in high school and naturally decided to continue in college.

Lucy belongs to the early bird category: she started HTML when she was ten years old, then took an AP CS class and recalls why:

> Since I started doing the web stuff when I was young, I've been constantly thinking about how much I can change and improve, using computers in everyday life and so by high school and having done a little more research and seeing more news articles, I was already pretty sure I wanted to go into computer science in college, so... It also counted as a foreign language. [laugh]

After this class, she indeed started studying computer science in college, as she planned.

The late bird

The second path, called the late bird, corresponds to a group where participants discovered programming late (in college) and then decided to study computer science/engineering. Late birds initially chose another major in college –sometimes even outside of STEM. They didn't participate in any advanced computing club or class in high school, because of a lack of availabilty or interest.

Amy is the typical late bird: during all her childhood, she mainly used her computer for typing and wanted to major in English. Her brother was very interested in technology and video games, but she was not: "At that time I wasn't really interested in doing computer science, I dont know... I was just like 'Its not my thing!'" During her interview, she mentioned her brother multiple times: he was the tech-savvy one, he got a very nice and expensive computer in high school, he took a programming class: "thats just been [laughs] his thing." In college, Amy decided to try a introductory class to computer science to fill her schedule and she got a revelation: "So I enrolled in that and it went great, it went so great. It was amazing, I was doing so well in that class –like everything he said to me, I understood perfectly for some reason." From this point, she decided to major in computer engineering.

Diane is also an example of a late-bird. Although she learned some administration systems skills with her father when she was young, she never programmed:

> He knew if you do like ip-config (...) the cache memory reboots the Wi-Fi. So, he told me how to do that, because he didn't want me to go to him and ask him how to fix the Wi-Fi. Hum, he told me how to use Word and Excel (...). He taught me basic things –but like I said (...) he never really taught me how to program.

Her high school did not offer a programming class. So she started a business degree. There, she took a mandatory Visual Basic class and also had a revelation: "I took the Visual Studio class and I was like 'I like this! I actually like this! And I wanna know more, I don't wanna do business.'" After that, she switched her major to computer science.

The second-time-around

The participants that are in the second-time-around group started programming early (high school or before) but then stepped away and re-discovered CS/CE in college. Some of these participants took a programming class or a technical club in high school, the rest got their first experience from somewhere else. But then something make them retreat from CS, e.g. poor teaching, lack of programming experience, or self-doubt. Luckily, they experienced CS/CE again in college, in the form of a programming for non-majors class (or other exposure) and decided to return to CS/CE.

Chris is a second-time around. The beginning of his path to CS/CE resembles that of Lucy, an early bird: he started web development at the age of nine and started programming at thirteen years old, with a coworker of his father. But the experience was disappointing –and here is where it diverges from an early bird path: "By the time I got into eighth grade I wanted to do computer science, and I had an interview with one of Dad's coworkers at his company, and he introduced me to programming

(...) He didn't really introduce it in the right way, so I kinda got distracted." By "got distracted", what Chris means is that he gave up programming and computer science. He majored instead in aerospace engineering. Later, he describes his second attempt at computing in college: "I was an aerospace engineering major and while I was there I took programming for non-major and I fell in love with programming for real."

Daniel is also a second-time around. In high school, he joined the robotics club where the main activity was programming in C++, but it went poorly:

> The teacher didn't know anything about writing programming in C. So, actually I had to go to my dad for most of help with that, because no one else had any background knowledge on how to work with that. (...) It was really hard at the beginning. My dad is not a great teacher. He's good at programming, but he's really bad at explaining things. It was kind of overwhelming.

After this experience, he gave up programming and started an electrical engineering degree. There he took a mandatory programming for non-majors class and got his revelation:

> I was like 'You know what? I dont know why I didn't wanna do this, this is suddenly really fun!' Because.. I mean, it just seemed like something that came really natural to me. I got to really appreciate the abstractness of computers (...) that I kind of missed or didn't notice back in the 8th grade.

After that, he switched to computer engineering.

The legacy

The legacies are the people who decide to study computer science/engineering to follow their parents' footsteps. Sometimes they did not have any previous experience in computing. But, still, they wanted to study CS/CE for a long time and drew their confidence from their parents' success.

Eleanor is the only participant who belongs to this group. Although other participants had parents in the CS/CE field (as a job or a hobby), she was most impressed by her mom's success in the field, as she describes when answering the question "Why did you decide to study CS/CE?":

> Because my mom did. (...) She looked at all the degrees that Emerald University[3] offered and she found out that this one was the one that made the most money, outside of college so she –that's when she decided to go, she had no computer experience at all. And so I figured I was at least half as smart as my mom, so if she would go through it and embrace, then surely I could do it too.

and earlier: "When I was little, at three oclock in the morning maybe, if you'd wake up you go see her, doing the magic [smiling] –that's what I thought it was. And, hum, that's what made me want to be a computer engineer in the first place."

Summary

Table 4.9: Four pathways to CS/CE

	1st experience	1st major	Participants
Early bird	high school	CS/CE	Lucy, Justin, Peter
Late bird	college	other	Diane, Barbara, Amy, Hannah
Second-time-around	high school	other	Chris, Sam, Daniel
Legacy	college	CS/CE	Eleanor

The above table 4.9 summarizes two characteristics of the four different ways the participants arrived in the CS/CE field. The first programming experience, which

[3] Pseudonym.

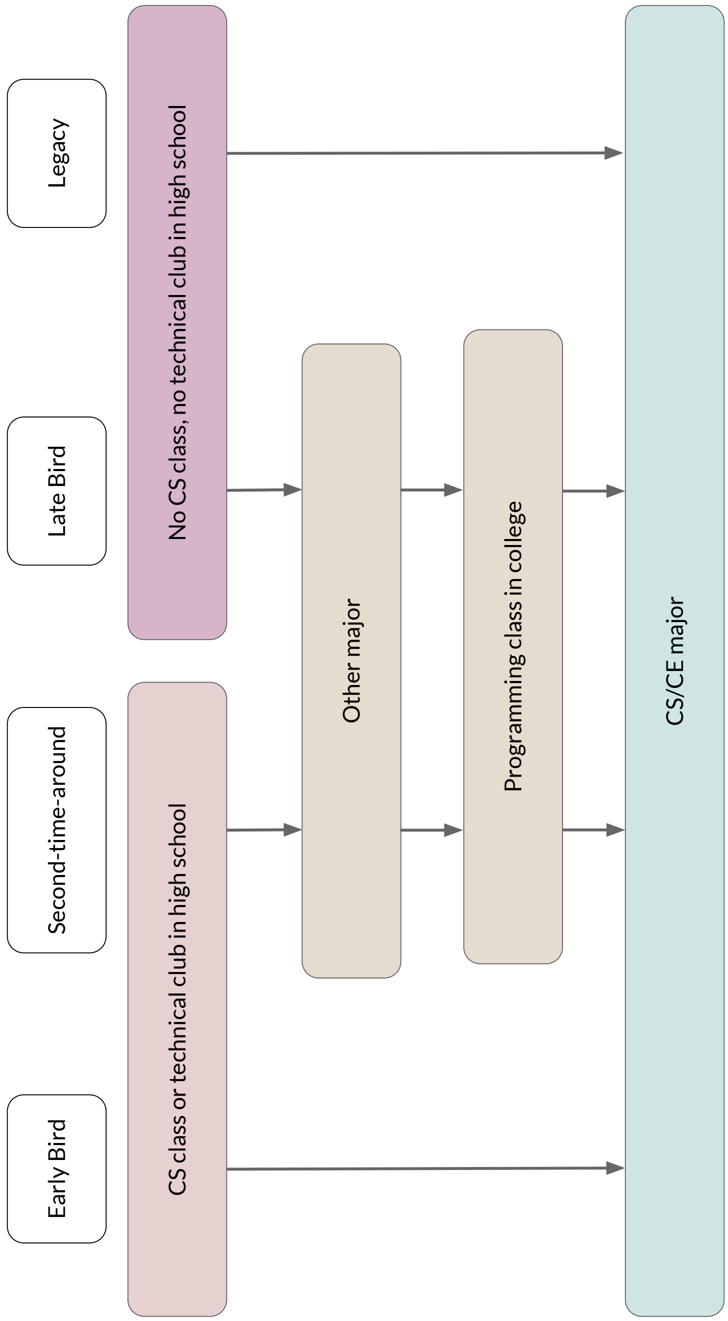

Figure 4.5: Pathways to Computer Science

occurred either in high school or college, and the first major, CS/CE or something else.

In UTC, we do not hear the stories of late birds and second-time-around people. Perhaps the highly competitive environment of CMU does not allow for second chances (in 2000, the acceptance rate for the School of Computer Science was 13% [23] and in 2018 5% [7]), or that CMU students are more secure in their early major decisions.

Another interesting thing coming from these results is the important role of a introductory programming classes: all of the participants except one took an introductory class in high school or college that motivated them to pursue a degree in CS/CE. In UTC, that pattern was prevalent for women but here both men and women experienced it.

All of the participants except one had an interest in technology or computers at first, even the late birds. The introductory programming class they took was simply the confirmation they wanted to enter the CS/CE field. Because most of the time, they did not think about CS/CE as a career or did not think they had the ability to program before taking this class. Actually, these doubts were the most common challenge the participants shared with us, as exposed in the next section.

In 2014, Cannady et al. proposed a similar model for students in STEM. Instead of the classic pipeline metaphor, they used the image of a network of pathways. They categorized four students' profiles with these two variables: taking a calculus class in high school, having an interest in calculus in high school. These four profiles all ended studying different STEM fields in different proportions [6].

Here, this study is focused on computer science and computer engineering. To characterize the four profiles, I also used the advanced class in high school, along with the first major (which could be seen as a measure of students' interest in the field).

But the first model does not include a legacy profile.

The parallels that can be drawn between the two models indicate that the profiles I found would probably be found again in potential replications. Both models allow for a better cartography of students' entry in and exit from the computing fields and should be further investigated.

4.4.2 Challenges in CS/CE

The participants also shared with me some of the challenges they faced during their pathway to CS/CE. The most common challenge found was doubt: self-doubt, doubt about the career itself. Hannah explains it this way:

> So, that's when it gets really hard and feels really frustrating: it's like, sometimes, there's this huge learning curve, it feels like everybody knows everything before. (...) I try to tell myself: You know, these people have been doing this for years, and I just started and they're really familiar with this system and I'm just, you know, a little puppy trying to learn how to swim.

Some female participants were also intimidated by a male expert in their family, like Barbara:

> I was really nervous, because my cousin is extremely smart in this, in this aspect, like that's what he does for the Navy –he codes and does hardware on aircraft for the Navy. (...) So, my cousin is extremely intelligent, so I was very intimated because when he would talk about it [computer science], I would have no idea what he was talking about, which is probably why I was apprehensive, to go in right away –it's because I was intimidated by him.

And there is also the fear not to match some unspoken CS/CE criteria. Sam struggled a lot with this issue, comparing himself unfavorably with friends in the field: "I was kind of intimidated, because I was like 'Maybe, you have to fit these certain criteria before you can be good.' Hum, and so there was like this beginner barrier that I was like 'Man, I dont think I can do it.'" But after a long battle with himself, and after succeeding in internships, he finally realized he could do it and now tries to encourage other beginners: "And you don't have to be a white man that was learning how to program since they were five –anybody can program! Like, you can be non-engineer, you can be engineer, you can be anything and learn how to code!"

These doubts are the main source of difficulty that the participants shared. This particularly resonate with a 2011 study by Lewis et al. who searched for the factors influencing the decision to stay in CS after the first introductory class in college and found that: "Comparisons with peers with respect to prior programming experience and speed caused some students to question whether they should pursue their interest in CS." ([22])

In chapter 5 of UTC, I also found a similar phenomenon: women are overwhelmed by the knowledge of their male peers and lack confidence in their own abilities. Here I discover that those who succeed enough in CS to stay still have the same fears and doubts.

Chapter 5

Conclusion

This study aimed to examine the childhood computer experiences of present computing students. We were interested in gender differences, comparisons with previous work (particularly Unlocking the Clubhouse) and the impact of these experiences on the decision to study computing.

We found that the technology advancement that have been witnessed in the past decades have changed how children and adolescents interact with computers and their desire to learn computing.

Some results found twenty years ago are still true today: the fathers still are the primary buyers, owners and experts in technology at home, reproducing gender stereotypes. At school, students do not always have access to advanced computing class (such as programming) and girls are still a minority in these classes.

We also found new profiles of students entering the computing fields: second-time-around students and late birds. These students discovered (or re-discovered) the computing world late in their path (in college). This shows that indeed, "You don't have to be a White male who was learning how to code since he was 5" to be in computing, especially in this case, you don't have to start very early. It also shows that the pipeline metaphor may need to be replaced by a "network of pathways" as suggested by Miller *et. al* and Cannady *et al.* [6, 27] to better picture the different realities of the students. Future research should continue to improve this model. For instance, some pathways may not be represented in this study because of the small sample size. With more data available, profiles may be better defined, regrouped or divided. Besides the role of the exposure to programming, future efforts should also investigate the role of the parents in the decision to major in CS/CE.

Since this research was conducted as a master thesis, time and scope were reduced. The number of participants in particular could be enlarged in future works, although it led to interesting findings. Qualitative research is always limited by its context, so reproducing similar experiences in other settings (community colleges, historically black universities, other U.S. regions...) could be very useful to further understand the varieties of pathways leading to a computing degree. Focus on underrepresented students (other than women) is also needed, since their experiences are probably different than those of their White and/or middle-class peers.

Acronyms

CE

Computer Engineering 16, 26, 55

CMU

Carnegie Mellon University 2, 16, 55

CS

Computer Science 1, 2, 5, 16, 26, 55

IRB

Institutional Review Board 20, 55

MU

Midwestern University 16, 55

STEM

Science, Technology, Engineering and Mathematics 7, 50, 55

UTC

Unlocking the Clubhouse 2, 7, 14–16, 19, 22–24, 27, 29, 31, 32, 34, 36, 42, 43, 50, 54, 55

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Appendix A

Survey

Below are included the survey questions that were asked to the participants. Parts of the questions are hidden to preserve the institution's anonymity.

Survey Questions

1. [redacted]

2. [mandatory, multiple choice]: Are you currently taking a 3000 or 4000-level course in Computer Science at [redacted]

    3000
    4000
    No (*If the participant answers no to this question, they will be excluded from the study.)*

3. [mandatory, unique choice]: Do you identify yourself as…

    Man
    Woman
    Other
    Do not wish to say.

4. [mandatory, multiple choice]: Which of the following best represent your race/ethnicity? Choose **all** that apply.

    American Indian or Alaska Native
    Asian or Asian American
    Black or African American
    Hispanic or Latino
    Native Hawaiian or Other Pacific Islander
    White
    Do not wish to say

5. [mandatory, unique choice]: Do you have a Graduate Equivalency Degree?

    Yes (*If the participant answers yes to this question, the next question is skipped)*
    No

6. [optional] Please fill the information below about your high-school:

    Name: __________
    City: __________
    State: __________

7. [mandatory, unique choice] What is the highest level of education of your first parent/guardian?

    Primary school or less (grades kindergarten to 6)
    Secondary school
    Attended some college

IRB NUMBER: 8791
IRB APPROVAL DATE: 12/18/2017

Completed college
Attended some graduate or professional school
Completed graduate or professional school
I don't know
I do not wish to say

8. [optional] What occupation does your first parent/guardian have?

____

9. [mandatory] Do you have a second parent or guardian?

Yes
No (*If the participant answers no to this question, the next two questions are skipped)*

10. [mandatory, unique choice] What is the highest level of education of your second parent/ guardian?

Primary school or less (grades kindergarten to 6)
Secondary school
Attended some college
Completed college
Attended some graduate or professional school
Completed graduate or professional school
I don't know
I do not wish to say

11. [optional] What occupation does your second parent/guardian have?

____

12. [mandatory] Please give us the following contact information so we may schedule your interview:

Name: _________
Email: __________

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Appendix B

Interview Protocol

Below is the protocol for the second phase interviews. It was developed with the help of Dr. Susan Walden. The first phase protocol did not include proper introduction and conclusion and included less "how" and "why" questions.

Start with scene setting

Thank you for being here. For my graduate research, I want to understand students' backgrounds with computers. I may ask about some things that may seem trivial to you, but please answer as completely as you can. Include examples and stories where you can to help me understand.

Please describe your first experience with a computer that you recall?

How old were you?

In what ways were you encouraged or discouraged to use computers?

How did you interact with others on or through computers?

What initially interested you about computers? If you lost interest at any time, what brought you back to computers?

How were computers used or treated in your home?

Did you have your own computer or use a shared family one?

- Location.
- Competition for the computer.

How did the way you used that computer change as you got older?

Describe how you got your own computer? How did that change how you used it?

In what ways were you encouraged or discouraged to use computers?

- Who encouraged you to use the computer? Who discouraged you? How did they do that?

Describe any experiences you had with computer hardware, e.g. putting cards or memory in, fixing or replacing failed components, building your own computer.

Describe any experiences you had with computer software: install new software, setup a new computer, creating accounts, backing up the computer, install an OS

How did your family members' computer skills differ and change?

Parents involved with computers as a hobby or job

Who was the go-to trouble-shooter?

How did your computer use for school change over the years?

How many computers were available in school?

How were computers used in school?

- Gender differences in school

What computer classes were available in school? Who took them?

If student took: What did you learn in them? How did they influence your interest in computer science?

How did you feel about those classes?

Did you participate in any technology clubs, summer camps or extra-curricular computing activities? How did those influence your interest in computers?

Describe the evolution of your computing skills?

Why did you decide to start programming?

- How was it challenging for you? How were you encouraged or discouraged?

Why do you study computer science?

Wrap-up

The full description of my research is that I want to understand the variety of early experiences with

IRB NUMBER: 8791
IRB APPROVAL DATE: 02/27/2018

computers and the interactions with other people about computers that may lead a young person to choose a computer science major in college. We started with questions from your beginning with computers, because It is easy and common for someone to overlook what may have been important sparks a long time ago.

- Now, thinking back on {insert a couple of their early and later experiences} - could you trace the most important parts and people on your path here - especially for any places where you made a decision that led this direction instead of another one?
- Is there anything else about your path to CS that you think I should know?

IRB NUMBER: 8791
IRB APPROVAL DATE: 02/27/2018