How CS Majors Select a Specialization

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ABSTRACT

As CS becomes a larger field, many undergraduate programs are giving students greater freedom in the classes that make up their degree. This study looks at the process by which students within the CS major choose to specialize in some area. In this study we interviewed student advisors, graduated CS students, and students currently in the undergraduate process about their view of CS and how they make decisions. The interviews were analyzed with grounded theory approach. The analysis presents four forces that affect student decision making. One, students often use the amount they enjoy individual classes as a sign of how well they fit with a particular specialization. Two, students often do not research, so they select specializations based on misconceptions. Three, students often rely on the curriculum to protect against poor educational choices. Four, students usually do not have a personal vision for what they hope to do with a Computer Science degree.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Curriculum*

General Terms

Design, Documentation, Experimentation, Management

Keywords

Curriculum, Concentrations, Tracks, Multi-disciplinary

1. INTRODUCTION

Recent trends in Computer Science education have given students more choices about their computing degree program. Schools such as Georgia Tech [7] and Stanford [14] have developed CS curricula that require students to select from specialized sequences of courses. Some of these specialized sequences highlight traditional areas of Computer Science (e.g., artificial intelligence, theory) and some highlight areas that combine CS with other fields (e.g., biocomputation). Students in these specialization–oriented curricula must select one or more specialization; each specialization contains both required courses and a constrained set of electives students select between. In general, colleges that have implemented these programs have reported that students are excited about the opportunity to specialize their coursework and that this excitement has improved CS enrollment [14, 7].

As CS Educators, the idea of students using specializations to design a course of study specific to their goals is appealing. Designers of specialization–oriented curricula are motivated by the idea that specializations allow students to pursue multidisciplinary options [14] and gain skills outside CS that make them more attractive to potential employers [7]. There are also potential problems. Students do not always make decisions based on the best educational reasons [11]. Previous work in Computer Science education suggests that students may not really understand what CS is [5]. Given that many CS programs are offering students more choices, it is important to understand how students choose the classes that make up their CS degree.

In this paper, we call a decision about which courses to take during a degree program a *curricular decision*. A curricular decision can be as small as choosing a particular elective course from a list or as large as choosing to switch to a major with different course requirements. Even in programs without specializations, students have to make many decisions about their curricula. In this paper, we will focus on how students select a specialization.

This paper presents a study of CS undergraduates at Georgia Tech. Georgia Tech has a CS degree program that allows students a great deal of freedom to customize their course plans. Students must select two of eight specializations or "threads": Devices, Information Internetworks, Intelligence, Media, Modeling and Simulation, People, Platforms, and Theory. By selecting two of these specializations, a CS major chooses about two thirds of the CS courses they take. Although this particular program is unique to Georgia Tech, we think that it is similar to curricular decisions students make at other schools. At other schools, students take a set of elective classes without ever officially stating they are pursuing one area of CS or another. Some schools also offer several CS–related degree programs (e.g., Software Engineering, Bioinformatics) that students select between. All of these curricular choices are similar because they require students to make real tradeoffs in their education and they require knowledge of the subfields of CS that ordinary col-

lege students would not have (e.g., the difference between CS and Software Engineering). Because many schools offer a great deal of freedom, it is worthwhile to look at what influences CS majors' choice at a more detailed level.

This study analyzes interviews of undergraduate students, graduated CS majors, and student advisors to understand:

1. Do students have an accurate view of the courses they are selecting when they make curricular decisions?
2. How do students make important curricular decisions such as which specialization to select?

2. RELATED WORK

In this selection, we look at two areas of related research. The first area is about student understanding of the field of Computer Science at the college level. Based on the related research, we argue that there may be some reason to suspect that students may still have some misconceptions about areas of CS when they have to make curricular decisions. The second area is about student college experiences and decision making beyond the CS field. Based on that research, we argue that student curricular decision making is likely to be complex (and, in some cases potentially problematic).

2.1 Student Understanding of the Field of CS

Much of the research in conceptions of the field of CS has focused on the perspective of precollege students, generally middle school and high school students. The large–scale WGBH study [16] of students age 13-17 indicates that careers in Computing interest students. That said, precollege students do not generally have a ready definition for "Computer Science"; both Greening [9] and Carter [3] asked high school students to define CS and found that students would generally indicate they did not know.

At the introductory college level, McGuffee [12] describes student responses to the question "What is Computer Science?" He reports that at the beginning of CS1, student conceptions are too broad, while at the beginning of CS2, students definitions are too narrowly focused on programming. In their work to develop a breadth–first CS1 course, Dodds et al. [5] find student views of CS to initially be mostly vague or naïve (though significantly improved after experiencing the breadth–first curriculum).

Biggers et al. [2] compares conceptions of CS in seniors: some of whom left the CS major and some of whom stayed in the major to completion. The CS seniors surveyed were likely to define CS broadly. This result was similar to a study by Hewner and Guzdial [10] in which CS seniors frequently emphasized the breadth of the field of CS in their essays about computing.

To sum up this work, what seems to be clear is that many students begin their study of Computer Science with an incomplete understanding of the field. By the end of their careers in Computer Science, their view definitely changes. But little is known about when students begin to gain a strong understanding of the field of CS; this suggests that students may be making educational decisions about what courses to pursue with a problematic understanding of the field of Computer Science.

2.2 Research on Student Educational Decisions

A great deal of research has been done on student choice. Large educational decisions like choice of college major have been shown to be influenced by a wide variety of both internal and external factors. Students differ in the amount of value they attach to different goals, self–efficacy, and how valued particular life goals are in their social groups [6, 17]. Students often change major in college, and the major change is often to a related field [1] which may suggest that they refine the partly uninformed choice they made when they arrived.

Once student have chosen a particular major, there is less research about how students come to understand the subfields and make major–specific choices like specializations. In longitudinal study of engineering students, Stevens [15] emphasizes that students experience the process of selecting a major and fulfilling degree requirements in very different ways. College requirements and factors outside the curriculum cause students to question whether they fit within their major. This "fit" with a major is often evaluated without really understanding what skills the major is trying to develop.

Even when students stay within a major, they can make their own decisions about what content is important if they feel the curriculum is not meeting their needs. Nespor's [13] observational study of management major culture at one school revealed that the student body felt the material learned in class was not valuable. As a result, the students collaborated to subvert their classes while at the same time practicing the interview skills and other interpersonal skills they believed were actually valued in the management community.

The main thing to take away from this research is that, in all majors, students struggle to understand and integrate themselves into their chosen major's curriculum. At least in some cases, students do make decisions about whether to persist in a major or focus on class material for different reasons than their instructors might expect. This suggests that understanding how students make decisions about their CS courses is likely to find some interesting results.

3. DATA SOURCES

This study is based on interviews with three different groups, for a total of fifteen interviews.

1. *Advisors.* At Georgia Tech, the Computer Science department has staff members to help undergraduate students succeed. All of the advisors worked with CS students for several years and answered student questions about what classes to take and academic problems. None of the advisors have degrees in Computer Science, although several have backgrounds in student advisement. We wanted to include undergraduate advisors because they deal with a broad range of students. We interviewed four advisors.
2. *CS Graduates.* We interviewed three participants who had graduated with degrees in Computer Science. We wanted to include graduated students because they could reflect on how the decisions they made as an undergraduate affected them afterward. Two of these students were in the Georgia Tech Ph.D. program, and one had a Computer Science masters degree who was working in industry. All of them did their undergraduate degrees at CS programs outside of Georgia Tech.
3. *CS Students.* We interviewed five students currently

taking the introductory Computer Architecture course. This course generally follows after courses on introductory programming, data structures, and discrete math. These students were all in the first or second year of their CS degree.

The introductory architecture course has an important place in the curriculum because it is the last course that every CS major, regardless of specialization, needs to take. Students are not required to have declared their specialization when they take this course but they will need to make a decision when they register for classes in the following semester.

Care was taken to select students that were having different levels of academic success in the architecture course. From our discussion with advisors, we knew that this course was often considered a "weed out" course for students, and from the literature [15], we knew that grade feedback has a strong influence on students' perception of themselves in the major. We also chose to interview two women, which was far greater than their representation in the actual class.

We also interviewed three students at later points in their undergraduate CS curriculum. We wanted to see how CS majors reflected on their decisions now that they had experienced specialization specific courses. These students were recruited from both traditional and interdisciplinary CS specializations.

The interviews themselves were semi–structured and took about an hour. Students were asked about their experiences in the CS major, how they viewed the field of Computer Science, and about the curricular choices they had made or were about to make. Students were also asked to reflect on how their views about CS had changed over time, and if they felt that misunderstandings of CS had caused them problems in the past. In situations where it seemed like students might have incomplete understanding of aspects of CS they were considering exploring, the interviewer would probe the student on details of what the student expected to learn and why they felt this area would be interesting or useful to them. We asked the advisors similar questions about their students: how the students viewed CS, how the students' views changed over time, and if students made choices that caused them problems.

4. METHOD

We chose a qualitative approach because very little is known about how students make educational decisions. Grounded theory was selected as the method for analyzing the interviews for several reasons:

1. *Emphasis on developing a theory grounded in the participants.* Because not much is known about how CS students make decisions about CS courses, we liked the explicit goal of developing a theory that could then be tested with other methods.

2. *Emphasis on integrating multiple data sources.* The interviews integrate the views of CS advisors, current CS students, and students whose undergraduate CS experience is long past. All of these participants are going to have a very different perspective; grounded theory encourages the integration of very different viewpoints as an important part of the theory development process.

3. *Theoretical Sampling.* Given the wide range of students, there is no hope of interviewing every combination of even a few factors that might influence student decision making. Instead, grounded theory suggests that the researcher should select later participants based on what emerges in the earlier interviews. This allows great flexibility, which is preferable in an exploratory study across a diverse population.

In our research, we chose grounded theory data analysis method outlined by Charmaz [4]. Our interview analysis started with line–by–line analysis of the relevant sections of interview transcriptions. We developed initial codes that describe what is being expressed in each line of the data. After developing initial codes, we went back through the body of research accumulated and selected 'focused' codes that explain larger segments of the data. Finally, we considered how each of the students fell on various dimensions (axial codes) that seemed to explain how curricular decisions were made. These axial codes formed the basis of the "forces" that we describe as our theory in the later sections.

To illustrate this process, here is an example quote that eventually became part of the "abdicating responsibility to the curriculum" force:

> Software engineering, it looked like it was more offered by lower tier colleges... I figured, even though I don't really like theory, there's probably some stuff in it that's useful and probably would make me a better programmer overall. So I figured I'll stick with Computer Science but try to take more practical side of classes.

One of the things we coded about this quote was the student's decision to rely on the reputation of the CS curriculum, despite negative experiences with CS theory in high school. The initial coding was abstracted into the focused code "trust in the curriculum", which included several other students who specifically mentioned they chose particular specializations because the specializations were considered "traditional" CS. When comparing looking at all our student choices, we noted the similarity between the code "trust in the curriculum" code and different students who argued that specializations were unimportant because they would all cover any really essential CS topics. From that, we created a superordinate axial code about how students negotiate with the perceived prestige of CS, even when they often don't know what parts of CS will be useful to them. Eventually, this code became called "abdicating responsibility to the curriculum".

4.1 Limitations

The larger study that these interviews are a part of is being expanded to incorporate students from different schools and in different stages of their degree program. As a result, the theories described here are still tentative; the data has still not fully reached saturation. That said, the particular part of the theory about student curricular decision making is one of the best elaborated portions of the developing theory.

Though this study attempted to get a variety of perspectives from current undergraduates, student advisors,

and graduated CS students, there are always limitations on interview–based studies. Because the size of the group was small, we cannot make claims about how prevalent the various viewpoints are in the student body. Other very different perspectives may exist in the CS student body. This study was based at a single school; every CS department's culture is in some ways unique. These limitations are part of any interview–based study: interviews allow us to deeply understand the situations of only a few students. Because not much work has been done about how CS students make curricular decisions, we feel that getting an accurate view of a few students is preferable to attempting to interpret the short responses in a survey or other larger–scale approach.

5. RESULTS

5.1 Enjoyment of CS Classes

In all the interviews, students made decisions based on how much they enjoyed particular classes. One student was hesitant to consider CS because of unenjoyable experiences in high school CS ("bad teacher") but was convinced to pursue the CS major because he/she enjoyed programming robots in the college–level CS introductory course. This sort of decision is common according to advisors – one might expect students who had initially incorrect views (e.g., CS as configuring computers and using applications) about CS to want to leave the major. According to advisors, whether students initially understood CS was less important than whether they liked programming. Students who enjoyed programming stayed in the major, even if it was not what they anticipated when they chose to major in CS.

Although grades and enjoyment seemed to be very strongly related, what students and advisors spoke about was generally enjoyment and not grades. In two cases in our interviews, students did not enjoy a class they did academically well in (although the reverse was never true – students never enjoyed a class they did poorly in). Despite the relationship between grades and enjoyment, the emotional experience of enjoyment (rather than pragmatic goals about maximizing their grade) was what students seemed to retain and use to think about future specializations.

Enjoyment of a particular class experience seemed to be a 'test' in students' minds as to whether they were a good fit within the major. Sometimes this led to students considering decisions that seemed counterintuitive. One student describes experiences in introductory architecture that caused him/her to seriously consider switching majors:

> Student: Well, I just wanna explore more aspects of where I could go and what I could do in the future, and so maybe having a more people-oriented major, more literature basically, which might involve the major computational media, so maybe I could explore that, but I just - I know that I'm interested in languages, and I've become more interested in history, so instead of just technology.
>
> Interviewer: So did you - would you say that it had anything to do with what you were learning about in [computer architecture] that made you reconsider this?
>
> Student: Yeah, I found it boring, and I didn't grasp it so quickly, so that generally discouraged me and what was good about that AP computer science class was that it was really slow and everyone was at your same level or below you.

What is interesting is that this student acknowledged that the architecture course was unusual—that the rest of the CS curriculum would probably be more like algorithms courses (which the student had enjoyed). Despite this, the student seriously reconsidered his/her major (although at the time of the interview he/she had decided to tentatively persist in CS).

Student enjoyment of a particular course seemed to trump specific life plans. The student who enjoyed robots in their introductory course planned to pursue robotics as a specialization. When we asked this student about future goals, the student was thinking about a career managing software developers, perhaps eventually returning for an MBA and starting his/her own business. None of the student's plans involved robotics. Not to say necessarily that robotics was a bad thing for this student; the point is that simply enjoying a particular course can exert a strong influence on a student's curricular decisions.

A student advisor who worked with students in choosing their elective sequences identified student enjoyment as a primary determinant of completion in a particular specializations sequence. The advisor argued that students would often choose a specialization such as Intelligence, based on an abstract intellectual interest (e.g., philosophical interest about the nature of human and computer intelligence). This caused problems when students were surprised by the large amounts of programming in the Intelligence specialization. By making the activities explicit in each of the specializations, the advisor hoped that students would have better success and not have to switch specializations later in their degree programs.

It's not news to say that students choose classes they think they will enjoy, or that students generally enjoy getting good grades in their classes. But a student enjoying (or disliking) a particular class may have a greater effect than their teacher realizes. Enjoying or not enjoying a particular course can significantly impact a student's curricular decisions and that change can happen without the student switching out of the major or failing the course itself. Oftentimes it is taken for granted that certain courses in any curriculum are going to be unpleasant; students experiencing these courses nonetheless attach meaning to what the bad experience means about them and about how they will pursue their degree going forward.

5.2 Confusion about Specializations

The students we interviewed were very close to the point when they would have to choose what specializations to pursue in Computer Science. They had all given some thought to the issue of what specializations they would choose, and some had taken an introductory 1–credit departmental course that introduced the specializations (among subjects relevant to freshman orientation). However, students often had incorrect ideas about the specializations they were considering.

Each specialization tended to have its on set of misconceptions. The Media specialization, for example, was often confused with with using commercial graphics applications such as Photoshop and Maya 3D. This specialization requires a computer graphics course which is then followed up with courses in video game design, computer animation,

or computer audio. The Media specialization was also often thought to include GUI design, even though HCI–oriented courses are in a different specialization. One student who was seriously considering the media specialization described it this way:

> Media? Well, that deals with media. So it could be anything in maybe the news, in broadcasting, certain media outlets like YouTube or Flash and basically design, I'd say. If you were designing a video game you might choose media as one of your [specializations] if you wanted to design one... [You would learn] Flash, different ways of representing just colors and to admit, that whole unit user interface.

Even when students did correctly identify the specializations associated with their interests, they often had only a preliminary idea of what content was associated with their specializations. One student was interested in robotics and correctly identified the two specializations of Intelligence, which is basically AI, and Devices, which is a mix of hardware–focused CS courses and ECE (Electrical and Computer Engineering) classes, as the two closest specializations. The student was trying to choose between these two specializations. However, the student could not identify any difference between what sort of robotics would be learned in the two specializations except that Intelligence likely had more theory (and was therefore a less attractive choice) while Devices had more to do with hardware.

Some students had an approximate idea of what would be covered in the various specializations; no student we talked to had a detailed knowledge of what specific topics would be covered in their specialization. Here is a student describing the Platforms specialization (which includes languages, compilers, OSes, etc.) in a way that is as specific as students were able to explain:

> Student: I think you really need a fundamental knowledge in platforms, how to create your own languages, operating system stuff, memory and all that. I think no matter where you go, whether you're working on a desktop or for mobile phones, you'll need a fundamental knowledge in platforms.
>
> Interviewer: So is there anything else? You mentioned creating your own languages and understanding operating systems and memory. Is there anything else that you think this is definitely important knowledge that you anticipate will be in platforms?
>
> Student: Yeah. Not really. I mean, I'm not really— I haven't set my plans in stone yet, so but this is like my general idea.

Based on this interview, this student seemed capable of making an informed choice of specializations. But it is worth noting that even students with strong interest in CS make curricular decisions based on approximate ideas about what they will learn.

In terms of selecting their specializations, students generally referred to the CS departmental website as their primary source for selecting specializations. The CS website does not get deeply into the specifics. For example, the website describes the Media specialization like this: "The media [specialization] prepares students by helping them to understand the technical and computational capabilities of systems in order to exploit their abilities to provide creative outlets." [8] While this is not how the student described Media in the quote above, it is also not specific about the serious programming requirements in Computer Graphics and other courses. The courses are listed specifically, but the student would have to do additional searching to find course syllabi or other materials. No students mentioned doing detailed internet searches, talking to advisors, or discussing things with professors. Several students mentioned talking with other students, but that discussion seemed to focus on which specializations were harder or easier.

Having a misconception about a specilization may seem like a small problem: if students have bad experiences in a specialization course, they can easily switch specializations (perhaps with the added benefit knowing a little more about a subject they might have avoided if they were better informed). Advisors noted that switching was a problem for some students because too many specialization switches could delay graduation. Students who wanted to switch out of one specialization often had to make a choice: either select a specialization that would guarantee them high grades (and on–schedule graduation) or choose another specialization based on interest (and risk delaying graduation if the new specialization had problems and they needed to switch again).

Even for students and advisors who fully understand the choices involved, selecting something like a specialization is rarely clear. Our interviews made it clear that students often do not take the time to fully understand the tradeoffs they are making when they select specializations. Instead, students are choosing specializations with vague ideas or sometimes clear misconceptions.

5.3 Abdicating Responsibility to the Curriculum

> Interviewer: Would you say there's any difference in sort of what your area of specialty would be if you take devices versus artificial intelligence?
>
> Student: Actually I really don't think so. I don't think, because when you graduate from Georgia Tech you just have like a computer science, you're a computer science major. It doesn't specify anything about [specializations] but I feel like once you take classes here you just focus on different aspects but you have some similar classes as well... While we're talking about it I'd rather take a devices [specialization] just because there's a lot more ECE classes and I think once I graduate the jobs, I think I would have the same number of jobs available if I took either of them. I don't think it'd make a difference.

This quote exemplifies the attitude of many of the students we interviewed: they generally believed that no matter what specializations they choose, it would not make a significant difference post–graduation. Although this student is probably right that both specializations have good career prospects, this student does not seem to understand the big differences in jobs between someone focused on device design and AI work. At another point in the interview, we

asked the student to talk about potential robotics projects in the various specialties: again the student suggested that the two specializations were pretty similar. By assuming that the curriculum ensures that all students are prepared for careers and just focuses on "different aspects" of the same thing, the student makes the choice of specialization more about personal interests than long–term goals.

One of the advisors stated that student ambivalence to specializations comes from CS industry recruiters. Because the employers student speak to at recruiting events, such as career fairs, do not understand Georgia Tech's specialization system and do not ask for particular specializations, students view their choice as essentially unimportant. It also may be that because students are not ready to commit to a particular long–term goal, they have no choice but to assume that there will be no long–term repercussions of a poor choice of specialization. However, looking at the curriculum, it is definitely true that the choice of specialization has a huge impact on what the student learns in CS. The specialization system at Georgia Tech gives students a great deal of control, including the control to avoid classes that employers in certain careers assume CS majors will have.

Students also left the responsibility for choosing courses to the curriculum in other ways. Several students, when explaining their choice of particular specializations, made it clear that they selected the choices they did because they wanted the "traditional" computer science experience. When we pressed them, they made it clear that although they were unclear on some of the courses in these specializations, they were confident that the courses would give them the best possible background to pursue CS. Their commitment to CS was interesting insofar as they frequently did not have a detailed idea of what they wanted to *do* in Computer Science.

One graduate student we interviewed had a story about their experience in CS that emphasized relying on the curriculum can sometimes make students unaware of parts of their education that may be missing. The student entered the Computer Science of a small liberal–arts school with an explicit goal to program video games. In the spring of his junior year, he applied to internships at a variety of video game companies (and no where else). In the interviews, he was surprised by the questions on computer graphics: his small school did not have computer graphics courses and he didn't realize that that would be important to a video game career. Interestingly, his school had paired him with a professor in the CS program as an academic advisor, who he met with to discuss course requirements but he never brought up the issue of video games. This student was positive about his experience in CS overall — perhaps because he was enjoying his CS coursework and making good progress, he did not stop and reflect about whether all the skills he needed were being taught in class.

Students were also quite willing to believe that the materials covered in their courses were good for them, even if they couldn't explain why. We asked students to comment on courses they disliked, then asked them to explain why they felt the material was in the curriculum. The most common answer was that the course taught ways about thinking about things that would change their perspective.

Students definitely seem to trust that the courses offered to them contain what they need to achieve their goals. Advisors mentioned that students frequently complain when courses listed in their specialization are not offered. Students do not, in general, request that the university offer courses about topics currently not in the course catalog. Students in interviews frequently said that they liked the control the specializations gave them over their curriculum, however before the specialization system was implemented advisors said that students did not in general complain that they had insufficient control. This suggests that students are willing to take their cues from the curriculum about what is "possible" in Computer Science. On one hand, this explains why students are attracted to curricula that explicitly include some of the broader possibilities of CS. On the other hand, when students simply assume that everything the curriculum allows is different aspects of the same content then they may be setting themselves up for surprises after graduation.

5.4 No "Big Picture" CS

Giving students freedom in their curricular choices allows them to engage with CS in new ways and potentially pursue multidisciplinary goals outside the framework of "traditional" CS. The CS departmental website deemphasizes programming and emphasizes that Computing "enables progress in nearly any field imaginable and drives social and scientific advancement in the world" [8]. Based on our interviews with students however, students are often vague:

> Interviewer: Okay. So what would you say your goal is post-graduation?
>
> Student: To get a job. That was basically my reason for going to Georgia Tech and technology is of the future, and we always need computer scientists if we're gonna have computers dealing with every part of our lives.
>
> Interviewer: Do you have any particulars as to sort of what kind of job would be particularly exciting?
>
> Student: Maybe in a bioinformatics field. I was considering that earlier, but anything's up for grabs, anything that would be involving design maybe or biology.

Other students expressed similar uncertainty. One student was considering either continuing in CS to get a Masters or Ph.D., perhaps joining the Navy, perhaps web programming. Discussion with advisors indicated that this sort of confusion is common, that students often are unsure what they want to do with their CS knowledge after they finish their introductory coursework. Even students who are focused on programming and know which specializations they are interested in do not seem to have a particular vision beyond "working as a game programmer" or "working at Google" (because they've heard it's a fun job).

Students as a whole seem to view CS as a set of technical skills that employers will find valuable. Although students generally thought of CS as something bigger than simply programming, they could not think of careers for someone with a CS degree that were not programming–related. At the time they selected their specializations, students did not think about themselves as innovating or their specializations as representing exciting multidisciplinary approaches.

One of the graduate students we interviewed expressed a similar feeling, that as an undergraduate he felt initially very excited about CS and programming, but that he viewed

it simply as techniques for implementing different kinds of computer programs. Near the end of his undergraduate curriculum, he decided that CS was boring and switched majors. Although he eventually returned to CS, he expressed regret that his undergraduate courses did not give him the "bigger picture" view of CS that he later developed in graduate school.

Some students we interviewed had approximate plans for after graduation and some students had no concrete plan. None of the students we interviewed were motivated by a view of CS as multidisciplinary or CS as a source for societal change or even had a particular area of CS that they had explored on their own. It is not unreasonable for students to be motivated by more practical concerns, but this does suggest that students do not treat the ability to customize their curriculum as a way to realize an innovative personal vision of the field of CS. This suggests that there may be a disconnect between the way flexible curricula are marketed and the way students within those curricula really make their decisions.

6. A TENTATIVE THEORY

Although the student interviews have not achieved saturation, based on the interview data described above we have developed a tentative theory that describes two unexpected influences that seem to be unexpected parts of student curricular decision making:

- *Abdicating Responsibility to the Curriculum.* Students are willing to assume that the curriculum is designed to put them in a good position to achieve their goals. For some students, this causes them to make the assumption that every specialization is essentially the same. For others, it encourages them to take what they view as the most "traditional" CS topics even if they do not fully understand the intentions of these courses. For both groups, trusting the curriculum allowed students to avoid making a commitment about what their long term goals are.

  The idea that students might be undecided about their long–term goals is not surprising. What is interesting is that when they are undecided, rather than explicitly choosing a set of specializations that are flexible, or choosing a set of specializations that let them explore a set of possible interests, students will assume that the curriculum itself will ensure they make good choices. Even more, it seems that students are willing to make this assumption without conferring with an advisor.

  This is also interesting because, based on previous research, there was reason to think that students in CS might explicitly reject their curriculum. The management students Nespor [13] interviewed exhibited the opposite behavior – building their own curriculum to match their view of the management world. There are also anecdotal stories about students rejecting the CS curriculum – for example students who refuse to learn languages not used in industry, or who question the utility of CS theory. At least at Georgia Tech students blindly accepting the curriculum seems to be a bigger problem than students rejecting it.

- *Enjoying Classes.* Although it is not surprising that students consider going further in classes they enjoy, it seems that for many students the extent to which they enjoy particular classes is an extremely strong motivator. Students pursue classes they enjoy, even when their personal goals are in other areas. When students do not enjoy classes, they can interpret that lack of enjoyment as a sign they are poorly suited for some area of CS, rather than as a problem with a particular teacher or class.

There are two things that we might have suspected would influence student behaviors but did not seem to, at least in the students we interviewed:

- *Detailed Understanding of the Specializations.* None of the students we interviewed had detailed knowledge of the courses they were considering. None the students referred to speaking to either faculty in the various specialization areas or trusted experts (e.g., other faculty, contacts from internships, etc.). None of them mentioned doing research for this decision beyond examining the CS department webpages. Sometimes, students even had very significant misconceptions about specializations they were considering. Overall, the impression the students gave was that they did no<t consider the selection of specialization areas to be a major decision.

- *A "Big Picture" Vision of CS.* Part of the argument for allowing students choices in their curriculum is that students' have individual opinions about what is exciting in Computer Science and want the freedom to design a multidisciplinary curriculum for themselves. Despite the language present in sources students used (such as the CS department website) students did not talk about things like computing's potential for innovation. Given the misconceptions students had about the content of the specializations, we are not sure that most of the students really had a clear enough understanding of what computation could do, to have a clear vision of computational innovation.

All the students we talked to were influenced by other normal forces that you might expect. Students were concerned about specializations that they had heard were academically difficult. Sometimes they preferred one specialization over another because it just "sounded more interesting". Advisors mentioned that students often selected specializations based on which could get them a degree most efficiently and by what specializations were thought to command the best salaries.

7. DISCUSSION

This theory suggests that students may not attach as much importance to curricular decisions as instructors and curriculum designers might hope. If we want to ensure students make well–informed curricular decisions, we need to treat the information about curriculum like any topic we teach. Students at Georgia Tech had taken a class that supposedly covered this material; perhaps more careful testing needs to be done to ensure students really understand what is being presented. Students may also be taking a cue from the fact that they never need to apply or officially 'declare' a specialization; by making the choice more explicit it might be possible to encourage students to evaluate their options more carefully.

Students were tentative about their goals in Computer Science; they were motivated by short term factors such as class enjoyment and were hesitant to commit to specific things they hoped to learn or do with CS. One of the rationales given for specialization–oriented curricula is such curricula allow students to pursue unique approaches that go beyond traditional CS degrees [7]. It seems that this sort of "big picture" goal does not come naturally to students. Students seem to like the idea of choice but that is not because they have a strong particular vision for themselves or the field of CS. With encouragement, students might be able to articulate a personal vision for CS. This kind of "big picture" view of CS might let students choose specializations without giving so much weight to classes they enjoyed or what specializations are easiest.

The extent to which bad experiences in classes were part of student curricular decisions is concerning. Obviously, no instructor designs a course to frustrate students. That said, a bad class seems to be able to exert long term effects on what courses students pursue in the future and how confident students feel as Computer Scientists. Even if some courses have to be difficult, there are plenty of ways to try and prevent student frustration from getting too high.

8. CONCLUSION

Although this study focused on the students at one particular CS department, we believe the results of this work can be useful in any CS program where students have to make significant decisions about what courses they should take. Students who feel strongly connected to the CS major are likely to take courses they view as "traditional", even if perhaps the longer term goals might benefit from exploration outside the major. Students who have had unenjoyable experiences in their CS classes are likely to try and select paths that let them avoid classes they feel ill–suited for. All students are likely to make curricular decisions based on a cursory understanding of what topics are covered and some students can have misconceptions about their courses that may cause real problems.

Although this paper has pointed out some significant issues with student curricular choice, it is worth emphasizing that the authors do not think the idea of student choice is necessarily a bad thing. In our interviews, students often remarked that they liked the idea of having choice. Beyond that, after graduation all CS major have to learn on their own if they intend to maintain their skills; graduates have to make educational choices. By understanding the difficulties students have with curricular decisions, we can help support students to make good choices in school as well as after graduation.

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