How CS Undergraduates Make Educational Decisions

Author details suppressed

ABSTRACT

Students in most CS curricula have to make a wide variety of educational decisions including what courses to take. Frequently, they must make these decisions based on a very limited knowledge of the content of the topics they are choosing between. In this paper, I describe a theory of CS undergraduate educational decisions, based on 37 qualitative interviews with students and student advisors, analyzed with grounded theory. Most students did not have specific educational goals in CS and, as long as their classes were enjoyable, tended to assume that any course required by the curriculum had useful content (even if they could not articulate way). Particularly enjoyable or frustrating courses caused them to make long term educational decisions and use a more strategic goal–oriented approach.

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, Multi–disciplinary

1. INTRODUCTION

> "Like I was signing up for fall classes. Okay, do I want to take processer design or operating systems class? And, to be honest, that stuff looks very similar to me from my shoes, right. I don't know anything about either one, so how am I supposed to distinguish them?
>
> So is there anything I wish like I'd been told? Well, yeah. I wish people would say like - I mean it's sort of impossible to tell you about it until you're actually in it and doing it . . . they don't sit you down and say, okay, look at this screen of assembly code. That's what you're gonna do if you go into platforms."
>
> —Junior, Engineering School

Undergraduate students in Computer Science find themselves in a difficult position. Their understanding of the field of Computer Science is still evolving, and yet in most curricula they must make decisions about what to learn. Often these choices are extremely subtle: operating systems or processor design. Both topics have their utility, yet understanding the trade-offs requires a solid knowledge of the topics covered. Yet students make these decisions routinely.

A student's decision is likely influenced by many factors [7]. If a student has specific goals in Computer Science, they will need to reason about the courses they are selecting and their benefits. This is complicated by the fact that students generally do not have a detailed view of the subfields of CS and how they are useful [9].

If a student does not have specific goals in CS, how do they make important courses decisions? They could choose courses based on causal interest. They could attempt to choose the easiest courses possible. They could attempt to select courses that would 'keep their options open' and expose them to a wide range of the field (although this requires detailed reasoning about the field of CS itself).

Based on my interviews, there is are two modes of student decision making. One mode is an exploratory: students take courses of casual interest, working within the framework of the curriculum. The second mode is goal directed; students do have a particular plan and are willing to do detailed research to achieve them. What motivates the transition between these two modes seems to be a strong emotional experience in a course. When students greatly enjoy or greatly dislike a course, it motivates them to make long term educational decisions and begin acting more strategically.

This work presents a theory of student educational decision making in CS, based on 37 interviews with students and student advisers and analyzed with a grounded theory approach. The goal of this research was to understand how undergraduate CS majors make educational decisions and if misconceptions about CS cause problems. This paper first presents the design of the research study, then discusses the resultant theory, then compares the theory previous work in CS and other disciplines.

2. METHOD

ICER '14,

My study was an open–ended qualitative interview study designed to understand how students think about computer science and their educational decisions throughout their undergraduate program. I interviewed 33 students, the majority of whom were undergraduate CS majors (a few were recent graduates or students who had not yet chosen to major in CS). The interviews were between 45 and 60 minutes. I also interviewed four student advisors about their experience advising undergraduate CS majors.

2.1 Sampling and Recruitment

Recruitment was done through presentations in CS classes. Students were asked to volunteer and offered a gift certificate to compensate them for participating. To select students to interview, I used the grounded theory practice of theoretical sampling [2]. In theoretical sampling, a researcher begins with an initial population to interview and then selects future candidates based on what would further help elaborate the developing theory. This allows the researcher to discover factors that seem to have an effect on interview responses and pursue them. However, this method does not attempt to make the sample statistically representative.

I selected students to interview in order to get a range of academic success, gender, and ethnicity. Students were recruited from CS programs at three different schools:

- A competitive engineering school with a curriculum that allows a great degree of student choice in CS courses.
- A competitive liberal arts school with a more proscribed CS curriculum but greater focus on multi–degree programs.
- A traditionally African–American Woman's college.

Students were interviews at all stages of their undergraduate careers, with particular focus on sophomores and juniors.

2.2 Interview Method

The initial goal was to explore if student misconceptions of the field of CS caused educational problems when students attempted to select their classes or otherwise made educational decisions that required them to reason about CS as a field. The initially proposed study included detailed questions about computer architecture, compilers, to probe if students understood the relationship of these sub–disciplines as they made educational decisions.

As is common in a qualitative approach, the initial research questions proved to not match the participants' understanding of the situation. Initial interviews used fairly focused questions, asking students about specific courses or topics and reflect on their relationships with their goals. E.g, "Do you think you might use [topic X] in the future . . . How?" Initially, it was quite clear that students had no familiarity with the topics of future CS courses. Some students were adept at reasoning about what might be covered in the future, some were very far off base (e.g. operating systems being about configuring Unix servers) but for both groups it was clear that they did not use similar reasoning when selecting courses. Even when selecting courses that students presumably had some familiarity with (e.g. courses they had already chosen to take next semester), students repeatedly reiterated that it was their expectation to have the course syllabus on the first day be their first introduction to the topics of a course.

In later interviews, questions began with asking students about their own experiences in the major. I asked students to describe their courses and courses they were interested in the future. Usually this would naturally segue into a discussion of decisions they had made and why they made them. Students would reflect more freely on their own processes and even occasionally probe their own decision making reasons.

2.3 Checks to Ensure Validity

When attempting to understand student conceptions, there is a risk of misinterpretation and bias. This is a common problem in qualitative research; even when participants and researchers act in good faith, it is difficult to understand when backgrounds and assumptions are different. There are a variety of techniques to mitigate this risk [10]. I used two: triangulation from multiple data sources and member checking.

For triangulation, I used a written survey instrument with concrete questions about CS, handed to students after the in person interview. However, there was difficulty taking the very open ended approach used in the interview process and turning them into questions of sufficient specificity in a written form. Given the completed theory, I think it would be possible to design an appropriate questionnaire but they surveys I used focused on issues of student conceptions and therefore do not provide an effective triangulation,

With three students, I also used member checking: providing the student with my analysis of their educational decision approach and asking for feedback. In one case, I contacted the research participant after the initial interview and reinterviewed them with the my interpretation of their viewpoint. In two others, I presented my analysis after the regular interview process concluded. The students agreed quite strongly with my analysis (even after careful probing to attempt to mitigate power differential that makes agreement suspect [2]). Still, a greater amount of member checking would be preferable.

2.4 Grounded Theory Analysis

A grounded theory is based off careful line–by–line analysis of interview transcripts. My process was based off the approach outlined by Charmaz [2]:

1. First the researcher develops initial codes that describe what is being expressed in each line of the data.
2. Second, the researcher goes back through the body of research accumulated and selects 'focused' codes that explain larger segments of the data.
3. Third, the focused codes are abstracted into categories in a tentative theory that is then checked against other parts of the data to test its explanatory power. There are several techniques to help the researcher attempt to develop the categories in this larger theory including: axial coding [4], theoretical coding [2], and situational maps [3].

For example, consider the quote below:

> "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."
>
> —Sophomore, Engineering School

One of the things I 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 student responses, I saw similar but different responses: students who argued that specializations were unimportant because they knew the curriculum would cover any really essential CS topics. I created a superordinate code about how students assume the CS curriculum will teach them everything they need to know, even when they often don't know what they really want from CS. Eventually, this code became called "abdicating responsibility to the curriculum."

2.5 Revising the Theory

Throughout the grounded theory process, there are tentative theories. These theories are being put to the test in later interviews, and during analysis processes like situational analysis (see the next section). Usually, initial generalizations turn out to not to be universally true. Contradictions triggered me to revisit the source data and to become more nuanced which moves the grounded theory forward.

For example, at one point in the analysis, the idea that enjoying classes was the main determinant for student educational decisions was a major part of the tentative theory. There were a variety of codes having to do with student enjoyment like "frustration causing reconsideration", "enjoying classes involved in educational decisions", and "just choosing what sounds 'interesting' ". But, by looking at the counts of each code, other codes like "parental involvement" were almost as common. That seemed wrong insofar as enjoyment seemed to figure greatly into student decisions, but parental involvement definitely seemed more peripheral. It was clear that something about student enjoyment was being missed, so I went back through the codes and attempted to understand the role of enjoyment more clearly.

> "I got [to my architecture course] and I was like, 'I don't understand any of this. I don't really like it.' So I switched to [the people specialization] which I like a lot more. I have a lot of interest in psychology. I'm actually getting a certificate in social and personality psychology . So I switched.
>
> And I was kind of hesitant at first when I talked to my — the advisor in the CS department, because I was like, 'This - that really isn't as good for a career in video game animation and special effects or whatever I decided to go into.' She was like, 'It's not.' "
>
> —Senior, Engineering School

Quotes like the one above made me realize that there were different kinds of enjoyment experiences. Weaker positive experiences encourage students to explore. But when a student has a very negative experience in a course, it often triggered them to make an educational decision. Then when they're making that decision, they solicit advice from parents or advisers (as in the quote above). But the experience triggering the sudden reorinetation is the emotional experience of enjoyment, which is why enjoyment seemed abstractly to be more important than, for example, parental advice. This idea eventually was revised even further into the overall idea of student educational decisions that is discussed below.

3. A THEORY OF STUDENT EDUCATIONAL DECISIONS

In this section, I propose a theory of CS student educational decision making based on my interviews. I begin with some of the puzzling student behaviors that suggests that students make educational decisions differently than one might expect. The overall theory is this:

1. Students initially start focused on *exploration*. They have *no concrete goal in CS*, and they don't attempt to gain a detailed view of the field quickly. Instead, they take courses as prescribed by the curriculum. They make the assumption that the curriculum is designed so that (regardless of what they might eventually pursue) it will put them in a good position. I described these students as *abdicating responsibility to the curriculum*. If the curriculum forces them to make educational decisions, they will select them mostly based on casual interest, confident they all options are equally viable.

2. The exploratory approach continues until students experience a contrasting enjoyment experience: a course that is either much more or much less enjoyable than the others (most commonly less). Then *contrasting enjoyment experience triggers the student to make educational decisions*. Often, they will narrow their educational focus and more clearly define their goals. The student may choose majors, specializations within majors, etc. Usually the student also solicits advice from parents, advisors, and websites at this point.

3. Once their educational focus is sufficiently narrow, students develop a concrete goal. At that point, students' approach changes to *making educational decisions based on long term goals*. At this stage, they do attempt to reason about future courses and make strategic educational decisions. For most students, this occurs late in the undergraduate career if at all. Note that a student can make an educational decision at one level of detail (e.g. picking a particular CS specialization) and then act in an exploratory way within that decision (e.g. trying various subspecialties).

The following sections explain the various parts of this process in more detail.

3.1 No Concrete Educational Goals

> "It's hard to remember [why I took a CS class at first] . . . I thought I was kind of interested in,

> cognitive psychology and stuff and there's basically one — cognitive science actually. There's basically cognitive science course and it has as its prerequisites one of the following and the intro to Computer Science was one of them. So I kind of had it in my head like 'Oh, I'll take that and that's offered in the fall.' So I couldn't take that in the freshman fall âĂŸcause I hadn't taken any of the prerequisites. And then I ended up taking, like, all of [the prerequisites] and never taking that other class."
>
> —Junior, Liberal–Arts School

The first thing to know about students' decision making is that most do not have a concrete educational goal in Computer Science. As with the student in the quote above, a student's decision to take classes in CS might have nothing to do with a particular interest in the major. Even for students who select the CS major before they come to college, they may have enjoyed programming on their own but they almost never have researched the field of CS or what job they would like after graduation. Not having a goal makes the process of student educational decision making much different than you would expect.

For example, when talking with a student advisor, the advisor estimated that a third of incoming CS freshman have a very off–base view of what CS is about. Given that, one might expect to see a fair number of students initially major in CS and then quickly shift to another major that is more in–line with their goals. However, this does not seem to be a problem because students really don't have concrete expectations for what they intend to do with CS. According to the advisors, students don't change majors just because CS was radically different from their expectations. Instead students start leaving when their GPAs begin to go down. The advisor estimated that only two percent of major changes are students who are doing well academically but find CS doesn't match their expectations. Even acknowledging that off–the–cuff statistics probably have a fair degree of inaccuracy, this suggests that many students enter CS with an inaccurate conception of what CS is, yet — once they change their view of CS is — most students (at least initially) persist in CS. Poor grades are what motivate students to leave CS, not innaccurate views of the field.

A second example of student decision making without concrete goals is how students making long term educational decisions like which courses to specialize in. When I explicitly asked students about their post graduation goals, they rarely had a specific job or category of job in mind. Except for students recently involved in a job search, students' goals usually were not committed enough to suggest specific educational paths. One student was deciding between continuing in CS to get a Masters or Ph.D., joining the Navy, or web programming. The student did not have a plan for how to purse any of these goals by taking courses in CS. Some students suggested they might want to become a professional programmer for a company like Google, although they could not give any specifics about what they would like to do in such a job or what Google might be looking for. Many students admitted they had no idea where they would like to work or what they would like to do.

The fact that students don't have concrete goals early in their CS education is not necessarily an educational problem. But it does raise a question: how do students make educational decisions without a goal? What made students select CS initially if not an idea of what they might do after graduation?

3.2 Abdicating Responsibility to the Curriculum

> "[I found my classes valuable not because] I had some predefined idea of 'this is what's important in this topic' and 'he should be teaching this'. It was because all of [my school]'s professors are very well-known . . . so when you go into a [class] and you sit down in front of a professor, it doesn't matter what he wants to say. You kind of listen because you know it's gonna be important. It's just the people they are, that you trust them to know what they're teaching is important, and that's why we come to [this school]."
>
> —Junior, Engineering School

At all the schools we talked to, CS students had a great trust that the content they learned in their CS courses would be valuable to them. Even when they were not able to articulate why a particular topic was valuable, they were confident they learned it for some reason (or at least that it was useful to some particular kind of CS major even if it was not useful to them). Students were also confident that whatever they would be taught would be useful in accomplishing their career goals, even though in general they were not sure what those goals were. As a result, students generally selected courses by looking at the degree requirements and selecting the next courses off the list.

Students' trust in the curriculum meant that students were very often exposed to different kinds of CS content, but it also had disadvantages. For example, a student who disliked architecture felt free to not take a second course in architecture, even though it significantly limited future course options. Because that was allowed within the framework of the curriculum, the student felt it was safe. This is not to say that the decision to leave the course was a bad one: simply that the decision about whether a particular course is valuable would ideally be about the CS content covered and a particular student's goals. The extent to which students believe the curriculum protects them against bad long term educational choices is perhaps more than their schools' curriculum designers intended.

3.3 Exploration

> "So basically what I figured I wanna be kind of like well rounded . . . [Networking] was the other one and I figured that that would come in handy like pretty much anywhere, you know? Because I have a feeling there's lots of jobs for that . . . I mean, media seemed like a lot more interesting like the classes you take and such rather than modeling. I mean, those are pretty interesting too but I just, I felt like this was more interesting."
>
> —Junior, Engineering School

When students were enjoying most of their CS courses, they selected courses in what I called an "exploratory" way.

They selected courses they were curious about, given descriptions on the school website. They occasionally considered what might be good for a job after graduation, but this was usually based on instinct rather than any concrete data or specific companies they were aiming at. They did not get advice from instructors or advisors. Only rarely did they consider course difficulty. Overwhelmingly, what was most important was that the course or specialization seem interesting.

This exploratory behavior can continue even until junior and senior year. Obviously by the senior year students need to start making decisions about careers post graduation, but students with an exploratory approach still did not have a specific goal. They had some areas they were considering going forward (either in graduate school or in industry) but it was still an interest rather than a specific commitment. Students with a strong specific commitment generally could describe an experience of contrasting enjoyment that triggered their focus.

3.4 Contrasting Enjoyment Triggers Educational Decisions

> "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 ... I found [my computer architecture class] 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."
>
> —Sophomore, Engineering School

Students used course enjoyment as a mechanism to test their own suitability for the field of CS. If they found a CS course enjoyable, that was generally construed as confirmation that CS was a good choice. Enjoyment was not the only aspect that students consider, but, when students reflected on their own significant educational decisions, it was almost always an unenjoyable class experience that initially triggered the crisis and forced the student to make the decision. Occasionally, a particularly good course amount otherwise average courses could trigger a similar experience. Either way, the strong constrast in enjoyment that made the student reconsider and being thinking about making a new educational decision. This was true even when students were aware that other non–content factors (e.g. unhelpful TAs) affected their enjoyment. Grades did effect student enjoyment (e.g. students found courses they did particularly bad in unenjoyable) but simply getting good grades was not enough to ensure a student would enjoy the course.

Unenjoyable experiences caused a student to reevaluate their options. This was when they would reach out and begin to do research into the various options within CS. This often gave them a more detailed view of the subfields of CS than other students. Students would also make decisions about themselves in relationship with Computer Science. Students would decide they didn't like the hardware–level parts of CS, or that they didn't want to program professionally:

> "I think that — I know I don't want to program, so I'm going to try to stay away from that ... Yeah, after my C++ course, I liked it and I still had to do it, of course. But, I just knew that I don't think I want to sit here up all night doing this. I think that I would much rather — actually, I took a course, too. It was a software engineering course. And, so that was the life cycle — a life cycle process, and project management. And, I really, really liked that. I was kind of able to see a task through, and I didn't have to be the sole one programming, or the sole one doing one thing. I was able to talk to people, gather information, gather requirements — I really liked that."
>
> —Senior, African–American Woman's School

Students who had an contrasting experience would often explain themselves in terms of being a particular kind of person (e.g. a *social* person who doesn't like just programming all the time). Students before this would usually talk about being curious about different areas of CS but not saying they were unsuited for a particular area of CS.

This overall process of educational decision making seemed to occur at two levels during a student's undergraduate career: the selection of a particular major, and the selection of a particular specialization with in the major. A student would have a experience that would commit them to CS, for example, and then begin engaging in exploratory behavior to find a specialization within the major. Not every student talked about both stages — and for many students the selection of CS as a major came from an experience in high school.

3.5 Making Educational Decisions Based on Long–Term Goals

> "Well, I got interested in robotics. I was enjoying the class. Things were going well ... but I wasn't sure exactly what I should go to towards learning robotics on my own and in the classroom. So I went to my robotics professor and asked him for some direction, and one of the things I asked was simply what threads would you choose ... And I suppose the difference between when I changed my threads from when I originally picked my threads was originally I was thinking from what I like and what I do what would be good threads. But then when I chose the threads I'm working with now, it was more where do I want to go and how do I get there that made me choose them."
>
> —Junior, Engineering School

Up to this point, we've discussed students who are choosing based on enjoyment and adopted an exploratory strategy. A minority of students had a different approach to educational decisions: they made educational decisions based on a relatively specific long–term goal for themselves. Most of these students had a contrasting experience that focused them in a particular area and encouraged them towards a

particular long term goal. For example, the student quoted above had a very good experience in a robotics course. He changed his threads and started strategically selecting courses to further a career in robotics — a change from his previous exploratory strategy. Not every contrasting experience would completely change a students strategy: for example, a student might have an experience that settled them on majoring in CS versus something else, but within CS classes the student would still adopt an exploratory approach.

Students approaching CS based on long term goals had much more use for reasoning about the field of Computer Science. They often had done research beyond their classes into what was necessary for their long–term goal. They would even take non–required classes that they anticipated disliking, because they believed they would be useful for their goal. This was very different from students adopting the exploratory approach, who would exclusively select classes based on what they imagined they would enjoy (within the framework of the curriculum).

3.6 Peers, Parents, Advisors, and Professors

A little should be said about the involvement of other people in student's process of making educational decisions. The first is that students were fairly independent: although many students did mention some others at some point in their process, generally they described most decisions as being self–made (perhaps with a little advice). The departmental website was by far the most commonly referenced resource. But when students did solicit external advice, they tended to use each group in different ways:

- *Peers.* What was most surprising was how little peers tended to come up in student discussion of educational decisions. Although students definitely talk with each other, they generally do not talk about (or at least retain) information about the concepts discussed in later CS classes. They do talk about the difficulty of courses, although plenty of students I talked to did not even have information about that. Students did not evangelize particular specializations, and it was even rarer for students to talk about being attracted to the major by others. What peers did seem to provide was gossip about particular specializations (e.g. 'everyone knows' the theory specialization is really hard), which students did occasionally use in their decision making process.

- *Parents.* Parents were heavily involved in some students' decision making, especially when initially selecting a major. Parents generally seemed to encourage students to make educational decisions with an eye towards careers. Some students seemed to talk about consulting with their parents frequently, some mentioned it hardly at all.

- *Advisors.* Only the engineering school had explicit departmental advisors that students had to meet with every year. At other schools, students were required to meet with CS professors yearly. Students did mention going to advisors when they experienced a contrasting experience. The advisors themselves mentioned that students mostly sought them out to ask about graduation requirements. No student mentioned an advisor that they regularly met with for advice.

- *Professors.* Some students had a professor they had developed a personal relationship with after enjoying a particular course. Students in a such a relationship frequently talked about getting advice about educational decisions. Most other students did not mention getting advice from professors, even when considering changing specializations or having a bad experience in a particular course.

4. RELATIONSHIP WITH EXISTING THEORIES

The majority of CS education literature regarding student goals in CS focuses on pre–college or early college students. Margolis and Fisher's work [11] studied students across their CS undergraduate career and finds enjoyment a significant aspect of student decision making, although the students interviewed seem to have stronger goals earlier than observed in my interviews. Biggers et. al [1] finds differences between student perceptions of the field, but the survey nature of the work makes it difficult to isolate causes. Other work has also been done on how students think about the field of CS (see [9] for a summary) but not how that understanding relates to educational decisions.

General education literature has done considerable research into student decision making processes [8]. In general, these models tend to be complex with a variety of factors influencing student decisions. The difficulty in applying these models to a educational situation tends to be identifying which of the factors are most salient for most students.

4.1 Eccles's Model of Achievement–Related Choices

One model that is particularly well suited to student educational decisions is Eccles's model of achievement–related choices, which has been applied to a variety of educational choices including selection of major and courses [6]. The Eccles model is an expectancy–value model: students made decisions based on both their estimated expectation of success and what they expect to gain (called the subjective task value). For educational decisions, these general aspects are further subdivided in several parts including values of society, individual utility, enjoyment, expectations of success, personal goals (both short and long term), and others [7].

Studies have shown that the factors outlined in Eccles model do affect student educational choices [7]. In my interviews, most of these issues did also make an appearance to later and lesser degree. But there are some clear differences between the Eccles model and my results.

Firstly, there is much less of a delineation between the various aspects of the model in my interviews. Students, for example, would routinely alternate in their discussion between their enjoyment of a subject (subjective-task value) and their feeling of skill in the subject (expectation of success). While it may be true that students subconsciously associate their expectation of success with enjoyment, it definitely seemed to be enjoyment that they used when explaining their own processes.

Second, many of the aspects of the model break down when students seem to have no explicit goals. What does 'utility' correspond to in such a student? How can students be thought to be doing expectancy–value analysis when they are unaware of their options? I think although the behavior

we saw in students could fit within the general framework the Eccles model, the aspects it highlights are not the ones that seemed most relevant in goal–based student decision making processes.

4.2 Deci and Ryan's Model of Intrinsic Motivation

Because enjoyment turned out to be a important aspect of the interviewed students' decision making we also examined enjoyment focused models of decision making processes. Deci and Ryan's model [5] seemed the closest. The model emphasize what factors are necessary for an activity to be subjectively enjoyable, which develops into intrinsic motivation.

Deci and Ryan identify three main needs that drive intrinsic motivation: competence (feeling skillful at a particular activity), relatedness (feeling connected to others), and autonomy (feeling in–control and consistent with one's sense of self) [5]. In this model, there is a more explicit relationship between the subjective experience of enjoyment and factors such as expectations of success.

Deci and Ryan use their model to explain how motivation develops over time. In that sense, it explains how despite the fact that students are aware their enjoyment/frustration in a class may be caused by other factors than natural affinity for the discipline, an enjoyable class causes a feeling of affinity. Over time (and after some long term educational decisions have been made) the activities of the discipline become internalized and intrinsic motivation emerges.

5. DISCUSSION

5.1 Detailed Conceptions of CS Don't Help Make Educational Decisions

The way students approach educational decisions is related to their conceptions of the field of CS. Students use enjoyment to measure their suitability for a particular major or specialization. A detailed understanding of CS would not let a student know what he or she is really interested in: 'What part of CS is enjoyable to me personally?'

Once a student has a particular goal, a detailed conception of CS becomes useful. With a particular goal in mind, a student can reason about courses that would or would not be valuable — independent of the question of whether a particular course would be enjoyable. If the students I interviewed are representative. then students do not generally decide on a particular goal in CS until late in their undergraduate curriculum after many major educational decisions have already been made.

Given that students use enjoyment as a measure of suitability, the strategy students adopt makes sense. Students take courses required by the curriculum. Students rely on the curriculum to ensure they are exposed to a variety of areas all of which are potentially valuable long–term. Where choices exist within the curriculum, students select what sounds interesting but it is not a problem if they are surprised.

5.2 Student Enjoyment

Enjoyment turned out to be a large component of student educational decision making. Students attributed enjoyment in a class to be a sign that they were well suited for a particular discipline. This was true even though students could often identify reasons for their enjoyment (or lack of enjoyment) that had more do to with pedagogical factors (e.g. frustration with TAs). Strong contrasts in enjoyment motivated students to make educational decisions and narrow their long–term options.

While it is not surprising that enjoying classes motivated students, what is surprising is the extent to which students conflated enjoying courses and being well suited for a particular discipline. From an educational perspective, this can be problematic because there are many factors that influence student enjoyment: difficulty in getting TAs, courses with too much required content due to curricular issues, etc. But a bad experience in a particular course has a potential to be much farther reaching than instructors might expect. A bad experience in a course may convince a student they are poorly suited for a subdiscipline of Computer Science.

This suggests that unenjoyable classes, especially unenjoyable classes that are prerequisite for many others, can make students consider themselves unsuited for (and avoid) large areas of Computer Science. Courses of this sort often have many stakeholders which can encourage too much material in the curriculum. Obviously no teacher intends to make a course unenjoyable, but most curricula have a few courses that are considered especially frustrating. These frustrating courses may cause students to prematurely decide that they are not suited for certain areas of CS that they might otherwise enjoy.

5.3 Lack of Student Goals

In our interviews, students definitely liked curricula which gave them control over their classes. However, very few students used the freedom to select specific classes for specific goals. Instead, students tended to make educational decisions fairly arbitrarily, in line with their exploration of the major.

Based on my interviews, encouraging students to specialize early in their academic careers seems to be counterproductive. Before I undertook this project, I imagined that greater control of their curriculum might encourage students to develop a more detailed conception of CS in order to make good choices. This does not seem to have happened: students rarely talk about researching specializations or talking with their peers about CS content. When students are forced to make educational decisions prematurely, they choose without much consideration. If they have to specialize early, it reduces their ability to explore.

Students rely on the curriculum and assume that any really essential content will be taught to them regardless of their educational decisions. Students ignore the fact that a decision to specialize early inevitably comes at the cost of some other material. Early in the design of the survey instrument, I asked students to select elective courses for a student who wanted to 'keep their options open' in CS. Students found this question quite difficult, and it is difficult question for CS educators as well. My research suggests that many students actually really do want to keep their options open in CS, and I think the curriculum needs to provide guidance in that regard.

6. CONCLUSION

Students do not approach educational decisions in the way we might initially expect. Even when students found their classes to cover content very different from their expecta-

tions, that did not motivate them to switch classes or majors. On the other hand, receiving poor grades in classes did seem to provoke switching — even though (based on my interviews) students did not seem to be overly concerned with maximizing grades. In our interviews, even students with detailed understandings of the field of CS treated educational decisions like which area to specialize in very casually. Students did not seem to get much advice from advisors or professors. In short, students do not seem to be reasoning about the field of CS when making educational decisions.

The theory of how students make educational decisions comes from two basic ideas. One: students do not have a concrete idea of what career or skillset they would like to pursue in CS; they are trying to figure out their goals within the CS program. Two: the primary way students evaluate what their goals ought to be is by examining their enjoyment of classes. Enjoyment of particular classes is used as a test for how suitable that area of CS is for them.

This situation creates three main behaviors:

1. *Exploration.* Students do not have a concrete goal when they begin studying in a particular field, but rather than attempting to gain a detailed view of the field for themselves, students rely on the curriculum to teach them. They choose their courses based on casual interest, but within the framework of the overall curriculum.

   This process rests on the assumption that is safe to abdicate responsibility to the curriculum, i.e. that the curriculum is built in such a way that anything which is possible within the requirements is viable in terms of a long–term career. Abdicating responsibility is not always a bad thing from an educational perspective. Students arrive in class with very few preconceptions about what they expect to learn and (at least initially) assuming the professor is an expert with their best interests in mind. It does put students at risk for ignoring valuable content or by relying too much on the curriculum to ensure bad choices are impossible.

2. *Contrasting Enjoyment Triggering Educational Decisions.* They view their enjoyment of their classes as a useful measure of whether they would enjoy pursing a particular area more. If all their classes are equally enjoyable, students select courses in an exploratory way. They choose courses of casual interest, while keeping in mind course requirements. If they notice a strong difference in how enjoyable some courses are (especially if they have a bad experience in a particular course), it motivates them to make educational decisions. Often, they will narrow their educational focus and more clearly define their goals. This is when they often seek advice from parents, advisors, and websites. It also motivates refining a conception of the field.

3. *Making educational decisions based on long term goals.* Once their educational focus is sufficiently narrow, students develop a concrete goal. At this stage, they do use their conception of the field to make educational decisions towards their goal, and often describe research activities to refine their conception. They also engage in behaviors that are very unlike students making educational decisions based on enjoyment, like taking non–required courses they expect to dislike because they will be useful.

Overall, student educational decision making follows a process that makes sense. Students do not generally make faulty decisions based on incorrect reasoning about the field. However, students do tend to over–value how enjoyable courses are in their decisions. Although students enjoy curricula where they can make a lot of educational decisions, early decisions may not be being made in the way the curricula designers intended.

7. ACKNOWLEDGMENTS

Redacted

8. REFERENCES

[1] M. Biggers, A. Brauer, and T. Yilmaz. Student perceptions of computer science. In *Proceedings of SIGCSE 2008*, pages 402–406, Portland, OR, USA, 2008. ACM.

[2] K. Charmaz. *Constructing Grounded Theory.* Sage Publications Ltd, 1 edition, Jan. 2006.

[3] A. Clarke. *Situational Analysis: Grounded Theory After the Postmodern Turn.* Sage Publications, Thousand Oaks, Calif, 2005.

[4] J. Corbin and A. C. Strauss. *Basics of Qualitative Research.* Sage Publications, Inc, 3rd edition, 2008.

[5] E. L. Deci and R. M. Ryan. The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4):227–268, 2000.

[6] J. S. Eccles. Understanding women's educational and occupational choices. *Psychology of Women Quarterly*, 18:585–609, 1994.

[7] J. S. Eccles. Who am i and what am i going to do with my life? personal and collective identities as motivators of action. *Educational Psychologist*, 44(2):78, 2009.

[8] J. S. Eccles and A. Wigfield. Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53:109–132, 2002.

[9] M. Hewner. Undergraduate conceptions of the field of computer science. ICER '13, pages 107–114, New York, NY, USA, 2013. ACM.

[10] Y. S. Lincoln and E. G. Guba. *Naturalistic inquiry.* Sage, 1985.

[11] J. Margolis and A. Fisher. *Unlocking the Clubhouse: Women in Computing.* The MIT Press, Apr. 2003.