Narrating Data Structures: The Role of Context in CS2

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ABSTRACT

Learning computing with respect to the context of its use has been linked in previous reports to student motivation in introductory CS courses. In this report, we consider the role of context in a second course. We present a case study of a CS2 data structures class that uses a media computation context. In this course, students learn data structures and object-oriented programming through a pervasive narrative about how real media professionals use data structures to model the real world and to construct the digital images, sounds, and animations with which the students are familiar in their daily lives. We found that context played a different role in a second course than in a first course. We found evidence that some students did not need context to appreciate computing, but we also found evidence that context can help students get engaged with the material that they otherwise do not find interesting. In particular, the narrative aspect of a context may help students in relating the elements of the course and may even help with learning.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Sciences Education—*computer science education, curriculum*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems

General Terms

Experimentation, Design

Keywords

Course design, CS1/2, media computation

1. INTRODUCTION

Computer Science is viewed by many students as difficult and boring [10]. To some, the term "Computer Science" brings to mind the image of the lonely programmer, cut off from the world and focused on the tedious details of program syntax [2]. This perception may be part of the reason that many Computer Science departments are enrolling few and graduating even fewer students than they have in the past [17]. Students do not want to pursue studies in a field that they view as being too abstract and irrelevant.

Teaching computing in a context of use is a promising approach for introductory computer science classes. At Georgia Institute of Technology (Georgia Tech), where every undergraduate is required to take a CS1 class, students learn computing in a context that is related to how they may use it in their lives. For example, engineers take a class that focuses on problem-solving and calculation using MatLab, while liberal arts, management, or architecture majors learn similar content by creating Python programs that allow them to manipulate images and sounds. Taking this tailored approach has shown improvements in student success rate at multiple institutions [16][19], perceived relevancy of the material [13], and motivation in the courses (both engineering and media) compared to traditional CS1 classes [6]. Context in CS1 serves as a concrete explanation of how the computing in the course might be used.

For those who want to continue, CS2 is the next step, playing an important intermediary role — introducing key concepts like data structures and getting a deeper understanding of abstraction. Could context be as helpful to students in the second computing course as it has been to those in CS1? In this paper, we examine a CS2 class in media computation, which aims to cover the material typical of a CS2 data structures class. Our hypothesis is that a pervasive context can increase motivation for students in CS2. Through the case study of the second media computation class, we hope to begin understanding the role that context plays in a CS2 class. We do not anticipate being able to present a definitive answer, but rather to tell a compelling story about our experience to explore the role of context in teaching Computer Science.

We begin by considering the evidence on the role of context in a CS1 class. We then present some tensions from the research literature on the role of the data structures class in the computing curriculum. We describe how the course we studied is situated within those tensions. We introduce our CS2 class at Georgia Tech that teaches data structures in the context of media computation, and present the results from a series of interviews and surveys that focus on the role of context and narrative in the course. Finally, we conclude with a discussion of the role context or narrative may play generally in CS2 courses.

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2. RELATED WORK

2.1 Context in Introductory CS

From Fall 1999 to Spring 2003, Georgia Tech taught all of its undergraduate students computing, all in the same class, regardless of major. The result was a high failure rate and unhappy students [13]. We decided to adopt a new approach where we contextualized computing education to present languages, examples, and homework assignments in terms relevant to the students' majors [6].

Forte and Guzdial found that tailoring the introductory CS1 class to allow students to study CS concepts in a personally meaningful or relevant context of *media computation* resulted in higher student success rates and subjective satisfaction [5]. For example, Management majors went from a 48.5% success rate[1] in the early course, to an 87.8% success rate in the media computation CS1 course [7]. Forte and Guzdial also found that students took advantage of the creative and collaborative aspects of the course to go above and beyond the requirements of the assignments. The contextualized alternative course for teaching Computer Science was particularly successful at engaging and retaining women — a scarce population in computing [13].

Other schools have adopted the media computation approach with similar results. Tew, Fowler et al. followed the media computation approach to CS1 to a two-year college, still finding improvements in success rate, engagement, and motivation over traditional CS1 classes [16]. Zografski recently replicated these finding at his institution, without involvement with the original Georgia Tech team [19] . Some of the reasons for this positive outcome include creative open-ended projects, a welcoming policy for collaboration and sharing project outcomes, and a context that is interesting and relevant to the students [7]. Because of the diversity of majors enrolled in the class, not all CS1 students view it as relevant to their future classes or careers; however, student still view the class as relevant to their personal lives. Students are aware that the techniques they cover in the class do not reflect those used by real media professionals — for example, a graphic designer would not use Python to iterate over each pixel in an image in order to apply a filter — but they are willing to suspend their disbelief in order to buy into the larger story presented by the class [7].

2.2 The Role of the Data Structures Class

According to the 2001 Computing Curriculum [1], one of the sequence of three introductory CS courses should cover elements of data structures. Some of these elements include:

- Review of programming concepts
- Fundamental data structures
- Strategies for using and designing for recursion
- Introduction to object-oriented programming
- Introduction and analysis of basic computing algorithms
- Fundamentals of software engineering

[1]All those students who complete the course with an A, B, or C grade—the additive inverse of the *failure* rate, which are all those students who withdraw or complete the course with a failing grade.

The media computation CS2 class at Georgia Tech meets most of the traditional requirements of a data structures class, but adds another element — the context in which these concepts and skills would be used by media professionals.

The role of the data structures class in the CS curriculum has generated a discussion and the identification of tensions [3]. Lister criticized the current approach to teaching computer science: "We encourage a geekish enthrallment with the machine itself, not the useful things that can be done with the machine" [4, p. 404]. In the spirit of teaching "useful things that can be done with the machine," Tenenberg argued for an alternative approach to teaching data structures that more accurately reflects the practices of real-world programmers [15]. He pioneered a CS2 class which emphasized knowing how to use existing library containers and how to integrate additional design elements with the existing classes in standard libraries, as opposed to a more traditional focus on the ability to implement these data structures from scratch.

In a phenomenographic study of instructor rationale for the purpose of teaching data structures, Lister, Box et al. identified five categories of rationale and two dimensions of variation in teaching computer science [8]. The five categories identified were:

- Developing transferable thinking for future computer science classes
- Improving students' programming skills
- Knowing "what's under the hood" of data structures
- Knowledge of software libraries
- Developing component thinking to see how different parts of a program fit together and interact

All of these categories, other than knowing "what's under the hood," were identified to belong to two dimensions of variation: computer science vs. object engineering and abstract vs. concrete. Categories that rate highly in object engineering focus on developing computational devices suited to a specific purpose, while the computer science rationale emphasizes universal computational devices. Abstract categories encourage transferable design skills, while concrete ones focus on implementation and utility.

The context of use of data structures are most closely tied to the object engineering and concrete edges of the dimensions. There is a tension between teaching abstract concepts divorced from their use and teaching within a context of a specific narrative. We propose that students are motivated by seeing concrete, real-world examples of data structure use for representing structure and behavior. The course that we are describing in this paper is a data structures class that weaves the context for representing structure and behavior through a consistent narrative that pervades the class. In the next section, we will describe this class in more detail as a case study for the role that context can play in a CS2 class.

3. CS2: REPRESENTING STRUCTURE AND BEHAVIOR

The media computation CS2 class teaches data structures in the context of manipulating media and modeling

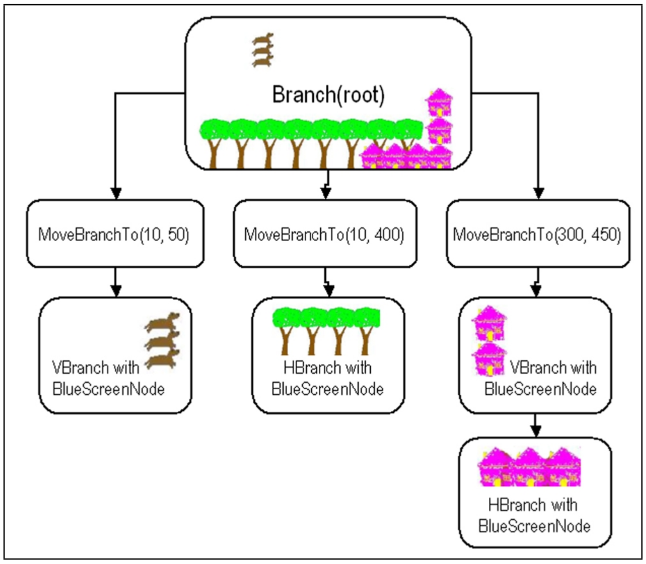

Figure 1: An example of class material: a scene graph of an animation, decomposing a scene into a tree of elements.

real-world behavior through simulation. In relation to the tensions described in the previous section, it focuses on areas we see as most relevant to non-CS majors — improving students' programming skills, knowing "what's under the hood," and developing component thinking. We seek to teach these through a story of how programming, understanding data structures, and object-oriented thinking help media professionals create animations and simulations.

3.1 Course Description

The pivotal moment in the Disney movie *The Lion King* occurs when a stampede of wildebeest rush over a ridge towards the helpless protagonist. Disney animators carefully crafted the moment by modeling the wildebeests' structure and behavior, then simulating these models in a herd, rather than using traditional hand-drawn characters. Understanding the process behind creating this segment of the film requires a thorough grasp of media manipulation, object-oriented thinking, and simulation techniques. Modeling characters and scenes requires data structures like linked lists and trees. Simulations require stacks and queues. Students in the media computation CS2 class at Georgia Tech study data structures in the context of this moment, learning how media professionals employ structure to model the real world and its behavior. The story of the wildebeest stampede is introduced on the first day of class, with a viewing of the relevant "making of" segment on the DVD *The Lion King, Special Edition*, as the driving question of the course.

The goal of the media computation CS2 is to provide the students with an understanding of using data structures to model real world structure and behavior. To achieve this, the course introduces students to Java object-oriented programming and data structures. As students learn to manipulate images and sound using Java, their experience is related back to the movie makers at Disney. Students begin to learn Java object-oriented programming by manipulating images. The first linked list that students use has MIDI (music notation) data in the nodes, so that traversing the linked list creates music. Within this context, weaving, repeating, and inserting linked list node behaviors are explorations of music composition, as in creating the soundtrack for a movie.

The concept of a linked list that branches (leading into trees) is used to represent music with multiple parts. We then shift media, and create linked lists with images. Linked lists are used to auto-position images in a scene and to explain layering (as in professional media tools like Photoshop and Powerpoint). The first real tree that students use is an n-ary tree representing a *scene graph* (Figure 1). Though the example provided for this scene graph is very simple, it is an accurate representation of a technique professional animators use. Each of individual pictures in the scene are leaf nodes in the tree (not explicitly drawn in Figure 1). Branches can either simply group components (as in the parts of the "village" in the lower right), or can change how the children nodes are rendered. `MoveBranch` branches set the position of the pen where the children will be drawn, and `HBranch` and `VBranch` branches auto-position the children along horizontal or vertical dimensions. Trees of sampled sounds are introduced and used for recursive tree traversals. Binary trees are later presented as an interesting and peculiar variation on our n-ary trees—they don't appear in the main narrative stream of the class since strict binary trees are useful for searching and less so for media representation.

During the first 2/3 of the class, the course is obviously quite concrete and is more about generalized computer science than object engineering. The course actually revolves around implementations of all of these node, list, and tree classes. As the class progresses, the narrative reaches a climax — students implement animations with sounds, where a scene graph represents the scene and a linked list of sounds is used for the audio track.

After the animation with sound, the emphasis in the course remains concrete but shifts to an object engineering perspective. As we introduce simulation, we stop using our hand-made data structures and start using Java's provided objects. We introduce GUI's using Swing, as an interesting and practical activity that provides the opportunity to talk about another kind of tree where different layout managers are implementing different traversals. The capstone of the class is learning continuous and discrete event simulations, when students are required to combine all the concepts covered earlier using Java's collection classes. We introduce UML class diagrams as a tool for managing the increasing class hierarchy size needed for simulations.

Students typically implement a continuous simulation as a homework assignment. In the Spring 2007 semester, it was a disease propagation simulation where students had to choose and then implement public health policies like quarantining and limited vaccination. The final assignment maps the students' simulations to an animation, to close the loop on the wildebeests charging over the ridge. Throughout the course, students are provided not only with information about the appropriate data structure and its implementation, but also about the way this knowledge may be used by a real media professional.

3.2 Course Demographics

The media computation CS2 course was originally created as a follow-on course for students from management, architecture, or liberal arts who enjoyed the media computation CS1 course. We knew from our earlier work that these students felt unprepared for a traditional CS course yet welcomed more media computation [5][16]. The course was offered Spring 2005 and succeeding semesters to classes of n=30 or less. Then, in Fall 2006, the Industrial and Systems Engineering school at Georgia Tech decided that the media computation CS2, with its lighter coverage of Java and a focus on simulations, was more appropriate for their undergraduate majors than the traditional CS introduction to object-oriented programming in Java. The course shot up to 150 students in Fall 2006 and almost 200 in Spring 2007. Across all these semesters, the success rate has remained close to or above 90%—this is a CS2 course for non-majors with a high success rate. This study follows the Spring 2007 cohort of 186 media computation CS2 students through the semester.

Thus, demographics of the media computation CS2 class at Georgia Tech are a little unusual for a CS2 class. Of the total of 186 students, 57 of those enrolled (31% of the class) were female. Considering that overall the Georgia Tech undergraduates are only 28% female, this is plained mostly by the majors who take the course. Still, it is an unusual level of enrollment for a field in which women are traditionally underrepresented [2]. Ethnically, the class seems to represent the diversity of the campus: 29% of the students are Asian, 8% are African-American, 8% are Hispanic, and the remaining 55% are Caucasian. Like in most introductory sequence computing courses, the majority of students in the class are just beginning their undergraduate career, with 20% freshman and 43% sophomore enrollment. Juniors represent 29% of the class, while the remaining 7% are a mix of senior and graduate-level students.

One of the things that distinguishes the media computation class from other CS2 classes is the mix of majors who take it. The majority (74%) of students in the class are Industrial Engineering majors, who are required to take CS2 as the last class of the introductory computing sequence. 11% of the students in the class are part of the relatively new Computational Media program at Georgia Tech, who are also required to take the class for the major, but will also go on to take future classes in Computer Science to graduate. The remaining 15% of the class represent a wide variety of majors, from Biology to Architecture to Modern Language. None of these students are required to take CS2—they choose to do it as a follow up to the media computation CS1 class or to fulfill some technical elective. In other words, our CS2 class is a mix of students who are regularly underrepresented in computing courses — non-majors, women, and minorities — who are taking the class for different reasons and with different goals in mind. It is significant to note that the majors for whom the course was originally designed (management, architecture, liberal arts, and the relatively new computational media) are now only one quarter of the course.

3.3 Role of Narrative

A significant difference between our earlier contextualized CS1 courses [6] and this CS2 course is that this latter course has a clear narrative—there is a story line. The media computation CS1, for example, covers "media": images, sounds, HTML text, animations, and video. These could be taken in nearly any order, and any medium could be swapped out without any real damage to the focus of the course.

However, the media computation CS2 is about the wildebeests charging over the ridge. The pieces of the course fit together in a sequence to explain that one moment: soundtracks with linked lists, scenes with trees, and simulations with queues. The whole course is structured around a single driving question, and the sequence of the course builds toward being able to replicate the answer to that question. A goal that emerged during this study became to understand the role of the narrative that pervades the course.

Gerrig identifies two characteristics of a narrative experience: the reader is transported to another place in a manner so compelling that the characters and places seem real, and the reader begins performing the narrative — experiencing and acting on the story as if it is real [14]. The characters for this narrative are not wildebeests or lions; the place is not the African veldt. The character is the Disney movie maker (e.g., animator, musician, computer scientist working on simulations), and the place is a movie studio. As we progressed through this study, we became aware of how the students more or less bought in to the narrative sequence and experience that we were trying to convey to them [7].

4. METHODOLOGY

We designed this study in three iterative phases conducted throughout the Spring 2007 semester. We administered an initial survey half-way through the semester. We used the results from this survey to decide on some questions that we wanted to pursue in more detail. We created a semi-structured interview that we conducted with a small sample of the class (7 students) during the last quarter of the semester. We analyzed the interview transcripts using data-driven approach to identify a set of emergent themes. While the interviews provided us with a wealth of rich qualitative data, we understood that such a small sample could not represent the entire class. Thus, we developed a final survey intended to gather more information on the themes discovered in interviews—essentially, to test the commonality of the hypotheses that arose from the interview data. This survey was administered to the class during the last few weeks of school. Combining qualitative and quantitative methods and utilizing an iterative design has allowed us to work towards a better understanding of the student experience in the media computation CS2 class. In this section, we will briefly describe the participants and procedure in each component of the study and discuss how the results of each component informed the design of the following one.

4.1 Initial Survey

The initial survey was distributed half-way through the semester and consisted of demographic questions, several Likert-scale questions measuring the perceived difficulty of the course and student engagement, and a series of free-response questions about the aspects of the class that the students find enjoyable, frustrating, or surprising.

4.1.1 Participants

62 participants elected to complete the initial survey. Because the students self-selected for participation, there may have been a bias in the results; however, the sample was representative of the overall class population on issues of gender, major, and year. In terms of ethnicity, African-Americans were underrepresented on the survey as they made up 0% of those who completed the survey, but 8% of those

taking the class. Conversely, the Hispanic population was overrepresented — making up 16% of survey-takers and only 8% of the class population as a whole. Other ethnic populations were represented proportionally to their class enrollment.

4.1.2 From First Survey to Interview

There were several themes that emerged from the surveys that we wanted to explore in more detail. We noticed that students often listed aspects of the media context as their favorite part of the course. For example, one student listed the music project as a favorite in the class, stating that "creating something that interests me helps me to learn it better." On the other hand, we also noticed that some students mentioned the media context at their least favorite part of the class. One student mentioned that he didn't see the material as relevant to his major: "all this sound, image manipulation doesn't really seem to be helping me."

4.2 Interviews

We administered 30-minute interviews, consisting of questions about the student's background and comfort with computing, his or her experiences in the CS2 class, and his or her general attitudes about Computer Science. Among the questions about the student's experience in the class, we were particularly interested in exploring what the student saw as the role that the media context and the *Lion King* narrative played in the course. We also asked about the students' experiences with the class projects, whether they found the course relevant to their personal or professional lives, and what they saw as the most rewarding or the most frustrating aspects of the class.

4.2.1 Participants

We interviewed seven students for this part of the study. Two of the seven students interviewed were women. Six of the seven students interviewed were Industrial Engineering undergraduates; the seventh participant was a cognitive science graduate student. Unfortunately, minorities were underrepresented in the interviews — five of the seven interviewed were Caucasian. We knew that our small sample could not represent the whole class; we were especially worried about the lack of variety of majors and ethnicities. However, we saw the interview as an opportunity to gain a deeper understanding of the role of context in the class. Our goal with the interviews was to identify major themes that we could then explore with a larger sample.

4.2.2 Interview Analysis

We used a data-driven approach to develop coding categories to be used with the interview transcripts. After the initial coding, categories were further focused by identifying repeating ideas. Finally, we identified pervasive themes in the interview data by clustering repeated ideas into related groups. Aware of the limitations introduced by the small sample size of the interview pool, we focused on identifying individual tensions within students responses rather than trying to identify themes that would be representative of the entire class.

4.2.3 From Interview to Final Survey

Through the data-driven analysis of the interview data, we identified several major points pertaining to the role of context in the media computation CS2 class from the point of view of the students we interviewed. Table 1 shows these, along with the statements from the transcript that are representative of each idea. We wanted to be able to get more feedback on these points and see whether they were representative of the larger class population, so we designed several instruments to include on the Final Survey to measure the student's outlook on each particular point. An example of an instrument probing each point is included in the last column of Table 1.

4.3 Final Survey

The final survey was deployed during one of the last weeks of class. It consisted of several multiple-choice demographics questions, a series of Likert-scale statements, and several free-response questions. The Likert-scale items provided the student with a statement and asked him or her to identify between "Strongly Agree" and "Strongly Disagree" on a scale from 1 to 5. Among the questions asked on the free-response portion, we asked the student identify and justify what was the most rewarding projects in the course, and we asked him or her provide recommendations for changing the class to be relevant and interesting.

4.3.1 Participants

91 students participated in the survey, though only 66 of those chose to answer the free-response items. 64% of the participants were male, 32% female, which is representative of the class population. The majority (74%) of those who responded to the survey were Industrial Engineering undergraduates, while the others represented students from the liberal arts, sciences, computational media, and architecture. Once again, this was a representative proportion of those enrolled in the class. 86% of those surveyed were 1st, 2nd, or 3rd year undergraduates, with each year represented proportionally. Ethnically, the sample was closely representative of the class population for all groups except African American, who were represent 8% of the students in the class but only 1% of the students who responded to the survey. Unfortunately, as the sample was self-selecting, there was nothing we could do to correct this imbalance.

4.4 Combining the Results

Looking at the two different surveys and the interview data allowed us to gain a richer understanding of the role that context plays in this particular CS2 course. Using a mixed-methods approach let us examine a single issue from several viewpoints and more easily identify possible tensions, inconsistencies, or themes in the students' experiences. In the next section, we present the major findings from the analysis of the three sources of information.

5. RESULTS

We begin by presenting the evidence for the value of context in the media computation CS2 class. While the context was beneficial to many in the class, some no longer need it — we describe the results for one such student. We then present a tension in the student outlook on the context: they view the context and the story arc that pervaded the class as interesting, but not relevant. Finally, we describe the role of the narrative of the Lion King metaphor that pervaded the class.

Table 1: Developing the Survey from Interview Themes

Interview Theme	**Example Quote from Interview**	**Sample Survey Item**
The media context is seen as motivating.	"You never want to do homework, but this actually has some entertainment value that comes out of it."	Working with media makes this class more interesting. (1 - 5 Likert Scale Agreement)
The media context is *not* seen as being relevant.	"I don't need to make pretty pictures, I need to be able to perform calculations..."	Working with media makes this class more useful to me. (1 - 5 Likert Scale Agreement)
The material is not seen as being useful to the students outside of class.	"...as long as I can get through this class and get done with this part, I'll never have to do it again..."	This class is useful in my life outside of class. (1 - 5 Likert Scale Agreement)
The material is not seen as being useful to their major.	"...for me I guess, being an Industrial Engineer, it doesn't really seem applicable to my major as much as it could be..."	This class is useful to passing future classes in my major. (1 - 5 Likert Scale Agreement)
The material is not seen as being useful to their future career.	"...right now, I don't really see how it relates at all to Industrial Engineering."	This class is useful to my future career. (1 - 5 Likert Scale Agreement)
There are different opinions on the trade-off between time spent making the material more interesting and time spent getting more deeper into the subject.	"I wish there would have been more concepts and less [media]..."	Working with media is a waste of time that could be used to learn the material in greater depth. (1 - 5 Likert Scale Agreement)
Some students did not understand the role of the *Lion King* metaphor in the class.	"Umm [laughs] yeah... I don't get it..."	Did you understand the Lion King wildebeest story that pervaded the class? (Yes or No Question)
Those who "got" the *Lion King* metaphor found it motivating.	"It made me interested enough to *try* learning this computational media stuff..."	The *Lion King* wildebeest metaphor was motivating. (1 - 5 Likert Scale Agreement)
Students do not see the class as authentic to the practices of media professionals	"...sure you can make an animation, but when you're watching a cartoon — nobody does it like that..."	Real media professionals use techniques we covered. (1 - 5 Likert Scale Agreement)
Students spoke with enthusiasm about at least one project.	"The animation was exciting, really exciting to see..."	There was at least one project that really excited me. (1 - 5 Likert Scale Agreement)
Students went beyond the requirements on the projects that excited them.	"I spent a good amount of time doing that homework. I did more than the minimum..."	Have you ever done work above and beyond the strict requirements of the assignment (for example, making your homework "cool)? (Multiple Choice, "Never" to "Almost Every Assignment")

5.1 Value of Context

Context was valuable in motivating the students in the media computation CS2 course. 70% of the class agreed or strongly agreed that working with media made the class more interesting. Granted, none of the students in the class had taken a traditional CS2 class, so they did not have a clear point of comparison for what it would be like to learn CS2 without media. However, interviews and responses to other questions on the survey corroborate the idea that context was motivating to the students.

When students talked about their favorite projects in the class, they referenced the media context as a reason for getting excited about the projects and doing extra work outside of the requirements. A student who described himself as having no interest in computer science in his personal life or career stated:

> I really enjoyed doing the homework on weaving, where you'd take bits and pieces of sound and weave it together and manipulate the music to kind of get it in an arrangement that you like and just messing around with that. That was enjoyable — I spent a good amount of time doing that homework. I did more than the minimum, so I enjoyed doing it ... I guess I like the interaction with the music — being able to make an arrangement and hear it. Also, I played jazz band during high school, so I kind of knew what notes I wanted to use and I knew how to read music — that kind of made it more enjoyable for myself...

This student exemplifies a theme that we saw in the data — the media context played a particular role for students who came into the class with a negative perception of Computer Science. As one student stated, "I hate CS, but this course does at least make it palatable to me."

The media context also helped motivate students by tapping into their creative side. Many students commented on the opportunity to be "creative" and "open-ended" with assignments as the most rewarding aspect of the course. One participant spoke about the creative aspect of the media as a motivation:

> ...for the animation that time, I had a story going on, so I wanted all the elements there. It was more interesting to do something extra [on that assignment], then just to do the minimum that was required...

In some classes, students are motivated to learn because they can see how they will use the skill or knowledge in the future. In general, this was not true of our CS2 — less than half of the students in the class agreed or strongly agreed that the class was useful to their life outside of class (42%), to their future career (49%), or to their major (46%). These are dramatically lower numbers than seen on similar questions in the media computation CS1 course, across several schools [16, 19]. Despite this, 67% of the students in the CS2 class agreed or strongly agreed that they were really excited by at least one class project and 66% reported doing extra work on projects to make the outcome look "cool." Motivating context may help explain the difference in these numbers. However, context wasn't helpful for everyone; in the next section, we will examine the evidence that some of the students in the class have begun "outgrowing" the need for it.

5.2 Outgrowing the Need for Context

The context that pervades the class seems to make CS2 more interesting, however some of the students we surveyed reported that they did not need media to want to learn computing concepts in more depth. These students were in the 11% that answered "agree" or "strongly agree" to the statement "Working with media is a waste of time that could be used to learn the material in greater depth." They do not represent the majority of class, but they do highlight an important perspective on the role of context. We cannot know for sure whether these students responded the way they did because *media* is not a context they appreciate, because they have an inherently different perspective on computing, or for other reasons. However, when we interviewed a student who fell in this category, we found that he cited his extensive previous experience in computing as the reason he no longer needed context to appreciate the Computer Science. This student has outgrown the need for context.

This interview was with a sophomore Industrial Engineering major who had several years of experience in programming. He reported understanding the benefit of context for others, but he simply did not think he needed the context anymore to understand or appreciate the computing concepts:

> I like all the concepts covered in the class, I just wish they were covered a little better, and I wish there would have been more concepts and less [media]...

However, the same student still appreciated the role that *narrative* played in the course. He said:

> I thought analogies like that are good. I attended the class a lot at the beginning of the semester [to get these].

Like our interview participant, there were a few other students in the class who reported wanting to incorporate a greater focus on concepts and "more sophisticated data structures" into the course. One student lamented that by learning context, he may be restricting himself: "[I] still don't know Java comprehensively — the media approach [is] too narrow." These students worry when they perceive the class as having "diverged a lot from the 'computing' part of computer science." These students appreciated computing for its own sake and did not require the external motivation provided by the context.

In our CS2 class, only a few students made statements consistent with the idea that they have outgrown the need for context, though they may still appreciate the narrative. In a class where students have had more previous experience programming, this population *may* be larger. It is up to the storyteller of the course — the course designer — to tailor the topic and genre of the tale to the audience.

5.3 Interesting, but Not Relevant

We found that there was an inherent tension in the way students spoke about the role of context in the class that reflects the idea that the stories that capture our attention are not always the ones that we view as the most realistic or useful. Students in the CS2 class saw the *Lion King* thread and the media context as motivating, but did not see it as relevant to their lives outside of class or future careers. During an interview, a junior Industrial Engineering student mentioned:

> ...some of the things [the professor] was talking about, that I was really fascinated by, about how the *Lion King* animations stuff worked was neat to me, but not relevant to me...

A majority of the class (70%) agreed or strongly agreed that working with media makes the class more interesting. However, only 45% said the same for the statement that working with media made the class more useful. Some students are aware of this trade off. One student, who is an Industrial Engineering major, was asked to talk about the role of media in the class:

> ...a lot of it is that you're just trying to just learn the concepts or Java by doing something. So, they try to make that something, something interesting, which I have a lot of respect for ... but, I just think sometimes that media are less relevant.

Other students had similar responses on the topic of the media context. They understand the trade-off between doing something that is directly relevant to their future work and doing something that may be more motivating, but not as relevant:

> ...If for me, we learned in another manner, that would be beneficial and relevant. But in terms of interest, I think some of the stuff we're doing is very interesting. I think working with these different pictures and things — maybe that's why we do it. I think for me maybe it sacrifices a little relevancy and makes up for it in interesting material.

Are students willing to make that trade-off? It seems that the majority of them are. When asked whether they viewed time working with media as time they would rather spend learning the material in greater depth, the majority of students disagreed or strongly disagreed (59%). In fact, less than 11% of students in the class were willing to exchange interest introduced by the media context for covering the computing concepts in more detail (agreed or strongly agreed with the statement).

The context of the course seemed to serve to motivate the students in such a way that they became engaged in the material without finding it directly relevant to their personal or academic lives. We propose that the students perceived the narrative that pervaded the class and thus became willing to suspend their disbelief and become engaged in the material. In the next section, we will present evidence that students saw the story behind the class and bought into it.

5.4 Seeing the Story

There was a coherent story arc uniting the material in this class. Understanding how the Disney animators created the scene in *Lion King* where the wildebeest charge over the ridge was the motivation for learning how to represent structure and behavior using media. Like any story, students who heard it from the beginning, were also more likely to understand it. Out of those students who attended the first week of class, 88% reported that they understood the *Lion King* metaphor. Only 60% of those who were not there the first week understood. This difference is statistically significant, $\chi^2(1, N = 88) = 0.003, p < 0.05$. Furthermore, there was a trend showing that those students who attended the first week of class were also more likely to find the Lion King metaphor motivating; however, the difference was not statistically significant, $\chi^2(1, N = 83) = 0.052, p > 0.05$.

Another indicator of the fact that students were drawn into the story arc was their awareness that the story came to a climax at the end of the course. Most of the students reported the final few projects — animation and simulation — to be the most rewarding aspect of the course. Students clearly saw these as the culmination of the class. One student reported animation as the best part of the class: "You could see the progress made from the beginning of the class." Another student listed the simulation project as the most rewarding aspect of the class because it was "just neat to put it all together." A third student reported being fascinated by the simulations because she saw them as "the goal of the course." This evidence supports the idea that students saw the pervasive narrative in the course as a coherent story with a beginning, climax, and end.

A benefit of having a pervasive narrative in the class was that it helped relate to relate one project to another. A student who was particularly verbal about not finding the media context relevant, admitted that he found that aspect of the class enjoyable:

> The [assignment] we just did was pretty neat ... because I feel like it accomplished the most ... being able to coordinate the sounds with the images and the images moving ... I complained some about the images, but it was interesting to me. I felt like that tied everything together, so that was pretty neat.

The free-response answers on the surveys reflected the connection between projects as well. Several students described their favorite aspect of the class as the projects that seemed to "tie together" the other material in the class, or made it "click." Rather than seeing each project in isolation, students could relate projects to the driving questions of the class, and they appreciated the projects that got them closer to answering those questions.

We found evidence that the students in the class who were motivated by the *Lion King* metaphor entered a narrative experience. A little over half of the students in the class (56%) agreed or strongly agreed that "The *Lion King* metaphor was motivating." We compared the responses to this statement with responses to other statements. There was a significant correlation between finding the *Lion King* story motivating and agreeing with the statement "Real media professionals use techniques we covered," $r(84) = 0.40, p < 0.05$. In other words, students who were motivated by the narrative also saw the media professional (animator) central to the *Lion King* narrative as a real and believable character. There is also evidence that students who were motivated by the narrative began "performing the narrative." There was a significant correlation between finding the *Lion King* thread motivating and finding at least one of the class projects exciting, $r(84) = 0.21, p < 0.05$. Furthermore, students who found the *Lion King* metaphor motivating also saw media as making the class more useful,

$r(84) = 0.23, p < 0.05$. We are careful to point out, however, that this correlation does not imply a causation. It is unclear whether the students found the *Lion King* metaphor motivating because they already held the belief in media being useful and the material being authentic, whether buying into the *Lion King* story caused the students to view the material as more useful and authentic, or whether there could be other variables confounding these results. However, the correlation is consistent with the idea that students recognized the narrative that drove the course. In the next section, we will discuss the implications of this finding.

6. DISCUSSION

At this point, we revisit the driving question of this study: what is the role of context in a CS2 course? We cannot speak to the role that it may play in every CS2 class, but we can use the media computation CS2 class as a case study to showcase some of the potential benefits or implications of incorporating a pervasive narrative and context into a course.

6.1 Role of Context

In our particular case, we found that context was helpful in getting students excited about the projects. Context served as a "hook" to reach some students who were otherwise interested in neither computing nor data structures. Sometimes context was successful in doing that because it spoke to the student's interests outside of class, as in the example of the student who related the music composition project to his experience in high school jazz band. Other times, the context worked because it encouraged people to work harder on the projects that spoke to them. In a class where most of the students did not see the material as relevant to their career or personal life, the majority of students reported doing extra work on assignments to make them more creative. Students were concerned not only with fulfilling the requirements of the project, but also their creative vision of the project. They did extra work in order to make their animation tell a story, to make a musical piece that satisfies their artistic aesthetic, or to get the feeling of accomplishment in creating a functioning simulation.

In the media computation CS1 class, students reported that the media context was useful to them — especially in their lives outside of class [5]. However, in the CS2 course, the media context was not seen by most students as something that was useful in their career *or* personal life. To the CS2 students, intellectually, this class represented a trip to another world, rather than a place of permanent residency. They let the narrator of the course take them on a guided tour of a place they probably would not have discovered on their own. The important question (addressed later) is whether they learned from the experience.

Another difference between how context was perceived by students in CS1 vs. CS2 is the presence of the population that has outgrown the context. In CS2, adding context may be helpful to some audiences but not others. As one student said, he just doesn't need the "pretty pictures" anymore. It is still not clear whether the need for context has to do with the student's personal preference or whether it is related to his or her amount of experience with computing. There is an inherent trade-off between how much context can be woven into the curriculum of the class and how much other material can be covered. This is related to the tension between concreteness and abstractness present in any data structures course.

6.2 Role of Narrative

Narrative has been previously considered as a possible tool for pedagogy [11, 18]. Wells proposed that narrative and storytelling are relevant in all areas of the curriculum:

> Through the exchange of stories, teachers and students can share their understandings of a topic and bring their mental models of the world into closer alignment [18, p. 194].

We may have seen some evidence of this effect in the media computation CS2 class. The narrative tied the projects into a coherent whole and let the students see the goals of the course as the climax of the story. Those who were motivated by the *Lion King* narrative were also more likely to view the class material as authentic to professional practices, media as useful, and find the projects exciting. We do not have evidence that these effects were caused directly by the narrative, but rather that there is a relationship between those responses. However, it is clear that those who were motivated by the *Lion King* story perceived certain aspects of the class differently than those that were not.

The media computation CS1 class included a media context, but did not include a pervasive narrative similar to that of the *Lion King*. While the CS1 students viewed media as useful and the projects as exciting, they did not perceive the media computation techniques as being authentic to the professional media community [7], as they did in CS2. One of the roles of a pervasive narrative may be that it allows students to believe in the authenticity of the techniques and concepts that are covered in the class. The question of whether students "buy-in" to the story is present in any project-based course that has a narrative [12] — there will always be students who do not suspend disbelief about the narrative.

Narrative may have other benefits to the student. Human beings find it natural to learn through stories. Our memories are set up to better process information when it is organized in a coherent, connected fashion. Narrative provides a powerful organizing structure and a way to connect ideas [9]. Perhaps that is why students reported outgrowing the context, but still appreciated the narrative. It may be that the narrative could improve learning, that the associations between the projects and the lectures helped to make the course coherent and memorable — an interesting question for future research.

6.3 Learning

An important question is whether the context and narrative facilitated or impeded learning. It is certainly the case that presenting the context took time that might have been spent on more data structures topics or on greater depth. We have not yet compared this course with another data structures course, nor do we have a standardized measure of CS2 knowledge to be used in determining the amount of learning in this course.

However, one measure of learning is how well the students are prepared for later courses. We have had some students go from the media computation CS1 and CS2 into later, more traditional CS courses. We have also had students go from the CS-specific CS1 and the engineering context CS1

Table 2: Student success rates from previous semesters by paths into later courses

Path	Number of Students	% Succeeded	% Failed, Dropped, or Withdrew
CS CS1	333	78.1%	21.9%
Engineering CS1	681	72.7%	27.3%
MediaComp CS1–CS2	20	60.0%	40.0%

into the same later courses. In general, the media computation students do not do as well.

Table 2 summarizes the success rates into a later course across four semesters[2]. These are results from previous semesters — we have yet to see how the students in the Spring 2007 cohort will do in this class should they choose to continue studying Computer Science. From these previous semesters, we see that students from CS and engineering succeed at a rate of 78% and 73% overall, as opposed to media computation students who succeed at only a 60% rate. It is the case that relatively few media computation students were going on — 20 compared to 1024 others. It is also the case that the students who came into CS from the media computation path were non-technical majors, who probably had less computing experience before arriving at Georgia Tech [10]. While it is disappointing that only 60% succeeded, perhaps the success is that the majority did succeed.

7. CONCLUSION

Students respond to context and narrative in our media computation CS2 course. They become engaged in material they otherwise view as irrelevant. While the students do not necessarily see the class as useful to their career or personal life, they are willing to suspend that sense of disbelief and enter the narrative world. In becoming part of the narrative, they are more likely to believe that what they are learning is authentic and get more engaged in the work they do. We know that we cannot make a claim about the role of either context or narrative in *all* CS2 courses. We have not done a direct comparison of the learning and engagement in the media computation CS2 and the learning and engagement in a traditional CS2 class. Our CS2 class is unusual in its student demographics. However, our results are encouraging.

There are lots of follow-up questions to explore. Our data say nothing about context and narrative for computer science majors. We do not know the role of narrative in improving learning for these students. Our results leave open the question of where context is no longer useful as students become more advanced. We offer the media computation CS2 class as a case study where context and narrative did play a positive role. Demonstrating the role of context and narrative in other CS courses is a compelling direction for future study.

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