Work in Progress: A Literate Approach to Graduate Computer Science Education

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***Abstract*— We have observed that many beginning graduate students, though technically skilled, are lacking the ability to disseminate technical knowledge to a broad audience. Students often write term papers that describe the intricate complexity of their work, but fail to place the work in context, to articulate the core argument, or to present the proper level of detail. In response, we are developing a curriculum-independent course format designed to develop the ability of students to write, speak, and argue effectively to a broad audience. This format includes an evaluative process in which students absorb and respond to technical readings within an existing curriculum and a highly literate technical project guided by several milestones.**

Those holding advanced degrees in computer science and engineering are expected to become not merely technicians, but leaders that must absorb, create, and communicate complex ideas in a public arena. However, our anecdotal experience is that many graduate students, though technically skilled, are lacking the communication skills necessary to disseminate technical knowledge to a global audience. For example, students often write term papers that describe the intricate complexity of their work, but fail to place it in context, to explain why complexity is necessary, or even to motivate why their work is interesting and useful. We believe this is partly due to the boundaries imposed by traditional university settings: students perceive knowledge to be boxed into neat little courses with narrow domains of knowledge and language. Thus, students tend to produce papers that are tailored to the lexicon and experience of the class in which they are assigned.

In response, we are developing a curriculum-independent course format designed to develop the ability of students to write, speak, and argue effectively to a broad audience The format has two complementary components. The first is an evaluative process in which students absorb and evaluate technical readings within an existing curriculum. Every class period includes critical evaluation of the reading's effectiveness. The second component is a technical but highly literate course project. Several courses work in concert for the second component, requiring students to present their work multiple times to different audiences in a variety of formats. This encourages students to reflect on the relationship between the audience, the medium, and the message.

Our immediate aim is to prepare students for the later stages of graduate school. As students move from classrooms into research labs, they will engage in a significant amount of writing. Student researchers will write short (10-14 pages) technical papers to report work at research conferences, expand successful papers into longer (20-40 pages) journal articles, and eventually produce M.S. and Ph.D. theses measured in hundreds of pages. For each paper, students typically give a public lecture at a conference or in a thesis defense.

Our longer aim is to produce graduates that are able to make a great impact upon the world through the use of effective communication skills. As students proceed from graduate school into business or the academy, they will be required to communicate effectively with educated people trained in different domains, such as business executives, peer researchers, governmental officials, educators, and the public at large. This does not necessarily mean that the message must be "dumbed down." Rather, the writer must choose motivation, argument, and vocabulary suitable to the audience. In this respect, we consider most undergraduates and beginning graduate students as *novice writers*. Although these students have written many term papers and essays, few have written lengthy technical material that must entice, persuade, and satisfy a critical audience beyond the instructor that gave the assignment. Our goal is to provide a sound basis for novice writers to approach the craft of writing to a broad audience.

Anecdotally, we have observed three common problems in works produced by novice writers. These weaknesses are consistent with earlier observations. [1].

1 - Lack of motivation and context. Novice writers often produce papers that describe interesting technical work, but fail to explain why it is interesting or useful to the world at large. This is partially because student-chosen course projects are usually arrived by adding a new twist to a well-known topic in the manner of *"Wouldn't it be cool if we parallelized data transfer in a web browser?"* Although this rubric is a perfectly valid method of generating a new idea, it is not sufficient motivation for new work. Students must often be reminded to identify a beneficiary of the new idea: perhaps a person viewing movies via the Internet. This is not just a formality: the motivation guides further technical decisions. If the movie is watched as it is downloaded, it must be sequentially accessed, so the parallelism must be fine-grained. If the movie must only be downloaded as a whole, the parallelism may be coarse-grained, improving throughput at the expense of response time.

2 - Poor articulation of core argument. Novice writers often have difficulty distilling a complex topic down into a concise argument appropriate for inclusion in a paper abstract

or highlighted as a thesis statement. The ability to strip away details, leaving only the essential argument, is absolutely required in order for the student to obtain a broad view of a field of study. The following quotations are examples of arguments that we would like students to produce:

- *Consistency management at the granularity of a file improves the scalability of a filesystem at the cost of single-client performance.*
- *Time in a distributed system can only be explained in terms of event causality.*

Obviously, the distilled argument is only a placeholder for the complete work. Readers familiar with AFS [2] and Lamport Clocks [3] should easily recognize these arguments, while others would gain little insight from such a brief explanation.

3 - Distraction with the wrong details. Novice writers will write at length on details that have little meaning to anyone not intimately involved with the work. For example, they may describe the names of computers used to run experiments, the command line options necessary to run their software, or incidental technical names (LDR.EXE) rather than a descriptive name ("the loader process"). Of course, there are appropriate times to include such detail, such as when describing how to repeat a particular experiment. However, such details must be chosen carefully and employed sparingly, otherwise the work as a whole will be incomprehensible to the reader separated from the writer by any significant time or distance.

To attack these three weaknesses, we are developing a curriculum-independent course format with two components:

A - Critical evaluation of readings. Each class period involves a discussion of several previously assigned technical papers. Although the primary intent of each class is to assist students with absorbing the technical material, there are ample opportunities for addressing the weaknesses described above. The question *"Who benefits from this idea?"* encourages broader thinking about motivation and context. Asking *"Who can summarize this paper in one sentence?"* exercises the ability to distill the core argument. It is also an excellent exercise in editing, as it may require five students and ten attempts before producing one crisp sentence. A short time at the end of each class is left to a discussion of the writing quality of each paper, typically by comparing the assignments for the day. Note that it is *necessary* to leave this to the end of the class, because students often come to class with an incorrect understanding of a paper! After gaining deeper knowledge, they may change their evaluation: a paper may be easy to read and yet not effectively communicate key details.

B - Highly literate course project. In addition to the technical readings, students undertake a highly literate course project, culminating in an polished paper that could plausibly be submitted to an academic conference. Although such a paper will certainly involve the construction of some software or hardware artifact, we emphasize that the paper constitutes the lasting contribution. Students develop a concept of their choosing through a variety of milestones, including a formal project proposal, an annotated bibliography, a short technical talk, a draft paper, a longer technical talk, and a final paper. At each stage of the project development, a student's work is evaluated by peers. Multiple classes are paired together in order to provide a mixed audience, requiring students to provide a sufficiently general introduction and motivation in addition to the technical details. Early in the project development, each student gives a 10-minute talk describing the project, motivation, background work, and research plan. The brevity of this talk requires careful preparation to distill the essential message into a form accessible to the audience. The first draft of the term paper is again evaluated by anonymous peer reviews. Detailed reviewed forms are provided before drafts are written in order to offer guidance in writing. After peer reviews are written and returned, each student prepares a final paper draft to be graded by the instructor. Finally, each student gives a 30-minute talk to the combined audience, describing the work in detail.

To evaluate this approach, we use a variety of written reflections. Students complete evaluations at the middle and end of each course. The peer reviews on draft papers serve triple duty: they give students feedback on how their writing is perceived, they give feedback to the instructor on how reviewers read papers, and they allow instructors to evaluate how papers are modified in response to reviews. In addition, instructors provide end of course reflections on class discussions, the writing process, and the final papers.

A one-semester pilot of this course format was conducted in fall 2004 in two small advanced elective graduate classes in Advanced Computer Architecture and Distributed Systems, totaling 11 students. Due to the small course size, it is difficult to draw statistically meaningful results. However, anecdotal results from surveys suggest that students believe the peer evaluation process to improve the introduction, motivation, and context of their work, but to have little effect on the technical and experimental aspects. This is the intended result, and also consistent with our professional experience in peer reviewing. Instructor evaluations of the course show that students were generally reluctant to engage in serious paper revising between the draft and final paper. We will address this in future classes with an increased emphasis on revising in the classroom and by adding a revising component to the final grading scheme.

The pilot will be expanded in 2005 to four beginning graduate courses, three instructors, and about sixty students. The larger sample will allow each element of peer review to involve a different subset of students, broader responses, and statistically meaningful survey results. Finally, by employing a literate approach early in the graduate curriculum, we hope to produce students that are well prepared to enter the research phase of their careers.

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