# Considering the Chalkless Classroom

**Joanna A. Ellis-Monaghan**
Saint Michael's College
Department of Mathematics
One Winooski Park
Colchester, VT 05439
jellis-monaghan@smcvt.edu
http://academics.smcvt.edu/jellis-monaghan/

**Abstract**

This paper shares some personal reflections on several years of integrating educational technology into mathematics courses while retaining the direct interaction strengths of the traditional classroom.

**Keywords**: educational technology, web-based learning, blended learning, teaching methods, liberal arts, residential campus.

## 1. Introduction

Recent years have seen enormous advances in classroom technologies, accompanied by the challenge of using these new resources effectively to enhance mathematics education. I teach at a small, residential, liberal arts college and am keenly interested in integrating the benefits of web-based, distance, and technology-augmented learning into the traditional strengths of a liberal arts curriculum. Over the past several years, I've experimented with a variety of educational technologies in a wide range of classes, from elementary statistics through abstract algebra, and particularly in the calculus sequence. Some technologies such as interactive whiteboards were successful, and they are now standard components of my courses. Some technologies such as static slides, did not deliver the benefits I originally envisioned, but with experience were used more effectively in subsequent courses. However, all these initiatives resulted in an articulation and assessment of classroom technology practices that seems worth sharing.

The struggle for pedagogically sound integration of technology and web-based resources into a course is largely independent of the specifics of course, text, version of Computer Algebra System (CAS) or graphing calculator, hardware, course management system, and source of web-based tools. However, for the sake of concreteness, specifics for the calculus sequence I teach are as follows. The text is James Stewart's *Calculus, Early Transcendentals*, [1]. The course uses the Maple CAS, and includes applied Maple labs developed specifically for the course, as well as interactive Maplets from MapleApps. I generally use a classroom equipped with SmartBoard electronic blackboard technology and a multimedia computer console. Many of the online animated visuals and interactive drills are drawn from the online resources that accompany the text and from

Visual Calculus [2], an online teaching resource developed in the late 1990's by Larry Husch at the University of Tennessee, Knoxville. Initially, I posted comprehensive course websites for my classes, but I have since transferred much of the material to eCollege as part of a campus-wide initiative. The web content of past courses (prior to the eCollege migration) is archived, but not supported, on my homepage [3].

After several years of minor technological augmentations (e.g., Maple labs, email correspondence, files posted on the local intranet), my first major foray into the world of technology enhanced education was an entirely web-based section of Calculus I that I developed and taught in 2002-2003. This was not an online course, but rather what might be termed a 'blended', 'hybrid', or 'web-enhanced' course. It was conducted in a regular classroom with a classic text and no reduction in student contact hours. However, I presented all of the material using web-based tools organized through an extensive course website instead of the chalkboard. All the course notes were online. Nearly every lesson was accompanied by animated visuals. There were interactive drills and practice tests, exploratory Java applets, Maple demonstrations, and links to ancillary resources. We had Maple labs and interdisciplinary projects. We were able to cover 30% more material, in more depth than previously, and in less time. It was wonderful! Unfortunately, in the Fall of 2002, the students hated it. Vociferously.

Based on this experience, I again redesigned the course in 2004-2005, and have continued to refine the integration of technology into the classroom since then. This has resulted in a much more positive experience for both my students and me, and, my students now respond enthusiastically to the technological innovations. I wanted the best of both worlds, the personal and the technological, and achieved it by reclaiming some of the valuable characteristics of a traditional residential campus classroom, and offering, rather than requiring, technological tools. I gained some valuable insights from this experience, both about what web-based resources might be successfully integrated into the curriculum at a smaller undergraduate institution, and also, perhaps more importantly, about how to do so while strengthening, and not detracting from, the personal teacher/student interactions at the heart of a residential college experience. While many of my choices are clearly predicated on my own teaching style, and other teachers might be better served by different approaches, the factors considered are common to modern classroom.

I've collected some of these reflections below, discussing the anticipated benefits that motivated these initiatives, a few of the pitfalls, and some of successful practices that eventually evolved. I conclude with some consideration of the broader professional context of this activity and some resources to support it.

## 2. What Was Anticipated

Prior to the 2002 initiative, and continuing thereafter, I researched educational technology literature for the anticipated benefits of distance or web-based learning. Many early references targeted institutional planning, and focused on technology leading

to a cheaper and more efficient way to manage large numbers of students and an ability to attract from a broader geographical area. However, as an individual teacher, my goals were not to generate revenue/cut costs, expand access, or to increase class capacity, but first and foremost to improve course content and student learning experience.

I sought primarily to build on the active learning paradigm at the core of my teaching philosophy. The benefits I anticipated from web-based delivery included:

- deeper and/or quicker understanding of the material due to better and more efficiently delivered visuals and interactive exploratory tools;
- a web-based asynchronous learning environment that would encourage greater independent learning from students;
- better mastery of basic skills from readily available interactive drills and on-line self-assessment tools;
- more efficient delivery of course content that would leave more class time available to work with students one-on-one or in small groups; and
- less time spent grading and preparing for class, which would free time for more out-of-class interaction with students.

Many of these benefits were realized, in particular better student understanding from carefully prepared animated visuals and self-assessment tools, and these I have continued to incorporate into my classes. There were also unexpected benefits, especially in articulating my own pedagogical goals and collaborative development of self-contained interactive tools. In some cases, however, the technology was problematic and proved more of an impediment than an asset, and, in others, students benefited more from exploring interactive web-based tools outside of class than they did from passively observing them during class. From this, I learned to cull and adapt, and assess technological tools as critically as any other aspect of teaching.

Finally, there was some initial disillusionment. For example, I was naive in my belief that I would spend less time preparing for class and more time with my students, and that I would be able to recover my time investment over a number of semesters. In hindsight, this technology time sink came from naiveté and, in some cases, from trying to reinvent the wheel. I have since recovered, and now am able to recover amply the vested time and effort through a more realistic understanding of the commitment involved and a more informed selection of projects. Furthermore, the resources to support educational technology are expanding daily, and it is now often a matter of choosing a desired tool rather than creating it.

## 3. What Needed Adjustment

Students at small residential liberal arts colleges expect a high level of individual attention. This is how we portray ourselves and it is one of our greatest strengths. Technology in the classroom must augment and not undermine it. This requires a delicate balance, because web delivery of course content often shifts the onus of learning

responsibility onto the student, which is valuable, but risks reducing personal teacher-student interactions. Educational technology must enhance, and not replace, valuable human contact time. In the initial 2002 course, I considerably underestimated the amount of necessary preparation time, which compromised my availability to students outside of class. Also, activities such as online self-testing that I saw as fostering independent learning, my students sometimes perceived as being unsupported. Addressing both of these concerns was a priority in subsequent semesters.

I currently choose to teach in classrooms equipped with a SmartBoard and a single computer/multimedia console, rather than available computer labs with individual computers for each student. However, with only one computer in the classroom, often the instructor (or at most one or two students) is the only one actively engaging the software. In the 2002 initiative, this resulted in passive observing, or "third grade filmstrip syndrome", particularly when students were viewing static slides, although they seemed somewhat better engaged by animated PowerPoint or Flash demonstrations. This was one factor in my decision to relegate a number of the web-based tools and demonstrations previously used during class to ancillary support material. They then became valuable supplements for students to explore independently outside of class, occasionally as specific assignments, but also sometimes simply as an additional source for learning the course material beyond the text and classroom lectures.

One of my biggest concerns with web delivery of content, even when done within a traditional classroom setting, was losing the mental processing fostered by note taking. In the 2002-2003 courses, I addressed this by having students prepare study guides for tests and by a series of writing exercises wherein students "annotated, illustrated, and applied" a selection of substantive theorems and proofs. While this was valuable, I didn't find that it sufficiently compensated for the process of carefully working together through the considerable number of very important theorems essential to a first semester calculus course.

In the Fall of 2002 initiative, I covered about 15-20% more of the text than in my previous classes, plus additional supplemental material. However, it was not a sustainable, or even desirable, gain. It derived as much from my own urgency to prove this experiment a success, coupled with one or two highly motivated students who set the tone for the rest of the class, as from any benefit derived from the web-based technology. Furthermore, students were also understandably resentful about having to do considerably more work in the web-based section than was required by traditional sections of the same course. It is probably very risky to deviate too far from the common practices of the rest of the department unless students have the opportunity to self-select in or out of the course. Subsequently, I have focused on using the web-based approach for greater depth of understanding and better student engagement rather than for increasing the volume of the course content.

I was also both over enthusiastic and too timid in my first foray. I wanted to add all the exciting new technology to the course, but was afraid to let go of the security of a traditional curriculum. This resulted in an overfull course and overburdened students (and professor!). Years of experience, my own and my department's, has established

appropriate workloads for our courses. Web-based material adds to this load, and can easily overwhelm a student in what are typically already very full and challenging classes. Now, every time I design a new course component or assignment, I ask: "What is this replacing? Does it do a better job than the previous activity? How does the time/benefit ratio compare?"

## 4. What Seems to be Working Now

In subsequent classes (including other courses, not just calculus), I have adopted the following practices:

- All of the course content is available via a comprehensive course web site, including the syllabus, assignments, links to demonstrations, class notes, computer labs, applied projects and resources, study guides, skills drills, etc.
- In-class course content is delivered as a balance of traditional lecture, collaborative group explorations, and individual participation, with a carefully rationed amount of on-line presentation of web-based content and software demonstrations.
- I introduce interactive technology, such as Java applets, very briefly, and then assign individual explorations outside of class.
- I keep static slide presentations to a minimum, using them only for compelling reasons such as displaying data, and intersperse slides with student activity, such as group work.
- I use SmartBoard technology to record and post daily course content to the website.
- In addition, for each section of the text, I provide a rich array of on-line resources as supplementary material. In this context, students view these resources as "value added" to the course and respond positively to them.

The successful practices for integrating personal interactions with technological resources in my current classes may be summarized as follows:

- Provide support and encouragement in person, and course logistics on the web.
- Do proofs by hand, and show visuals via the web.
- Work example problems by hand, and provide drills and self-assessment tools on the web.
- Set the stage for interactive explorations in class, and post applets and other demonstrations for students to explore asynchronously outside of class.
- Cover the basics in class, and provide a rich array of ancillary materials linked to the course web site.
- Integrate writing, application, and synthesis projects into the course, and provide resources for these activities on the web.

Finally, and most critically, I consider the following before integrating new technological resources into my courses. The innovation must serve the course and student learning better than the method it replaces. Moreover, the improvement must be sufficient to justify the time cost (both in and out of class, and both for professor and for students) of interacting with the necessary hardware and software, as well as any attendant development and preparation. Alternatively, the technology must be at least as effective as traditional methods, but with a significant time saving for both myself and my students. A blackboard and chalk approach is very robust, quite efficient, and is historically proven to be a quite satisfactorily effective pedagogical tool. It does not require special training in the use of pencil and paper to prepare handwritten lecture notes, and these notes do not need to be upgraded each semester to conform to new hardware or the latest version of some software program. The tangible assets of a traditional classroom should not be sacrificed except for significant and demonstrable pedagogical improvement. This isn't as curmudgeonly as it may sound since many technological teaching tools actually do meet this criterion, which is probably the source of the whole teaching with technology revolution. The challenge is finding a balance that delivers the best of both worlds.

One of the clearest results of assessment surveys conducted at the conclusion of the first web-based courses (and reconfirmed each semester in course evaluations) was that students respond very favorably to having a comprehensive course website. I now develop such a course website for all of my classes, and the process has become quite efficient and streamlined with repetition. The site includes the syllabus, all daily class notes, homework assignments, programming examples, computer labs, course grades, links to interactive drills, java applets, animated visuals, on-line text supplements, and ancillary materials, as well as information about upcoming special events and resources such as help sessions and study skills workshops. An excellent guide to course website content by Ernest Ackermann can be found at [4]. These guidelines are independent of the online delivery mechanism, whether it is simply a course website or a course management system such as eCollege or BlackBoard.

My Fall 2002 students, having all content delivered via the web, seemed to have a better intuitive grasp of the material than previous students, primarily due to better quality graphics than I could provide with hand drawings (especially the animations). However, I felt that their understanding of proof processes was compromised, largely because at that time my handling of online slide presentations did not allow adequate time for absorbing logical connections. In subsequent classes, I retained what worked well with a careful selection of the richest online visuals for inclass use, for example Riemann sum animations and interactive applets illustrating the formal definition of the limit with moveable $\delta$'s and $\varepsilon$'s. Other material, such as more complex interactive explorations and less engaging demonstrations, became homework assignments or ancillary supports, respectively, for asynchronous use.

For careful, formal, proofs however, I have returned to a more traditional lecture format, handwriting them on the SmartBoard, and then capturing and posting them to the web at the end of each class. The visual aids, explorations, and active learning modules all contribute to a depth of conceptual understanding, but mathematics also requires a

written formalism that must be modeled to be learned. I find that hand writing notes on a board (albeit a SmartBoard) forces a slower classroom pace that counteracts my tendency to go too fast. There is a valuable rhythm to speaking the words, writing the words, repeating the words, waiting for students to write the words, pausing for mental processing, making eye-contact, soliciting feedback to confirm understanding, and only then moving to the next step. This rhythm, its tempo set by face-to-face contact, effectively communicates and models the structural formalism of mathematics. Moreover, it communicates a logical progression that is generally quite difficult for students to absorb from static printed text without guidance regardless as to whether that text is delivered via the web or on paper. There seems to be a sensory mnemonic quality to handwritten notes from experienced content, almost a texture, that is absent from a typeset page.

End-of-term evaluations now repeatedly testify to students' appreciation of having class notes posted online. The class notes include not only the handwritten proofs, but also any inclass Maple examples, sample exercises, and annotated web-based visuals from that day. Students report using the online class notes to verify their own notes, to review from, to enable themselves to concentrate and participate more freely during class, and to compensate for classes missed due to athletic events. Although there is a time-cost associated with using this technology, including the initial training, boot up and shut down time, and saving and posting the files, it is well worth the benefits.

Many example problems are also done by hand, either by myself, by individual students, or by groups of students working collaboratively in class (I establish study groups both in and out of class, and a small residential campus is especially conducive to this). A selection of these examples is posted to the web. Students also use threaded discussions on eCollege to exchange homework hints and resources, both among themselves and from me. I find the threaded discussions particularly time efficient, since I need only answer a common homework question outside of class once, not thirty times, and students can have immediate access to postings without having to wait for office hours.

Additionally, my students consistently respond very positively to online drills and self-assessment tools, particularly those designed as teaching tools with hints or step-by-step solution options. I use these drills occasionally in class, early on simply to familiarize students with them, but also later, because some, particularly those with detailed graphics, are faster to use than copying problems from my notes or the text onto the board. More importantly, I have replaced some sets of routine textbook exercises with online drills, and have observed a greater facility with the types of problems targeted by online drills than in past students. I am also careful to include problems modeled on the drills and online assessment tools on inclass exams, just as I include problems modeled on textbook exercises.

I now limit inclass use of interactive online tools such as Java applets and Maplets, although I provide links to quite a number of them and encourage and assign their use outside of class. I briefly demonstrate them in class, provide the conceptual context for the ideas they illustrate, and then have students explore asynchronously them

outside of class. I have considered teaching in labs with individual student computers so students may explore these activities during class while they have ready access to me and to classmates, but that is an initiative for another day. A remaining challenge is how best to ascertain, acknowledge, and assess student time and effort spent on such endeavors as exploring a concept through an interactive tool.

The essential content of a course is covered during class time as always. However, now in addition I provide as rich an array of ancillary materials as possible, content-linked to course concepts. This includes the drills, demonstrations, applets, and Maple resources mentioned above, and also links to various calculus and precalculus sites. These latter sites give students learning options beyond class notes and the text, and can be a particularly effective way to address individual learning differences, since resources might include, for example, audio/visual lessons difficult to integrate into actual class time, but helpful to an auditory learner outside of class. Precalculus resources allow students to review basic skills quickly at need without consuming precious class time. Most textbooks now come with an array of web-based ancillary materials (and this has become one of the criteria I consider when selecting a new text). I also use Visual Calculus modules that correspond to most of the concepts in a traditional calculus sequence. Visual Calculus may no longer be supported, but it is still a valuable resource and is archived online (see [2]). My current students respond very favorably to the web content of the class, perceiving it as 'value-added' and enhancing their understanding of the material

Because the underlying pedagogical philosophy builds on a foundation of active learning approaches, I design number of synthesis projects for each class that incorporate assimilation of course concepts, written expression, integration of computational software, and exploration of web resources, with each project ideally presented in a real world context. The internet provides an excellent forum for these projects. Not only do I post resources for the projects on the class website myself, but also students use internet research tools to find additional resources that they then share with classmates via web-based tools such as threaded discussions.

One of the unexpected, yet satisfying, benefits of this enterprise is developing (usually in collaboration with students and/or colleagues), and sharing computer resources. This has included many Maple labs and about two dozen interactive two- and three-dimensional visual Maplets (applet-like graphical user interfaces for Maple available from the application center at Maplesoft.com). These interactive programs explore various calculus concepts such as traces, osculating circles, line integrals, and gradient vector fields. My students have also created a comprehensive set of animated graph theory demonstrations. One of the advantages of the internet content over printed text is that it is infinitely adaptable. While single-handedly developing all the content for a fully realized on-line course is beyond my current resources, I've found it quite realistic to target a specific, self-contained concept (or cluster of concepts), develop online tools for exploring it, and then disseminate these tools via an online community.

There were further unexpected benefits, especially in articulating my own pedagogical goals. In order to determine if a new technology-based approach is better

than an existing traditional approach, it is first necessary to think very clearly about what I hope to accomplish and why. This may well be the source of some of my own greatest personal satisfaction with the process of integrating technology into the curriculum.

## 5. Some Final Considerations

The broader environment can be an important factor when implementing new education technologies. This includes individual time constraints, departmental priorities, and institutional support. Full-blown course redesign with the goal of transitioning in one step from a traditional lecture format to entirely web-based content is a tremendous, possibly even unrealistic, time commitment for a single individual unless specifically contracted for that task. At large institutions, particularly those committed to distance learning, the costs and benefits of such a venture are distributed over many individuals and many sections of the same course. However, at a small residential college, a more conservative, paced approach probably serves better.

I had some sense of this (although not nearly enough) in 2002, and chose to adapt existing material available on the web as much as possible for the course content, rather than creating it from scratch. Even so, I was not prepared for the amount of time even "adapting and posting" required in that first initiative. It far exceeded normal lecture preparation time, and watching some of the material crumble into electronic obsolescence from one semester to the next was demoralizing. The time cost of software upgrades and maintenance of online material is a serious concern, particularly with advanced courses that may not be offered every year on a small campus. However, the good news is that resources for web-based content are growing exponentially. Comprehensive software resources now accompany many texts, and the maintenance of this material is handled by the publisher. Similarly, there is a wealth of pedagogical materials available online as ancillaries to various computer algebra systems such as Maple or Mathematica and course delivery software such as eCollege or BlackBoard.

Securing departmental, Information Technology (IT), and institutional support for new educational technology initiatives prior to their implementation can be essential to their success. Because of the time commitment involved, pre-tenure faculty in particular should solicit strong support and participation from colleagues and discuss the initiative thoroughly with the department chair and relevant administrators in light of the tenure process at their institution. Although the first 2002-2003 experiment in a web-based curriculum did not immediately garner the rave reviews I had hoped for from my students, my department recognized its value in curricular development and communicated this to campus review bodies. Their support continued into subsequent semesters as I reevaluated and redesigned the later, much more successful, approach to integrating the benefits of web-based resources into the pedagogical paradigms of a residential campus. The educational technology and technology steering committees, as well as the IT department, also recognized and communicated that such efforts to appropriately integrate technology with our traditional strengths forwards institutional priorities. I am very glad that I worked, and continue to work, with these groups, keeping

them apprised of my progress, and soliciting their input into various aspects of course design.

Two resources I have found helpful are Project Kaleidoscope [5] and EDUCAUSE [6]. Both are organizations with very broad scopes, but within their sites are valuable resources for thoughtful implementation of technology enhanced education. Many of these articles address 'pure' distance learning, or emphasize financial advantages, particularly for large institutions, but there are often important pedagogical and logistic considerations that pertain to smaller colleges and the individual course or faculty member as well. There are also a number of important benchmarks and readiness criteria, careful consideration of which can contribute to the success of a new educational technology initiative. Particularly thought provoking are the 2001 PKAL Roundtable on Information Technology in the Service of Student Learning [7], and "Distributed education and its challenges: An overview," by D.G. Oblinger, C.A. Barone, B. L. Hawkins [8].

Ultimately, I feel I eventually gained all the benefits I originally envisioned from integrating educational technology into my courses. Technology-based visual aids and interactive tools have been particularly effective for building deep intuitive understanding for my students. I continue to assemble a library of these, and enjoy developing them myself in collaboration with my students and colleagues. Asynchronous learning via online resources has become a standard course component accepted and valued by my students. The success of these efforts is reflected in greater student satisfaction and engagement with course content.

I believe I have even achieved the most elusive goal of the technological enhancements, that of creating more time for interaction with my students. This has come from a paced integration of new technologies so as not to overwhelm myself or my students, careful assessment of time/benefit ratios, and replacing course features with better versions rather than just adding to them. I now present graphics and data more effectively during class, thus reallocating valuable board time to conveying difficult concepts and proofs. Efficient communication through web postings and less grading due to web-based self assessment tools has made more of my time available to students.

It is possible to have they best of both worlds, the personal and the technological. The key seems to be building on the real interpersonal strengths of a traditional residential campus classroom, and augmenting, not supplanting, them with effective and enriching technological tools.

### *Dedication*

These reflections are dedicated to the outstanding IT staff here at Saint Michael's College. The IT department is the *sine qua non* of any educational technology initiative, and any success in the endeavors described here owes a tremendous debt to the expertise, commitment, and most especially patience, of the Saint Michael's College IT staff.

## 6. References


[1] Stewart, James. *Calculus, Early Transcendentals,* editions 4-6. Thompson, Brooks/Cole, pub.

[2] Husch, Lawrence S. *Visual Calculus,* http://archives.math.utk.edu/visual.calculus/ copyright 1995-2001 Lawrence S. Husch and University of Tennessee, Knoxville, Mathematics Department.

[3] Ellis-Monaghan, Joanna. Homepage at http://academics.smcvt.edu/jellis-monaghan/.

[4] Ackermann, Ernest C. *Tools for Teaching: The World Wide Web and a Web Browser*. http://people.umw.edu/~ernie/facacad/WWW-Teaching.html, copyright 1996, Ernest C. Ackermann.

[5] *Project Kaleidoscope*. http://www.pkal.org/, copyright 1989-2008, Project Kaleidoscope.

[6] *EDUCAUSE.* www.educause.edu, copyright 1999-2008, EDUCAUSE.

[7] *Information Technology in the Service of Student Learning, 2001. A Report from the 2001 PKAL Roundtable on the Future.* http://www.pkal.org/documents/InformationTechnologyRoundtableReportPDF.cfm, Project Kaleidoscope, 2001.

[8] Oblinger, Diana G.; Barone, Carole A.; Hawkins, Brian L. *Distributed Education and Its Challenges: An Overview.* http://www.acenet.edu/bookstore/pdf/distributed-learning/distributed-learning-01.pdf, copyright 2001 American Council on Education


## Biographical Sketch

Joanna Ellis-Monaghan is an Associate Professor at Saint Michael's College, in Colchester, VT. She received a B.A. in visual arts and mathematics from Bennington College, an M.S. in mathematics from the University, and a Ph.D. from the University of North Carolina at Chapel Hill in 1995 in algebraic combinatorics. Her current research areas are algebraic combinatorics and applied graph theory, with an emphasis on bioinformatics and statistical mechanics. She is a proponent of active learning and has developed a broad range of classroom materials, much of it technology-based, to augment a variety of courses. She is also involved in undergraduate student research, is a Project NeXT consultant, and is on the Maple Academic Advisory Board.