

WebCalC — Two Years Later

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The WebCalC Project – Inception

The **WebCalC** Project, whose team members are Michael Stecher, Philip B. Yasskin, and this author, is a complete “course-in-a-box.” The course is calculus I, a typical engineering calculus course, equivalent to an AP calculus (but without a graphing calculator component). The inception of this course was in the Spring of 1997, when the team decided to generate an online course. Several months of discussion ensued, particularly over the two most essential points.

- What should be the method/software for delivery?
- What does an online course need to be?

Dozens of other issues, from the file management system to the creation of graphics, were ignored at first, though each eventually required careful attention.

The second question has a simpler solution summarized as follows:

“At a minimum the complete online course must do everything a book does. To succeed, it must do very much more. Developers should look for computer assisted teaching devices that the classroom teacher cannot match.”

A rather simple statement to make, satisfying it is not easy. For one thing, what is the “more” alluded to above? For another, the continuous and rather steep learning curve of Web technology on which most of us find ourselves offers it own challenges. It would be easier if the technology was relatively static – like book technology, but web technology and its correspondent hardware technology, are changing at an ever-increasing rate. So, decisions made one day may not valid the next. It is daunting to realize that a whole online text effort may have to be scratched and recast in some new format, possibly even before completion.

However, the summary above, formulated ages ago in “web-years” seem to remain valid. Our experience has shown the online course must be every bit as complete as a book and more so. For example, answers to sample questions should contain more detail than the typical textbook. Mathematics textbooks, by the way, are not written for self-study and fail miserably if so used without supplementary materials. Even so, they are used exactly this way, and without supplements, in many distance education efforts. The online course, however, must be written exactly for that purpose.

For content creation, what we decided on what can be termed an “onion” paradigm, from which we would begin with a core text, then modify and add to it as time, technology and skills permit. In essence, we build the course a layer at a time.

While the second question can be dismissed with lofty goals, the first question, a significant operational detail, remains. What presentation software should be used? Conventional wisdom dictated that HTML-only is not only the reasonable choice, but also the only choice. While this prescription is adequate to convey information for many courses, we questioned whether HTML-only was good enough for a mathematics intensive course? The decision did not come easily. It was essential to determine exactly what the student should see. With this in mind, we prioritized those features we assessed as most important. Overall, the course should have an economical, functional, and attractive design [Lynch and Horton, 99]. Precisely, the course should have:

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| 1. Perfect mathematical typography
— math should look like math | 6. Complete solutions to examples
and exercises |
| 2. Great color and graphics | 7. Question-answer notes |
| 3. Interactive quizzes and exams | 8. Animation and Java |
| 4. Internet linked; fast downloads | 9. Sound and Video |
| 5. Symbolic mathematics
capabilities | 10. Years of testing |

The logic for most of these have been discussed in some detail in [Allen, et. al., 1998a and 1998b]. So, here we make only a few points. First of all, students are accustomed to the highest quality software, whether from the viewpoint of a word processor or spreadsheet program, or from their vast experience with computer games. Therefore, the key point of excellent mathematical typography is in the interest of the student and student expectations, particularly the beginning student enrolled in calculus. While mathematics instructors have little difficulty reading mathematics in almost any form, the beginner does have trouble. For these students, the presentation must look as perfect-like-a-textbook as possible. This decision clearly limited available choices. The most direct way to achieve good mathematical typography is through GIF images created by programs such as LATEX2HTML or say through HTML export of a MSWord document. Both procedures generate mathematics of good appearance, but neither prints well. In addition, resulting file sizes tend to be large. This means files download slowly, and fast download times are essential. Student interest and attention fade if lengthily downloads persistent. (Roughly, a consistent twenty seconds download time per page is near the maximum time students will accept.) A couple of other methods are available, but they each suffer one or more defects, as above. In a recent paper, Robson (Robson 99) discusses objected oriented course design for Web-based authoring to alleviate some of the extraordinary complexity for developing one of these projects.

The last three points were considered only after the project was under way. Indeed, we have added a few animations (animated GIF images) and Java applets. Such devices have not yet become an *essential* course feature, although students do like them. Sound and video were unfeasible when we began, but this year, thanks to new highly

compressed streaming software, they are. This fall we will begin to add narrated slide shows to the course in select places. [Levine, 99] The last point about testing was unrecognized only after testing began, and we began to understand how complex this aspect of the project was. Briefly, it is important to understand that learning how to use an online course is a separate skill altogether. Hypothetically, even the perfect online course could fail its field tests if the instructor is not given directions on how to administer it. Further details of this fact, vis a vis WebCalC, are developed below.

Our software decision was to use Scientific Notebook, a TeX¹ typesetting engine, with a built in browser and a Maple kernel. This generally makes for very small files, normally 5-10 KB excluding graphics. The browser part of program “builds” the page from the TeX codes when it arrives at the client’s computer. With the Maple kernel, which is also menu driven, most students can answer the “what if” type questions that come up or produce great graphics with hardly more than the click of a button. Finally, it is exceptionally easy to typeset mathematics using Scientific Notebook, as that feature is also menu driven and is WYSIWYG, as well. Often portions of the material must be rewritten as the developer notes how students respond to it. Remember that without the lecture, there is little opportunity to clarify what has been written.

Though graphics have emerged in mathematical textbooks in abundance only in the last half of the twentieth century, they are today regarded as essential. In that connection students, having experience with the most cutting edge programs today, are again the experts. The graphics must be excellent. We construct ours using a variety of methods, the most dominant being to use Corel Draw to generate windows (WMF) metafiles, i.e. vector graphics. These are superior to GIF or JPEG images in almost every way except possibly file size. Most of our graphics are thirty kilobytes or less. They are in full color – as needed – and are in quality at the level of modern textbooks. As line speeds increase over the next few years, we look forward to generating graphics that are ever more sophisticated and interesting.

The WebCalC Project – more features and remarks

Basically, our course does have all the features above. Importantly, the lean and lively text pages [Douglas, 1986] are written to cover all the essential points needed for the topic at hand. Neither lengthily introductions nor long summaries are included. It is curious that in recent reviews of WebCalC one of the reviewers noted this as a negative feature (they should be there) but then noted that the preponderance of students don’t read them anyway. We’ve noted that just as in the traditional course, students tend to begin with the problems and read the text as needed. Without the lecture wherein student see examples worked and theory explained, students of online courses have less instruction than their traditional counterpart. Therefore, proceeding directly to the problems is a riskier strategy. One fundamental observation is that

Learning from an online course is task oriented.

¹ TeX is the de facto standard for mathematical typesetting today. It has been used for more than twenty years and produces the best appearing mathematics of any competing method.

Simply assigning chapter to be read and exercises to be worked is too vague to be effective. It is important to give precise tasks to the student on a daily basis. This can be accomplished through quizzes and worksheets. To drive this point home, every instructor, following the traditional method of teaching is substantially the *metronome* for the course. The lecture sets the tasks and the students respond by working the problems or reading specific material. This facet of traditional teaching needs an analogue in the online course. While there may be better methods yet undiscovered, for now the quizzes and worksheets seem to be working.

The online course needs a number of other features and WebCalC has them.

- Randomized quizzes
- Links and hyperlinks
- Homework with complete answers
- A consistent, attractive look and feel, that is artistic!
- Notes (pages-within-pages)
- Symbolic mathematics functionality
- Animations and Java applets
- Select online quizzes

Many of these can be lumped under the rubric of *interactivity*. It is important for the course to communicate with the student by asking questions and then providing the answers. This is accomplished in a variety of ways. One method is the randomized quiz. These quizzes are generated on the fly and provide different questions (over the same topic) each time the button is selected. For example, think of a problem involving solving a linear equation where each time the button is chosen a different linear equation appears. When answers to the question or questions have been selected, the student receives immediate feedback. The course also contains “Blue Ball Quizzes”, so named because of the blue balls next to the multiple-choice answers. These quizzes are carefully crafted with feedback provided with each wrong answer and explanation given for the correct answer. (Some students choose buttons until the correct one is found.)

The online course should have a nonlinear structure. Thus the student can be maneuvered about as the links and hyperlinks determine. One particularly useful – and nonlinear – feature is the popup notes. For example, when explaining the solution to a problem it may be necessary to invoke a previous concept, say the Pythagorean Theorem. At this point, a button is inserted and the student, by choosing it, automatically sees the needed information. This is just one use of the popup note. They can also be used to enhance text information by supplying additional facts that would clutter the main page. They can be used for definitions and reinforcing a concept. They can also be used to supply a relevant graphic. Such notes are downloaded with the page and appear only if “chosen.” Our greatest use of the pop-up note has been to supply answers to exercises. Next to each exercise problem there is an “Answer button”, which the student chooses to view the answer. Overall, such notes give a definite appearance of interactivity. Links and hyperlinks are used for larger notes and for additional information of a nature inappropriate for a smallish popup box, and of course, the next page.

WebCalC has a few animated GIF images that students like. We also have a few fully interactive Java applets. One applet plots a user-supplied function and then display a secant line evolving into the tangent line. As interesting as this is, students don't seem

to use it. We believe that some specific task must be associated with the applet for it to achieve a more prominent place within the course. By the way, some Java applets tend to download and launch slowly. A delay of a minute or more is not uncommon.

The WebCalC Project – Using the Course

In an ideal world, pre-selecting students is possible. Hence the question: Who should and who should not take an online mathematics course? Our first choices would be to select students that are: (i) Strongly motivated — self starters, (ii) Intellectually mature, (iii) Home-schooled, or the (iv) handicapped. Our last choices would be students that: (i) have low mathematics pretest scores, (ii) are generally unmotivated, or (iii) need the classroom environment. At this point of online course development, the temptation to view them or require them to be suitable for all students is at best misguided, at worst a recipe for disaster. At minimum, a key ingredient to the success of the online course is a clientele that has very good reading skills. A very few (about three of 150) of our WebCalC students decided that online calculus was not for them. Every effort was made to transfer them to a traditional section.

Beginning in the Spring 98 term we have taught WebCalC to a total of five (25-35 student) sections. Taught during the '98-99 academic year as Math 171, the course was listed in the Texas A&M Course Timetable as being computer intensive. However, of the four sections offered, two were scheduled for freshmen Mathematics majors to be delivered in the traditional mode and the other two as online. In effect, the two sections for WebCalC had all the freshman Chemistry, Physics, Genetics and Geoscience majors. Thus it was not the ideal world indicated above. Though we did not survey students about their course selection at the time, we did survey them extensively as the terms progressed.

The mode of teaching, termed the *facilitator mode*, has several essential factors in common with the traditional mode. In the facilitator mode, the instructor is in the classroom with the students during a regularly scheduled period. The students however set at a computer terminal and learn from the online course. The facilitator

- Answers questions in situ
- Assigns/collects/grades homework
- Keeps the pace
- Makes/grades exams and quizzes
- Holds office hours

In brief, the facilitator performs all the traditional functions except deliver a lecture. The time traditionally spent lecturing is spent helping individual students with individual problems, usually to explain a worked example or to explain how to answer homework questions. The facilitator is generally occupied with student questions throughout the period.

What we have noticed is that students group in pairs or sometimes trios to study/learn together. Called *spontaneous group learning*, this remarkable phenomenon differs from other group learning not being contrived. ([Gantt, 1998], [Jensen & Sandlin,

1991]) Other students work strictly alone. Many of them never even ask a question. Most groups formed within a few weeks; other individuals migrated from one group to another. While we have no precise data about the results, our impression is that well over half the class worked in some loosely or tightly formed group, and that the grades of these students were higher on average compared with the “loners.” That the more socialized students do better seems to be true, but there is a law of diminishing returns. Too much of this good thing seems to decrease grades.

We have yet to discuss the true distance education mode, where there is no regular meeting time or place and where most communication is *not* face-to-face. In one sense, that is fortunate. Our experience with online courses has suggested that going to the full or true distance mode may have proved difficult had it been attempted earlier. The single most difficult question remaining is how to give proper and timely mathematical help to students as it is needed. Other documented problems include student isolation and frustration. The first, true distance education version of WebCalC will be offered during the Fall '99 term. We are mindful that students completing Calculus I must then proceed to a traditional formatted Calculus II. Therefore, students must be provided first quality education from WebCalC.

Some believe that because of technology, the very nature of the course, the syllabus itself, should change. This alters the burden of online course development. However, before massive changes in the course syllabus are implemented in synchrony with this philosophy, online courses should first satisfy the “proof of concept” of any new design which respect to the traditional syllabus.

The WebCalC Project - Survey Results

The measurement of course efficacy for the traditional course has been long abandoned. Typically, students are surveyed about the instructor with a sampling of questions about the course included. Traditional pedagogy is old, time-tested, and well understood. On the other hand, online courses seem to need to prove themselves to a higher standard. College and high school administrators are anxious to join the new age of online courseware but are nervous about the quality of the product. Perhaps trust for their teaching colleagues is not what it could be, and perhaps they fully comprehend the difficulties presented by this new medium, but surely they desire that online courses meet a level of quality consistent with their institution.

The developers are conscious as well about the quality of their new product. This is typically done by a panoply of surveying instruments. The most basic measures of course efficacy are surveys that measure students' impressions and studies that measure students' grades in subsequent courses. The surveys taken for this study do not follow precise standards of statistical sampling (Hall, et. al. 1999) but are rather preference surveys given and collected during a class period, four times per semester. The randomness of the sample was addressed earlier.

Having offered the course just five times, there is little firm data to convincingly establish what we hope is true, namely, that online mathematics taught in the facilitator mode is competitive – or better - than the traditional mode. Indeed, supposing results are

just comparable after only three semesters of use, then this marks a positive indicator of the potential of web technology as the medium of the future.

A number of questions were posed to students, many of them routine in nature, many key questions of great importance to the project. Responses were on a scale from “Strongly Disagree” to Strongly Agree.” The more important questions and responses are displayed below. Less significant questions to the reader are those involving material comprehension. Example: *I understood the material on inverse trigonometric functions well.* Other questions were included to measure students’ “comfort level.” Example: *I am very worried about the upcoming third exam.* Finally, some of the same questions were posed in alternate ways. Example: *The level of the material in the course was too advanced.* Or: *I found the chapters adequately explained the material.* These questions are similar to the first question below.

Question. I found the material paced evenly, with just enough explanation given.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	1	2	5	6	13	3
	2	1	5	10	10	2
	3	1	8	9	14	0
	4	1	5	10	10	1
Spring '99	1	1	4	10	13	2
	2	2	7	4	14	5

The mild “Disagree” response indicates the normal confusion and difficulty that many students have with a beginning college mathematics course. Overall, the surveys indicate that the level and pace of the material is acceptable – at least to the students.

Question. I found learning from the web far more challenging than I ever imagined.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	1	2	6	12	6	3
	2	0	5	9	6	5
	3	1	1	9	4	8
Spring '99	1	3	6	7	7	7
	2	4	7	3	12	6

Should these responses be considered surprising? Not at all, because the student is doing most of the work in the class. No longer is the atmosphere passive, where the

disinterested student can simply let a lecture flow around but not through his/her awareness. Students come to the lab to work.

Question. I preferred to work on the course at my home, over the net.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	1	2	5	14	7	3
	2	1	9	7	7	1
	3	3	7	8	5	0
Spring '99	1	5	6	10	9	0
	2	5	9	8	9	1

The responses are generally neutral overall, being well balanced. The indicator here points to possible results for the distance mode, which is being attempted in the Fall '99 semester. It also demonstrates that many students feel that they accomplish much in the class period and can supplement their learning in the open computing laboratories throughout campus.

Question. I used the symbolic features of Scientific Notebook to experiment or check mathematics often.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	1	8	8	5	3	6
	3	6	8	4	4	1
	4	5	10	2	8	3
Spring '99	1	6	11	5	8	0
	2	14	8	8	2	0

The responses here were a little puzzling. Scientific Notebook, our browser, typesetting, has a powerful menu driven Maple engine. It is very, very simple to learn and to use. Why didn't students use it? Probably, because it wasn't emphasized in the classroom. Several students used their graphing calculator to help them resolve questions. A few (of the better) students actually taught themselves how to use the Maple engine. Overall, though, most students didn't venture far from the path of assigned work.

Question. Adequate help in class or elsewhere is available when I need it.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	1	1	2	0	19	8
	3	0	3	3	14	3
	4	0	3	7	14	3
Spring '99	1	0	2	8	14	5
	2	1	3	4	16	8

The responses here were gratifying, but more importantly illustrate the effectiveness of the facilitator mode. Let us note that students did not often come to my office for help. These responses are generated from in class help, as it was requested. The strong “Agree” and better responses indicates that even the loner-type students seemed to feel that adequate help was available, though they may never have requested it.

Question. I regularly work on class materials with other students.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	3	0	6	3	8	6
	4	1	5	4	14	5
Spring '99	2	3	6	6	12	5

The responses to this question would have been the most surprising of all, had it not been observed directly. From the chart it is clear that a strong majority of students the learning process was collaborative. Called *spontaneous group learning*, this learning format was attractive to many students and is radically different to the traditional lecture mode. Oftentimes questions would be answered to a small group of students. Oftentimes the very best students would find themselves helping weaker students, though I am not convinced of the efficacy of this². In fact, it seems that learning in this mode is a social process. What is even more fascinating is that the students in the spontaneous groups tended to perform better on examinations, though these were administered in the traditional way – with no student interaction permitted.. However, this has not yet been measured from grade results data.

² The principal reason for this is that the stronger student, though very capable, may not be in tune with the real problems of the weaker student. He/she may give help that results in further confusion. The most tangible example of this, which may be peculiar the mathematics instruction, is to notice the better student showing the weaker one a special way of solving a problem that is apparently quite different from the methods being taught. Indeed, the facilitator mode of teaching works best when the facilitator is a highly experienced teacher well grounded in all the subject’s methods and techniques.

Question. The lab atmosphere is distracting.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	3	0	10	6	4	3
Spring '99	2	5	14	9	3	1

Even though the lab atmosphere, with all the conversation would be distracting in a traditional sense, most students did not regard it so. We could have insisted on strict independence of work and silence, leaving in the lab only the hum of CPU cooling fans, but we would have lost noticing the remarkable feature of social learning in a task-oriented environment.

Question. If the next calculus course was available online in the same format, I would take it.

	Survey	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Fall '98	4	4	5	7	5	2
Spring '99	3	5	6	7	7	2

The responses to this question were remarkably consistent over both semesters. They reflect the fact that the class had to work hard, that they believed they had learned the material, but that they are not yet ready to embrace online courseware with full vigor. These students, mostly freshmen, were able to learn calculus in a way entirely new to them, and this is significant.

Conclusions

WebCalC is a successful online project, principally because it works. By this we mean that students can learn online calculus I, perform successfully on traditional examinations, and perform well in successive calculus courses. Moreover,

- Students adapt to online learning without difficulty.
- Students learn to “get to work” right away, making efficient use of their time.
- Students like the task-oriented environment.
- Students can work together.

Some course revisions, but not many, have been required. More enhancements will be added as time allows. Precisely, we envision enhancements to include the following:

- Greater student friendliness

- Increased task orientation
- Increased ease of navigation
- Sound and video slide shows
- Faculty bulletproofing

Student friendliness and faculty bulletproofing are particularly important until the preponderance of instructors have experience with online courseware. There are numerous pedagogical techniques that must be observed to allow the online course to work. At this juncture in online education, many instructors, if given an online course teaching assignment, will treat it as some modification of what they know. Administering the course on the basis of traditional face-to-face teaching may lead to devastating results.

However, it will be important to measure the “value-added” component, as enhancements come at an increasingly high cost. High production costs, high development skills, and high production time schedules are each deterrents to further online course development. For example, a professional quality Java applet may require several months of programming effort. Commercial costs can run into hundreds of thousands of dollars. Then, it must be tested for efficacy. In contrast textbook technology is well tested and well understood, and accurate methods exist for estimating production costs.

It is significant that no doubt many false starts and many revisions to online pedagogical designs will be needed to perfect this mode of education. If costs are excessive, the expenses may not be forthcoming, certainly from public institutions.

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