Session T4C2

Mathcad in the Classroom – 15 Years Later

D.M. Griffin, Jr.
Professor of Civil Engineering

Michael Baumert
Assistant Professor of Civil Engineering

Louisiana Tech University
Ruston, Louisiana

Abstract

This paper examines the integration of the software application, Mathcad, into coursework in the civil and mechanical engineering programs at Louisiana Tech University during a period from the late 1980s to the present. Mathcad is routinely used as the primary means of conveying material in the classroom in courses in dynamics, fluid mechanics, hydrology/hydraulics and environmental engineering. Early use of Mathcad met with lukewarm success; however, as a result of improved classroom technology as well as experience gained in using it as a teaching tool, current feedback from students in these courses is now almost universally positive. *Dr. Griffin's Mathcad*, a web site devoted to illustrating how Mathcad can be used to solve engineering problems received over 20,000 "hits" in 2005 from nearly 200 domains. Personal email responses to the website describing how Mathcad is used in industry have been received from 35 companies ranging from local consulting firms to Berkeley National Labs, DuPont, and Corning.

Introduction

Computer applications designed to carry out various types of mathematical operations have become a ubiquitous part of the undergraduate engineering curriculum. One of these is Mathcad. This paper describes the use of Mathcad in the classroom, primarily in the civil engineering program at Louisiana Tech University, during the period from the late 1980s until the present.

Mathcad is a software application designed to carry out a variety of mathematical operations ranging from elementary to complex. Mathcad is unique among these applications in its free format input. Text and mathematics can be input in the same way one would do if creating a document by hand. In this way Mathcad documents can be understood even if the reader has never been exposed to Mathcad. A second

characteristic of Mathcad is the ability of the user to create plots quickly and easily. Mathcad was initially released in the late 1980s as a DOS based application. It evolved to Windows in release 5. The senior author is currently beta testing an upcoming version.

The senior author became aware of Mathcad in the late 1980s and began using it sporadically outside of class. Then, as now, there was concern regarding the extent to which the various courses in the standard undergraduate curriculum were integrated and the extent to which this integration was recognized and appreciated by students. As a result of this concern, in the fall quarter of the 1989-1990 academic year an experiment was conducted where Mathcad (version 1.5) was incorporated as a teaching device in an introductory calculus class (Mathematics 230) team taught by a member of the civil engineering faculty and a member of the mathematics faculty. Each class was divided into two parts, a 45-60 minute lecture by the mathematics faculty member followed by a 15-30 minute computer aided instruction session lead by the senior author. Each student in the class had access to an IBM 8086 computer. Response to the class by students was generally positive. Students who did best in the traditional portion of the class also performed well with Mathcad; the reverse was also true. Additional details of this experiment can be found in Griffin Jr., D.M.., Nelson, J.D and Marion, J.P, 1990. One of the students from this class, Rick Plummer, is now a principle in a consulting firm in Louisiana (PPM and Associates). He was one of the first to incorporate the use of Mathcad into design computations commonly carried out in Civil and Environmental consulting firms in Louisiana. The use of Mathcad in consulting engineering firms as well as other technically oriented companies inside Louisiana as well as across the country appears to be commonplace.

In 1992 Mathcad was used as the primary means of presenting material in an engineering dynamics class (Griffin, D.M., 1995). At the time computer projection capabilities did not exist and Mathcad files were presented as overheads and handouts. Table 1 is a subjective summary of the course evaluations.

Table 1 - Summary of Dynamics Course Evaluations

favorable	6
favorable but...	25
no opinion	1
unfavorable but...	0
unfavorable	1

Typically dynamics has had a reputation as a difficult course. A large part of the problem results from the fact that there are very few principles in dynamics that are applied to systems that vary enormously in size, purpose, and character. The course seems very abstract to many students as a result. Most textbooks generally present problems and ask for a single solution value, for example "compute the velocity after 3.8 seconds." If one assumes that problems are being done manually this is somewhat understandable from a "time required" point of view. However, the use of Mathcad allows a large number of calculations to be carried out and/or a large number of points to be plotted with little effort, thus allowing students to get a "feel" for how a "dynamic system" operates. Students find that once a problem is solved using Mathcad, correcting mistakes is much easier than correcting a solution on paper. This is significant if homework is required to be redone until it is correct. Students also find they can create "templates" for certain classes of problems where only changes in input parameters are required. This minimizes the time required to work problems that are similar in nature. It also reinforces the notion that the fundamental concepts in many problems are quite similar. If a student is having problems with an assignment, Mathcad files can be attached to emails and sent to the instructor, the instructor can diagnose the problem, and return the problem to the student by email. This eliminates the need for students to "track down" the instructor or travel substantial distances to meet with the instructor during office hours.

Subsequent Use

Between 1992 and the present Mathcad has been used in a variety of courses in the civil engineering curriculum to cover the following topics:

- numerical methods and matrix algebra (CVEN 314, 310, 411, MEMT 312, 313) - Mathcad allows numerical computations and matrix algebra to be done effortlessly. At present, students get no numerical methods in the current undergraduate mathematics sequence.

- courses dealing with water and wastewater treatment (CVEN 314) - specific useful applications include the solution of Newton's Law of Settling to determine the terminal velocity of a particle under turbulent conditions.

- environmental chemistry (CVEN 314) - the solution of chemistry problems using Mathcad is a somewhat unique engineering application, Mathcad offers a variety of advantages to engineering students who, in general, do not have the extensive chemistry background required to make the assumptions often used to simplify problems, see the web site for examples.

- hydraulics (CVEN 310,411) - iterative solution for the Darcy-Weisbach friction factor in the transitional zone. Such solutions are now required for smooth surface pipes such as PVC in order to obtain correct values for flow rate.

- hydrology (CVEN 310, 411) - development of templates for unit hydrograph procedures

- statistics (CVEN 314, 310, 411) - Mathcad has a number of statistical functions for several different distributions as well as functions for creating histograms. Mathcad allows probability plots required in hydrology to be done easily.

To date the senior author has accumulated approximately 9000 Mathcad files for use in class and at short courses.

Mathcad Issues

Initially (1992), the response from civil engineering students as well as students in basic courses (dynamics, fluid mechanics) was not particularly favorable. While a few individuals in any class become enthusiastic users, many viewed obtaining and using Mathcad as a frustrating experience. In hindsight, the frustration resulted for several reasons which are listed and discussed below.

- Difficulty early on in obtaining high quality versions of the software. Early student versions of Mathcad were published by Addison-Wesley had limited capability, and a 2-page limit on file size. Subsequently, Mathcad released its own student version, identical to the commercial version (not upgradeable however). This version is available in the University bookstore for a reasonable price. In addition, the COES maintains a multi-seat site license for in-house computer labs. Access to working printers for students working in COES computer labs remains an issue.

- Access to documentation and instructional materials. There has never been good, third party documentation for Mathcad. Recent versions of the software have improved help screens where users can get basic assistance and the Mathcad web site provides a wide variety of files covering a number of topics. Based on limited student feedback within the COES, one of the most successful attempts at providing useful assistance resulted from the production of a short video dedicated to those features in Mathcad that give new users the most trouble (subscripts, equals signs, vectors). The fact that few students take courses any longer where they are required to write code manifests itself in a variety of ways, one of the most notable is a lack of knowledge and appreciation of vectors and matrices. The aforementioned video is located on the University web site and can

be viewed by anyone. Finally, a website (*Dr. Griffin's Mathcad*) dedicated to demonstrating the uses of Mathcad has been developed and will be discussed below.

- Ineffective/improper methods of presentation when using Mathcad as well as lack of experience in teaching and presenting Mathcad derived results. The advent of computer projection capabilities in the classroom requires that the notion of effectively presenting material in a classroom be reassessed. Prior to widespread use of computer technology activities such as writing on the board" and "taking notes" controlled the pace of a technically based class. With computer capabilities these activities are curtailed and it becomes very easy to present material faster than students can absorb it or take notes during the presentation. One way this has been dealt with is to supply handouts to be used concurrently as well as allow frequent stops for questions. The use of handouts seems to slow the pace of the class. Students like handouts because they can make notes (or corrections) on them during lectures and have the material to refer to later.

- Student Preparation in Mathcad: Student preparation in Mathcad prior to taking courses that require its use has always been a difficult issue and there are certain realities that must be dealt with. The most notable issue is state mandated limits on the total number of hours in the curriculum that make it difficult to justify a course whose sole purpose is teaching students Mathcad. In addition there are those, both students and faculty who argue that attempting to require the use of Mathcad by unprepared students adversely affects ability of the student to learn the underlying material and the ability of the instructor to teach it. Surprisingly, even though students often express the need for a separate course devoted to Mathcad, experience by the senior author seems to indicate that unless instruction in Mathcad is followed by immediate use in other coursework much of the material is quickly forgotten. At present, students at Louisiana Tech are exposed to Mathcad in the integrated curriculum. By the time they reach their late sophomore or junior year, if it has not been used, most have forgotten much of what they learned, making the process somewhat wasteful and inefficient. So far no definitive solution to this problem has been agreed upon. The procedure currently in use is to provide a single upper level, Mathcad capable, undergraduate to serve solely as a Mathcad tutor for one or more courses during the quarter.

Progress?

Between 1992 and the present progress has been made, and student comments, course evaluations and ABET assessment surveys now suggest that student opinions concerning Mathcad and its use have become almost universally favorable, at least in civil

engineering. At the end of 2001 a website *(Dr. Griffin's Mathcad* http://www2.latech.edu/~dmg/) was set up within the civil engineering program dedicated to providing illustrations and examples of how Mathcad can be used to solve engineering problems. The target audience was industry as well as students. The number of "hits" on this site by year is provided in Table 2 below.

Table 2 - Web Site Hits
"Dr. Griffin's Mathcad"

year	number of hits
2001	4450
2002	16449
2003	13260
2004	16117
2005	21273

Hits to the site in 2005 originated from nearly 200 different domain names. Domains that were the source of the largest numbers of hits included commercial (.COM), educational (.EDU), government (.GOV), military (.MIL) and the Russian Federation (.RU). Requests for various types of assistance resulting from the website were/are numerous and many cannot be handled because of time constraints.

Website visitors that used Mathcad were requested to email the author, providing details of the company with whom they were employed by and how Mathcad was used in that company. The responses were compiled and made available to students in order to demonstrate how the software is used in the "real world". Some of the companies represented by respondents are listed in Appendix 1. Several of the respondents were Louisiana Tech graduates who either introduced Mathcad to the firms who employed them found it already in use. As shown, the site is used by academic and commercial entities as well as state and federal agencies. Two example responses are provided below:

"Dr. Griffin,

I am Joe Mulholland and I work for the Arizona Power Authority. I use MathCad for electrical engineering problems, statistical analysis and

economic studies. We are the organization that is responsible for the Hoover generated power used in Arizona. I would be happy to share data and analysis with you. Colorado River flows, voltage drop calculations, steam powered generation heat rate data are examples of the analysis we do. A few years ago I emailed you about the "S" curve analysis I did for the high temperature superconductor program at DOE. I applied my program to the ant colony problem. I have used your fluid flow pipe analysis here at the Authority to calculate power requirements for well pumps as part of a demand side management analysis. I enjoy your Web site and I find your programs helpful.

Joe Mulholland"
"Dr. Griffin:
Just visited your website to update some of my MathCad references and am replying to your request for firms using MathCad. Our company is a large construction/engineering firm with over 30,000 employees. In my group of 100 or so professionals we use MathCad for Hydrology and Hydraulics. My colleagues also use it for groundwater modeling, erosion modeling, air quality modeling and geotechnical engineering.

Thanks for keeping the website up and running. It's a great resource.
Regards,
John Arambarri, PE
Washington Group International
PO Box 73, Boise, ID 83729
PH. (208)386-5945 "

A complete copy of responses obtained to date is available from the authors. A recurring theme in the responses received is that Mathcad and other applications like it will continue to be increasingly used in industry and consulting because they save time and time is money. Another frequent comment is that Mathcad text and calculations can be understood by those unfamiliar with the software.

Recent Student Feedback

ABET assessment surveys now required at the conclusion of each course is a convenient way of obtaining data to gauge student opinion regarding the use of Mathcad in the classroom. Generally, the questions asked concerned the use of Mathcad as a teaching tool as well as whether or not the students felt they were properly prepared with respect to the use of Mathcad prior to the class. The questions are listed below; the same questions were not asked for each course. Results from assessments are presented in Table 3 and discussed. CVEN 310 is a hydrology/hydraulics course, CVEN 314 is the

undergraduate environmental engineering course, CVEN 411 is a hydrology/hydraulics elective and MEMT 312 is engineering dynamics.

Questions asked:

1. I felt competent using Mathcad in this course

2. I found the Mathcad handouts to be useful study tools as well as potential reference materials

3. I found Mathcad to be a useful tool in this course

4. I had adequate knowledge of Mathcad prior to entering this course to perform appropriately

5. I found the Mathcad handouts and files (emails) useful
6. I had adequate knowledge of Mathcad prior to entering this class to perform satisfactorily

7. Once the learning curve is mastered I believe Mathcad is/could be very useful in this type of course

8. Mathcad was valuable tool in this course

9. Once mastered Mathcad was valuable tool in this course

Table 3 - Assessment Results Concerning Mathcad in the classroom

course	question #	s. disagree	disagree	neutral	agree	s. agree
CVEN 310 spring 2002	1	0	0	5	11	10
CVEN 310 spring 2002	2	0	0	0	4	22
CVEN 310 spring 2002	3	0	0	1	2	23
CVEN 314 spring 2003	4	0	3	3	14	4
CVEN 314 spring 2003	5	1	0	3	5	16
CVEN 310 spring 2005	6	13	3	2	13	6
CVEN 310 spring 2002	7	0	0	1	3	33
CVEN 411 Fall 2005	8	0	0	0	5	20
MEMT 312 Fall 2005	9	0	0	2	3	28

The overriding theme in Table 3 is that students agreed that Mathcad was a useful learning tool. It should also be noted that students found that handouts prepared using Mathcad as well as Mathcad files sent as email attachments were useful also. This is encouraging given that some students had only minimal exposure to Mathcad prior to the class and reinforces the notion that a well prepared Mathcad file can be understood by someone without substantial Mathcad exposure. Another significant point is the large number of students in MEMT 312 that felt Mathcad was useful; approximately half of the students in this class were civil engineering and half were in other engineering fields, primarily mechanical engineering. Many in other engineering majors had never had any significant exposure to Mathcad or its use as an instructional tool in a classroom setting.

Summary

In summary, the integration of Mathcad into selected coursework in the civil and mechanical engineering curricula at Louisiana Tech University currently meets with almost universal approval from students, although it has taken time and experience to reach this point. Graduates have found Mathcad to be a valuable tool in the “real world” and it has been introduced into a number of companies by Louisiana Tech graduates.

Other graduates found it already in use at the firms where they were employed. *Dr. Griffin's Mathcad* website seems to enjoy substantial popularity among Mathcad users around the world.

References

Griffin, D.M., Nelson, James D and Marion, James P., 1990, "Mathematics and Engineering: An Attempt to Provide Perspective to Lower Division Engineering Students, *ASEE Annual Conference Proceedings*, Session 2631, pgs. 1670 to 1675

Griffin, D.M., 1995, Mathcad for Windows as an Aid in Teaching Dynamics, *Computers in Education Journal*, Vol. 5, NO.1, pgs. 1-6

D.M. GRIFFIN, JR.
Dr Griffin currently serves as a Professor of Civil Engineering at Louisiana Tech University. His research interests involve water and wastewater treatment as well non-point contamination, the use of Mathcad to solve engineering problems, and applied mathematics. He is a registered Professional Engineer in Louisiana, Virginia, North Dakota and the Province of Saskatchewan, Canada

M.E. Baumert
Dr. Baumert currently serves as an Assistant Professor at Louisiana Tech University. His research interests are focused in the area of trenchless technology, and electro-osmotic treatment of expansive soils. He is a registered Engineer in the province of Ontario, Canada.

Appendix 1

Companies Represented in email Responses to Dr. Griffin's Mathcad Web Site

*indicates Louisiana Tech graduate as respondent

Berkeley National Labs

EFW

Proctor and Gamble

Dupont

DRS Technologies
Sensors and Technology

BAE SYSTEMS (U.K.)

Hyder Consulting

Arizona Power Authority

Washington Group International

Alenia Marconi Systems Limited

G.E. Transportation Systems

Eastman Kodak

Corning

SSAI Support Systems Associates

Department of Environmental Quality
State of Idaho

University of Michigan

Railroad Commission of Texas

Foster and Freeman
Ltd

Network Elements, Inc

The Wilderness Company

DASHIELL CORP.*

WINK Incorporated

Aker Kvaerner

Civil Design, Inc*

Hunt-Guillot*

DIS-TRAN *

Meyer-Meyer LeCroix and Hixson*

Vistawall*

U.S. Army COE

U.S.A.F.

Texas Transportation Institute

Thomson, Inc

Engineering and Hydrosystems

Bechtel BWXT