2006-2030: LEARNING MATLAB - JUST-IN-TIME OR FRESHMAN YEAR?

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Abstract

The report describes an initiative to introduce MATLAB to the students of the Mechanical and Aerospace Engineering Department (MAE) at University of Florida. It contains a comparison of the effectiveness of a tutorial series open to students in all years versus an incorporation of the material in the 1-credit EML 4920 Professional Orientation course (incoming freshmen and transfer students section). The topics covered in both Fall and Spring semester 2005 are presented, followed by student population information, student opinions and instructor recommendation.

History/Motivation

The College of Engineering has a site-license for MATLAB with SIMULINK, and a number of the senior level courses taught by the Mechanical and Aerospace Engineering Department, including Control Theory and Intermediate Engineering Analysis, presently use the software. More junior and senior level courses can naturally use the program, but have no time scheduled to teach it. Outside the department, a large number of classes in Electrical Engineering as well as the Computational Matrix Algebra course offered by the Mathematics Department use the software, and some of those courses are popular with MAE students.

In this context, in Fall 2004, the chairman of the MAE Department, decided to support a short course in MATLAB and the author of this paper was responsible for designing and teaching it. Two versions were implemented: one as a series of tutorials, open to students in all years (and highly advertised in the courses that presently use MATLAB), the second as a part of the EML 4920 Professional Orientation course (incoming freshmen and transfer students section).

The two series had equal length (8 weekly meetings of one hour each) with the tutorial series being offered in the first half of the semester and the EML 4920 part in the second half (following the content about engineering societies, professional licensure, and engineering ethics usually taught in EML 4920). The tutorial series had homework assignments suggested but not collected or evaluated, while the for-credit EML 4920 offering made weekly homework part of the grade. The experience obtained in teaching the tutorial series was used in adapting the material of the for-credit class. These teaching materials were further refined during a second set of offerings in Spring 2005. Furthermore, the Spring 2005 tutorial series coordinated the timing of its subject material with EGM 4313 (Intermediate Engineering Analysis) and EGM 4344 (Introduction to Numerical Methods).
Topics Covered: Selections and Observed Difficulties

As a result of discussions with other faculty members, a core list of subjects was compiled and subsequently covered in all four offerings. Supplementary topics in the tutorial series depended on the supported courses for the semester; for example an introduction to SIMULINK was offered in Fall to support the students in Control Theory, while a discussion of numerical integration in MATLAB was offered in Spring to support the students in EGM 4344). The topics are presented in Table 1.

| Topics                                                                 | Offerings | Tutorials | EML4920   | Tutorials | EML4920   |
|                                                                      |           | Fall 04   | Fall 04   | Spring 05 | Spring 05 |
| desktop interface; help/lookfor commands; HELP menu and tutorials    | X         | X         | X         | X         | X         |
| Vectors, matrices: definition, basic operations                       | X         | X         | X         | X         | X         |
| 2D graphics: plot, hold, legend, xlabel, title, figure, subplot       | X         | X         | X         | X         | X         |
| 3D graphics: meshgrid, mesh, surf                                    | X         | X         | X         | X         | X         |
| Symbolic toolbox: subs, diff, int, pretty, simplify, ezplot, solve    | X         | X         | X         | X         | X         |
| Variables, scripts and .m functions                                  | X         | X         | X         | X         | X         |
| Conditional statements and loops: if, else, switch/case, for, while    | X         | X         | X         | X         | X         |
| Saving and im/exporting commands and data                            | X         | X         | X         | X         | X         |
| Explanation of common error messages                                 | X         | X         | X         | X         | X         |
| Linear Algebra: det, poly, eig, eigs, inv, lu                         | X         | ---       | X         | ---       | ---       |
| Inline and .m functions in MATLAB, functions of functions            | ---       | ---       | X         | X         | X         |
| Intro to SIMULINK                                                    | X         | ---       | ---       | ---       | ---       |
| Polynomials: roots, poly, polyval, conv, deconv                      | ---       | ---       | X         | ---       | ---       |
| Reporting results: format, fprintf, single                           | ---       | ---       | X         | ---       | ---       |
| Norms in MATLAB                                                      | ---       | ---       | X         | ---       | ---       |
| Fourier series and integral transformation                           | ---       | ---       | X         | ---       | ---       |
| Numerical integration: quad                                          | ---       | ---       | X         | ---       | ---       |
| Runge-Kutta solver: ode45                                             | ---       | ---       | X         | ---       | ---       |

Table 1: MATLAB topics covered in each offering

The MATLAB module and the tutorials did not use the support of a textbook, and we found that our choice was not approved by beginning programmers. The classes were based on Powerpoint presentations created by the author, and included examples of MATLAB commands and answers, as well as impromptu MATLAB sessions to answer questions from the public. Numerous references were made both to the MATLAB help documents and to the on-line examples provided by Mathworks.

In all offerings, a confusing subject for most students was 3D graphics, specifically creating data matrices using meshgrid and using those data matrices together with mesh or surf. Students without any previous programming experience also had difficulties programming
while loops, as well as in understanding how MATLAB interprets an expression like $A(b)$ when $A$ is a MATLAB function or a matrix, and $b$ is a variable or an index. Most of those students had also difficulties interpreting the error messages and debugging their code.

**Audience Analysis: Students Interest and Demographics**

For the first offering, the Fall 04 tutorials, the number of students in attendance had a peak at 45 and decreased as the semester progressed. Not surprisingly, there was a clear peak in attendance at the tutorial and office hours when homework involving MATLAB was due in one of their 'for credit' courses, such as Control Theory or Thermodynamics. For example, twelve students asked questions via email or arranged for an appointment during the semester, with as many as 20 students showing up at office hours the week before the Thermodynamics project was due.

The second offering started in the 8th week of the Fall semester, as part of EML 4920-Professional Orientation (for freshmen and transfer students). An attendance sheet was not collected but the weekly attendance was close to 100% for the 35 students registered in the section.

For the third offering, the tutorials offered in the first 8 weeks of Spring 05 were designed in close collaboration with the faculty members teaching EGM 4313 (Eng. Analysis) and EGM 4344 (Numerical Methods), courses which where using MATLAB, and the topics were offered just-in-time for the homework assignments in those for-credit courses. As a result, the number of students present for tutorials varied less during the semester, with a peak of 35. Eleven students asked MATLAB questions outside office hours via email. Because MATLAB homework was regularly assigned in EGM 4313 and EGM 4344, the office hours attendance and the email volume was relatively constant during the semester, without the pre-project surge observed in the Fall offering.

For the fourth and last offering, EML 4920- Spring 2005, an average of 55 students participated in the MATLAB classes, with a peak participation of 60. We have more data about the students in this last offering, because they answered two surveys administered during the semester. The following section presents this data.

In summary, the MATLAB offerings as part of a course (EML 4920) were better attended in average than the tutorial series. One of the reasons is the potential schedule with other academic or extracurricular activities, as the tutorials were not announced until the first week of class. The tutorial series were effective, however, in familiarizing students with the basics of MATLAB (first two tutorials) as well as in offering a ‘go-to’ person for (coursework-inspired) MATLAB questions.
Students’ Opinions on MATLAB Teaching – EML 4920 Spring 05

The numbers presented here refer specifically to the students of the EML 4920-3172 Spring 05, incoming freshmen and transfer student section (as in Fall, 4 senior-level students were registered in the class as well). This was the first section for which a documented attempt to collect data regarding previous programming experience was made. The only other data comes from informal discussions (presented in the next section) and the results of a hand vote in the EML 4920 Fall class, showing that 4 students had previous experience with MATLAB (all were senior-level students) and one student had extensive programming experience.

55 students in EML 4920 Spring semester answered a background programming survey administered via WebCT (the medium used to post course materials and manage grades) and the results of the survey are summarized in Table 2 below.

1) What programming experience do you have?                                     #   %
None at all                                                                 33  61%
Some (one of C, C++, Visual C, Fortran or Pascal)                            20  36%
More than one programming language used.                                      2   4%

2) How much previous experience with MATLAB do you have?                      #   %
None at all                                                                 46  84%
Some (I have used MATLAB in another course or for one individual project)   7   13%
A good deal (I have used MATLAB in two or more other courses or for two or more projects) 2   4%

Table 2: Background programming survey

If we consider this sample to be representative of MAE incoming freshmen and transfer students, this survey shows that most of them do not have any programming experience before joining our department. However, if we compare the average MATLAB grade of the students with none, some and extensive programming experience, we obtain 52.78, 57.67 and 60.25 respectively (out of 70 points obtained from 7 weeks of homework). That shows that previous programming experience is beneficial but not essential in learning MATLAB.

A second survey was administered mid-semester through the website of the University Center for Excellence in Teaching, and answered by about half of the population of the fourth offering (28 students). The exact results will be presented in Appendix 1. In summary over 70% of the students felt that the course is meeting their expectations, 75% felt that they are learning “a fair amount” or “much” in the course, 50% felt that the pace of the course is “just right”, while 42.8% thought it is “fast” or “too fast”.

Even more information was obtained from the open-ended questions, and the comments regarding the MATLAB content are summarized below. For the question on “Other strengths of the course organization and topics”, learning MATLAB was perceived as a good use of time, helpful and enjoyable. For improvements to the course materials or organizations, a student expressed his wish to have had “more meetings to learn MATLAB,” while another student perceived the pace of the course to be too fast for someone without any previous programming experience.
experience: “I signed up [for] a course that was supposed to be for freshmen, with little or no computer programming training, so I expected [an] introduction to programming. The course jumped into MATLAB too fast.”

For improvements in the course materials, the addition of a textbook on MATLAB was suggested, as well as dedicating more time to MATLAB work. Two senior-level students (out of the four such students taking this section of the class) felt that people with advanced MATLAB experience that are enrolled in this class should be offered the option of a project or more complex programs. Students commented favorably on the integration of MATLAB programs in PowerPoint presentation, as well as on the rapid feedback provided by the discussion of the homework problems in class.

From the nine students answering the open-ended question regarding the strengths of the course (EML 4920), 6 students commented positively on MATLAB. One senior level student went on to say “MATLAB is a crucial tool in the future of any engineer. Providing students with a basis of its features and workings early in their college career is imperative.”

Other Students’ Opinions on MATLAB Teaching and Miscellaneous Concerns

While no formal surveys were administered for the Fall offerings or the Spring semester tutorial series, the students commented favorably on the opportunity of learning MATLAB in an organized fashion. An example of the cascade effects that MATLAB teaching can produce is the comment of a junior level student enrolled in the Fall EML 4920 on his use of MATLAB to double-check the results of complex integrals for the EGM 4313 homework.

Informal discussions before or after the tutorial sessions repeatedly produced questions regarding “which programming language is used more in practice//which programming course should I take (Fortran, C, Java).” The other information collected this way was that the 3-credit hour programming class taught in the Computer Science (CISE) department had a reputation of being demanding, and the Fortran or C oriented versions were comparable in terms of teaching style and homework load (being in fact taught by the same faculty). As a result, some senior-level students were ‘putting away the scary stuff” and as such did not have any programming (or dropped out of the C class) before their final year or before they were taking the Numerical Methods (EGM 4344) class.

Instructor Recommendations

In the authors’ opinion, four courses of action were possible after this experience:
1) Abandon the organized support for MATLAB teaching at departmental level.
2) Keep MATLAB instruction as part of EML 4920 professional orientation-freshmen section.
3) Organize a semester-long Introduction to Programming course at the departmental level or in collaboration with CISE, and illustrate syntax with examples in MATLAB (optionally in
addition to other programming languages).

4) Substitute the tutorial series with MATLAB support at course level (allocating supplementary resources for instructor or extra TA time).

While the first solution is the least expensive solution in the short run, it will not address the growing demand for MATLAB support expressed by both faculty and students. It might be possible however to address this demand by working together with other departments in College of Engineering and maybe include MATLAB instruction as part of the EGN 1002: Introduction to Engineering course.

If adopting the second solution and keeping the MATLAB instruction as part of EML 4920, possible improvements over the 2004-2005 format would be:

(a) to alternate a week of MATLAB instruction with a week of Engineering Ethics or more traditional content (this would keep the workload more uniform during the semester)
(b) to organize the class as an introduction to programming class, with syntax examples in MATLAB.

As long as the weight of the MATLAB grade is well described in the syllabus, the team teaching format of the class was not a problem. In fact, this format can allow a suitable Ph.D. candidate or post-doctoral associate to obtain teaching experience under the supervision of a more experienced faculty member. Course materials need to be prepared for an audience with no previous programming experience, with the option for programming-savvy students to substitute a project for the weekly homework.

If the third option (a semester-long Introduction to Programming class) is adopted, care needs to be taken to develop a ‘low risk’ course that is taken in the first years of study, as opposed to replicating the current situation where a rigorous programming course is perceived as a ‘stumbling block’ in the student career and taken as late as practically possible (with unintended negative effects on all other courses using programming).

To decide if option (2) or option (3) is more appropriate for a particular engineering department, it might make sense to collect data regarding (a) the formal and informal programming experience of students at the beginning of courses that use programming and (b) the programming languages used by employers of the department’s graduates. Survey administration on these subjects can be integrated with other data collecting activities for ABET accreditation purposes.

For options (2) and (3), managing the course materials posting and homework submission via Web-CT (or other Learning Management System, as adopted by the institution) is preferable to a departmental web-page and an email submission approach, as the Web-CT submissions are easier to organize and archive.

The fourth option is proposed because the tutorial series proved that many students seem to be interested in having “the minimum amount of knowledge necessary for solving the homework” and as such the MATLAB support needs to be finely tuned to the coursework. MATLAB
support at course level would mean to have a graduate student (teaching assistant or OPS position, 5-10 hours/week) dedicated to answering MATLAB questions during office hours and via email, grading MATLAB related homework, and conducting at the beginning of the semester two overview tutorials on the basics of MATLAB. This approach would address the needs of the undergraduate students while creating more teaching (as opposed to grading) opportunities for the graduate students.

Starting with Spring 2006, our department will be using a variation of the fourth course of action (instructor position). However, what is more appropriate for your department depends, finally on your own resources and needs.

Appendix 1: Percentage answers to the MidTerm Assessment survey

University Center for Excellence in Teaching
MIDTERM COURSE ASSESSMENT

Directions:
Thank you for taking the time to complete this feedback form on the teaching and learning experience thus far in this course. Your teacher has requested this feedback so that he or she can provide you the most enjoyable and effective course experience for teaching and learning.

Your answers are confidential and for the purpose of sustaining and improving a quality UF experience for both faculty and students, please be as honest as you can. This survey is intended also to encourage you to think about what you can do as a UF student to ensure the best possible learning experience for you and your fellow students.

There are no direct benefits or risks to you for participating in this study. Your identity will be kept confidential to the extent provided by law. You do not have to answer any question you do not wish to answer. You are free to discontinue participation in the survey at any time without consequence.

COURSE EVALUATION (Select the best answer)

1). COURSE ORGANIZATION- Mark all that apply

| The syllabus and/or other course materials clearly outline the topics, goals and objectives of the course.......... | 71.4% | 28.6% |
| The syllabus and/or other course materials clearly define my responsibilities as a student to satisfy the requirements of the course. | 75.0% | 25.0% |
| The lectures focus on the key ideas of the course......................... | 85.7% | 14.3% |
| The topics in the course are well laid out and well coordinated.................. | 75.0% | 25.0% |
| The topics and requirements challenge me as a student........................ | 89.3% | 10.7% |
| The course web site (if applicable) is well structured........................ | 85.7% | 14.3% |
| The course web site is well used by you (if applicable).......................... | 92.9% | 7.1% |

Other strengths of the course organization and topics are: (ans) 25.0%

I wish that the course materials or organization did the following: (ans) 35.7%

2). COURSE LECTURES- Mark all that apply

| The lectures are well organized......................... | 85.7% | 14.3% |
The instructor has an effective speaking style........................................ 32.1% 67.9%
The instructor emphasizes key ideas........ 67.9% 32.1%
The instructor provides effective examples 78.6% 21.4%
The instructor links key ideas to current for stimulating and challenging ideas........ 57.1% 42.9%
The instructor differentiates between core concepts and examples............. 71.4% 28.6%

I really like that the instructor does the following: (ans)32.1%
I wish the instructor would do this in the lectures: (ans)39.3%

3). COURSE INTERACTION AND DISCUSSIONS- *Mark all that apply*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>The instructor responds well to questions</td>
<td>78.6%</td>
<td>17.9%</td>
</tr>
<tr>
<td>The instructor provides enough opportunities for student participation and involvement</td>
<td>75.0%</td>
<td>21.4%</td>
</tr>
<tr>
<td>The instructor values student contributions</td>
<td>85.7%</td>
<td>10.7%</td>
</tr>
<tr>
<td>The instructor encourages active participation</td>
<td>71.4%</td>
<td>21.4%</td>
</tr>
<tr>
<td>The instructor involves students in interaction appropriate to the size and type of class</td>
<td>71.4%</td>
<td>25.0%</td>
</tr>
<tr>
<td>The instructor incorporates useful in-class activities, such as group discussions and demonstrations</td>
<td>28.6%</td>
<td>60.7%</td>
</tr>
</tbody>
</table>

4). COURSE MATERIALS- *Mark all that apply*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>A textbook is assigned.........................</td>
<td>7.1%</td>
<td>89.3%</td>
</tr>
<tr>
<td>The textbook assigned (if applicable) is well-organized and written with quality content...</td>
<td>10.7%</td>
<td>42.9%</td>
</tr>
<tr>
<td>A textbook is not assigned (if applicable), but the compilation of readings and materials are of high quality, well written, etc..........................</td>
<td>60.7%</td>
<td>21.4%</td>
</tr>
<tr>
<td>The materials in the lecture (PowerPoint, slides, demonstrations, etc.) are well organized and clear, emphasizing key ideas................................................</td>
<td>71.4%</td>
<td>17.9%</td>
</tr>
</tbody>
</table>

The materials in the lecture could be enhanced if: 17.9%
The biggest change I would make in the course materials is: 25.0%
Which of the materials in the course best enhance your learning experience? 25.0%
Which materials in the course are not a useful component of your learning experience? 14.3%

5). TESTS AND ASSIGNMENTS- *Mark all that apply*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>The assignments challenge me.........................</td>
<td>96.4%</td>
<td>3.6%</td>
</tr>
<tr>
<td>The assignments provide good breadth and depth of the content.......................</td>
<td>82.1%</td>
<td>17.9%</td>
</tr>
<tr>
<td>The assignments have clear grading criteria.................................</td>
<td>28.6%</td>
<td>71.4%</td>
</tr>
<tr>
<td>The tests challenge me.............................................</td>
<td>82.1%</td>
<td>10.7%</td>
</tr>
<tr>
<td>The tests are unreasonably difficult........</td>
<td>53.6%</td>
<td>39.3%</td>
</tr>
<tr>
<td>The tests are appropriately graded or assessed..............................</td>
<td>50.0%</td>
<td>39.3%</td>
</tr>
<tr>
<td>The tests have a clear grading criteria................. 67.9%</td>
<td>17.9%</td>
<td></td>
</tr>
<tr>
<td>The tests provide good breadth and depth of the content..............................</td>
<td>67.9%</td>
<td>21.4%</td>
</tr>
<tr>
<td>The tests are of an appropriate length.................................</td>
<td>78.6%</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

The tests or assignments for this class could be enhanced if: (ans) 28.6%
The concern that I have about the assessment for this course: (ans) 17.9%
The assessment tools in the course are not useful learning tools because: (ans) 7.1%

6). GENERAL CLASSROOM CLIMATE- *Mark all that apply*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>The instructor is personable and approachable..........................</td>
<td>85.7%</td>
<td>7.1%</td>
</tr>
</tbody>
</table>
The instructor appears to avoid interactions with students........................... 14.3% 78.6%
The instructor is readily available outside of class during specified hours, and responds to inquiries/questions within specified time frames........................................ 85.7% 3.6%
The instructor is concerned about students’ learning experiences............... 78.6% 7.1%
The other students are respectful toward the faculty member...................... 85.7% 3.6%
The students are respectful toward one another....................................... 89.3% 0.0%
One particular strength of this class/course is: (ans) 21.4%
A particular weakness of this class/course is: (ans) 14.3%

OVERALL EVALUATION (Select one for each question)

7). How heavy/light is the workload for this course compared with other courses you are taking this year?
   Much lighter.................................................. 7.1%
   Lighter ....................................................... 35.7%
   About the same .............................................. 42.9%
   Heavier ....................................................... 3.6%
   Much Heavier ................................................ 7.1%

8). How is the pace of this course?
   Too slow ...................................................... 3.6%
   A bit slow ................................................... 3.6%
   Just right .................................................... 50.0%
   A bit too fast ............................................... 32.1%
   Too fast ..................................................... 10.7%

9). How challenging do you find the course?
   Too easy ...................................................... 0.0%
   A bit easy ................................................... 7.1%
   Just right .................................................... 39.3%
   A bit difficult ............................................... 42.9%
   Too difficult ................................................ 10.7%

10). How much do you think you are learning in this course compared with other courses you have taken?
   Almost nothing ............................................. 14.3%
   A Little ...................................................... 10.7%
   A fair amount .............................................. 53.6%
   Much ......................................................... 21.4%
   A great deal ............................................... 0.0%

11). How well is the course meeting your expectations?
   Not at all ................................................... 10.7%
   Not very well ............................................. 17.9%
   Adequately .................................................. 57.1%
   Well ......................................................... 10.7%
   Very Well .................................................. 3.6%
12). What are the important features to retain the next time this course is taught?  
(ans) 35.7%  

13). What are the most important changes you would suggest the next time this course is taught?  
(ans) 32.1%  

**STUDENT INFORMATION** (Select one answer for each question)  

14). Main reason for taking this course:  

- Required .................................................. 64.3%  
- Interested .................................................. 7.1%  
- Required and Interested .................................. 25.0%  
- Other (please specify) ..................................... (ans) 10.7%  

15). Current student classification:  

- Freshman .................................................. 46.4%  
- Sophomore .................................................. 32.1%  
- Junior ....................................................... 3.6%  
- Senior ....................................................... 14.3%  
- Master's ..................................................... 0.0%  
- Ph.D. candidate ............................................ 3.6%  
- Other (please specify) ..................................... 0.0%  

16). Current projected grade in the course:  

- A .................................................. 32.1%  
- B+ .................................................. 10.7%  
- B .................................................. 42.9%  
- C+ .................................................. 3.6%  
- C .................................................. 0.0%  
- D+ .................................................. 0.0%  
- D .................................................. 0.0%  
- E .................................................. 0.0%  
- Don't Know ............................................. 10.7%  

17). Number of classes missed:  

- None .................................................. 60.7%  
- 1-3 .................................................. 39.3%  
- 4-6 .................................................. 0.0%  
- 7-9 .................................................. 0.0%  
- 10 or more ............................................ 0.0%  

18). How many hours are you registered for this semester?  
(ans) 100.0%
Thank-you for your participation. You may be asked to fill out this form again at the end of the semester for comparative purposes. Any questions regarding your rights concerning this survey may be directed to the UFIRB office, Box 112250, University of Florida, Gainesville, FL 32611-2250.

Any inquiries regarding this survey can be addressed to the University Center for Excellence in Teaching; Phone:846-1574 or e-mail Dave Bloomquist at davidb@ucet.ufl.edu. Adapted from Carnegie Mellon's and City of Hong Kong's evaluation forms.