

Incorporating *Mathematica* into Mathematics Courses

Final Report

Project Participants: Liam Donohoe, Wataru Ishizuka, C. Joanna Su

- Amount of Award: \$7,000.
- Cost of 30 concurrent user *Mathematica* licences: \$6,160. ¹
- Purchase of 3 *Mathematica 5 Manuals*: \$110.68. ²
- Total stipend for three project participants: \$729.32. ³
- Duration of project: July 14th 2004-July 14th 2005 (licences expire one year from initial agreement).

Project Rationale: The Project was undertaken by the participants as an experiment to see whether and by what means a sophisticated symbolic computational tool such as *Mathematica* could be successfully integrated into courses offered by the Mathematics Department at Providence College. Since the project was by its very nature exploratory each of the participants decided what approach was to be taken in his or her own class. Each participant has provided an outline of the deployment of *Mathematica* in individual classes below.

Teachers of mathematics in third-level-institutions are charged with delivering material to two distinct groups of students; to mathematics majors,

¹The initial expenditure for 20 licenses was budgeted at \$5,200 however the project participants decided to forsake \$1,070.68 of their stipends in order to fund the purchase of 10 additional licenses and 3 *Mathematica 5 Manuals*.

²The Department of Mathematics purchased 2 manuals and a further one was shipped with the package. In all there were 6 manuals available for consultation. Two were placed on reserve in the library, two were retained in the Mathematics department and two were retained by the project participants.

³Originally budgeted at \$1,800. Some project participants used portions of their share of the stipend to purchase personal copies of the *Mathematica 5 Manual* and related texts.

naturally, but also to non-majors for whom mathematics is a pre-requisite for some reason or other, e.g., science or engineering majors. At Providence College the majority of our students fall into the latter category and this fact has to be borne in mind by a teacher when decisions are made about what material is to be covered in a course and to what depth it should be covered. In all cases though, one can say that what we attempt to teach our students is not just how to *do* mathematics but how to *understand* it⁴; our philosophy, and it is one which we believe is broadly shared within the community of mathematics teachers in general, is that it is of no real use to provide a student with an algorithm for performing a particular type of calculation unless one can provide a theoretical foundation upon which understanding of that algorithm is based. Our approach to teaching our subject can broadly be described as proceeding from *first principles* and consequently, we insist that, at least in the initial stages of encountering a new concept, our students should not merely provide us with a numerical answer to a particular question but that their calculations exhibit evidence of understanding.

Mathematica is an exceptionally powerful tool; it executes commands, performs calculations and returns results rapidly, however, it does so without exhibiting the intermediate steps involved in the calculation. For instance, one can ask *Mathematica* to evaluate

$$\lim_{x \rightarrow 2} \frac{x - 2}{\sqrt{x + 2} - 2} \quad (1)$$

and get the correct answer of 4 but one's understanding of limits is hardly enhanced by typing one line of text and pressing the *enter* key.

It should be understood that the goal of the project participants was to investigate in what way, if any, students could be provided with a computational tool which would enhance their understanding of course material by allowing them to formulate their own examples, perform their own computations and therefore deepen their own grasp of the subject-matter of the course. It was not the purpose of this project nor the goal of the project participants to make their students' understanding of the course material *dependent upon* their facility with *Mathematica*.

⁴To a mathematician 'doing' is 'understanding' however, as a community, we accept that to the general populace there is a difference.

Individual Approaches and Experiences:

C. Joanna Su:

As we state in our rationale, *Mathematica* does not replace understanding of Mathematics but enhances it. One thing that I learned while working at a commodity-futures-trading investment house is that such employers often preferred hiring mathematics majors over some other majors because of the naturally analytic mind and logical manner of thought that mathematics majors possess and further develop through their study and practice of mathematics. So, when deciding how to incorporate *Mathematica* into my classes, I determined to challenge my students through their practice/usage upon the programme: almost every Monday there was an assigned *Mathematica* project. To complete it successfully, the students first had to comprehend the concepts and/or the calculation methods taught in class in advance of coming up with a plan (or plans) of how to solve the problems described in the project. Secondly, they had to search, on their own, for the commands in the software which perform the desired calculations and finally they had to complete the assignment with notes and/or an essay that set out their reasoning and explained how their methods and plans worked. They would typically have three to four days, depending on the schedule of each course, to complete their task. There are many advantages to this approach - one is that the practice in using *Mathematica* is turned into somewhat of a research experience, which is one of the most important lessons that any student can be exposed to; another is that the focus is not only on the individual student's use of the software but also on how she or he acquires a deeper and more comprehensive understanding of mathematical concepts learned in class.

I feel that care and commitment to the students from the faculty are absolute requirements in order for this approach be successful - so as to reduce and minimize the frustration or disappointment that students might encounter in their search of suitable commands and in the process of trial and error; to this end I made myself available to the fullest practicable extent during both days and evenings for assistance, help, and support. To make these *Mathematica* projects even more fun, I made each one a little contest - each week the individual being the most successful and creative received a

small present specially picked for him or her.⁵

I was not sure at first whether or not it was a wise decision to employ this particular approach to *Mathematica* in my courses, however my students proved to me that my concerns and worries were groundless. They often surprised me; for example, on some of the early assignments many students found and used commands from the programme and taught themselves the related mathematical concepts that I had intended to address later in the course. Personally speaking, it has been a joyous experience and also a wonderful teaching incentive for me to see my students trying their wings out and exploring for themselves in contrast to spoon-feeding them and having them manipulate what had already been provided to them by way of example.

Conclusions & Final Remarks:

I would say that it was a great opportunity for my students and me to the practice on *Mathematica*, one of the most powerful symbolic computational tools available, and that it has been a tremendous learning experience from various viewpoints. However, in future, in addition to handing out booklets containing brief overviews of formulae to input to solve problems, I would incorporate a weekly non-mandatory tutorial help/recitation session in computer labs for further instructions on various commands about the programme.

Liam Donohoe:

I taught six classes last year: Mth 109, Mth 110, Mth 131, Mth 132, Mth 223 and Mth 215. There was some overlap in material between Mth 109 and Mth 131, and between Mth 110 and both Mth 132 and Mth 223, for the most part Mth 223 and Mth 215 were independent of each other and of the other classes. Students enrolled in Mth 132, Mth 223 and Mth 215 were, for the most part, science, mathematics, computer science and engineering majors; students in Mth 109 and Mth 110 were, for the most part, life-science and business majors; Mth 131 had a diverse enrollment some science majors, some business majors and some students who were undeclared

⁵Some students expressed their affection for the presents as the ‘incentive’ treats of the projects.

or from the humanities. I wanted to employ *Mathematica* in each course in a manner which would allow my students to perform calculations and generate examples for themselves without, however, creating the notion that understanding how to deploy *Mathematica* in a certain situation is equivalent to understanding the mathematics that underlies the calculation.

With this end in mind, I lectured in class in more or less the same manner that is my custom and left the students to investigate *Mathematica* on their own time. In the first semester students in Mth 109, Mth 131 and Mth 132 were brought to a computer lab for an introductory *Mathematica* class. In the second semester students in Mth 110 were brought to a computer lab twice for lectures on *Mathematica*, Mth 223 and Mth 215 students did not receive any in-class instruction on using *Mathematica*. In both semesters students in each class were provided with handout sheets with the basic *Mathematica* commands and command formats that they would need to employ. I posted examples of calculations performed using *Mathematica* on Angel and each class had a number of assignments to do using the computer package. The average of these assignments was counted as one quiz. The grading scheme in each class was such that students could drop their lowest quiz which had the effect of making the *Mathematica* assignments optional, as was my intent. The assignments for the classes below Mth 223 were, to my mind not overly difficult, and involved little more than adapting a previously seen example or performing a calculation which would be impractical, but not impossible, to do by hand. The problems for Mth 223 and Mth 215 were of a more challenging and open-ended nature; given that neither of these classes had any in-class instruction on the use of *Mathematica* I was gratified to see the generally positive comments these students made concerning their experiences with the programme.⁶ There were more Angel postings and assignments for Mth 132, Mth 223 and Mth 215 because those classes afford the opportunity for problems of a more computational nature than the other classes do, there were slightly fewer postings for Mth 131 and Mth 110 and fewest of all for Mth 109.

In the fall semester I conducted a reading course in abstract algebra with Ms. Meredith Brown PC'05 in which, among other topics, we covered the basics of *Finite Fields*. Finite fields are finite sets which mimic the structure

⁶It should be noted that some students, especially in Mth 223 had had some exposure to the program in the first semester.

of the numbers we are familiar with and which possess the four arithmetic operations we are familiar with. There are many results that one can prove about these sets — for instance one result is that any two finite fields with the same number of elements are really the ‘same’ finite field; another result is that if N is the number of elements in a finite field then there is a prime number p and a positive integer n such that $N = p^n$ — in shorthand one says that the number of elements in a finite field is a *prime power*. One consequence of this latter fact is that one cannot have a finite field which contains 12 elements because 12 is not a prime power. While it is easy to see that there is no finite field comprised of 12 elements it is not so easy to answer the following question: ‘if p is a prime number and $n \geq 4$ is a positive integer is there a finite field which contains p^n elements?’ A question of this type is called ‘an existence question.’⁷ In fact, it can be proven, that the answer to the existence question for finite fields is ‘yes,’ the proof that the answer is ‘yes’ is based on an elaborate counting argument which proves that there must be more than one member of a certain type in a certain set; however, the proof, while ingenious and elegant, gives one no idea of how to ‘construct’ a finite field of, say, $14641 = 11^4$ elements.⁸ I charged Ms. Brown with investigating whether or not *Mathematica* could be used to construct this type of finite field; I felt sure that there was a way to use *Mathematica* to this but I did not know for certain that this was the case. I provided Ms. Brown with a copy of the *Mathematica 5 Manual* and a rough outline of how to proceed but without any instructions about where to look for help (other than the generally unhelpful Help Index). Ms. Brown discovered how to use *Mathematica* to discover exactly how to go about constructing a finite field of order p^n for a given prime p and positive integer n while at the same time providing an example which verified the general existence theorem in particular circumstances. Ms. Brown’s work on this mini-project will be presented at the College’s Technology Fair in October. To my mind Ms. Brown’s work is an example of how *Mathematica* can be most successfully used in a class; in her case *Mathematica* performed a great number of calculations very rapidly,

⁷The existence of finite fields of order p^n is established using several elementary results in the case $n = 1, 2, 3$ and in the proof one can outline precisely how to go about finding such a finite field.

⁸A proof of the existence of a particular set without actually exhibiting a member of the set in question is called a non-constructive proof. Non-constructive proofs tend to be rather baffling to students who, naturally enough, would rather see an actual pink elephant rather than a proof that it cannot be the case that there are no pink elephants.

each one of which could be performed by hand, but whose total number make the overall calculation practically impossible. In conducting her project Ms. Brown did not learn any new mathematics, rather she learned how to use a powerful tool to generate examples of objects which she knew existed but which she could never have seen without the aid of a sophisticated computational tool.

Conclusions & Final Remarks:

In the hands of a sophisticated and motivated student *Mathematica* is undoubtedly a powerful computational tool, as Ms. Brown's work shows, and it is therefore of great utility for that reason alone; however, given its somewhat opaque command structure its role as a teaching tool in lower-level classes is, I think, dependent on the amount of time that one can afford to devote to its use in the classroom and, unfortunately, in courses without scheduled laboratories, time one spends on *Mathematica* instruction, is time not spent on mathematics instruction. I think it is evident, from the survey responses, that while stronger students can learn to use the program effectively on their own, students in lower level classes require, on average, more explicit instruction in order to make effective use of *Mathematica*. This is probably not that surprising a finding.

In anticipation of the College agreeing to fund *Mathematica* through the Mathematics & Computer Science Department budget for the coming academic year, I have requested the use of a class room with a Smart Board for two of my classes next semester; I plan on being able to do one or two calculations per class using the *Mathematica* and then saving the results to a folder on Angel. *Mathematica* assignments will, once again, be optional.

Wataru Ishizuka:

When learning a new mathematical concept, it is very helpful to visualize it and to go through its supporting examples. Our lack of ability to carry out computations by hand forces us to consider the simplest examples possible, but technologies allow us to efficiently consider more complicated ones. We still teach the same concepts, but technologies help us provide our students with clear visual images and ample numerical results that will deepen their

understanding of the concepts. *Mathematica* was chosen for that purpose.

In the last two semesters, I have been integrating *Mathematica* into my MTH107, 108, 109, and 132 courses. The majority of the students in my courses except for MTH132 are non-Mathematics majors, so I expected some difficulty due to its strict syntax rules. In the beginning of each semester, I introduced the software to my students either by an in-class presentation or by a lab session. I found the latter more effective since we could go over the basics together. After my students became familiar with the basic commands as well as mathematical concepts in class, I included up to three *Mathematica* problems in daily homework whenever appropriate. These problems usually require complicated graphing or rather heavy numerical computations, and they are counted toward homework grade. In addition, we had two projects which required students to use the software to complete fairly complicated problems. Those projects were counted as 5% of the course grade. To help my students with the software, a discussion forum on ANGEL was used to answer questions and to post hints and examples.

As shown in our students' survey results, *Mathematica's* graphing, equation solving, and compatibility with ANGEL were well-received by our students. *Mathematica* also proved itself to be an excellent mathematical writing tool to post supplemental material on ANGEL. This use of the software was instantly accepted by my students since it does not involve using the software on their part; however, it was a very effective tool for that purpose. Unfortunately, many students found *Mathematica* difficult to use and had hard time getting used to it. Another very common problem was the lack of its availability in the library and in residence halls. It was also inconvenient for commuting students.

Conclusions & Final Remarks:

I believe that *Mathematica* is an effective tool to provide students with visual aids and numerical examples in order to deepen their understanding of mathematical concepts; however, it takes time and patience to learn to use it for the first time. Gradually, our students will be able to see more and more benefits of the software as they become accustomed to it. I think that students will eventually view *Mathematica* as user-friendly as graphing calculators. When it happens, we can really benefit from the software.

Concluding Remarks

The *Mathematica* Project members would like to thank the members of the Instructional Technology Development Program and the Faculty Technology Project Review Committee for their support.

Appendix: Survey responses by instructor

Survey responses from Su's students.

41 respondents – Math 131: 5; Math 223: 13; Math 215: 23

1. How useful did you find *Mathematica* in your mathematics class this semester?

- Very useful: 6. (Math 131: 1; Math 223: 1; Math 215: 4.)
- Somewhat useful: 32. (Math 131: 3; Math 223: 10; Math 215: 19.)
- Not useful at all: 3. (Math 131: 1; Math 223: 2; Math 215: 0.)

2. How often did you use *Mathematica*?

- Daily: 0. (Math 131: 0; Math 223: 0; Math 215: 0.)
- A few times a week: 5. (Math 131: 1; Math 223: 2; Math 215: 2.)
- Once a week: 31. (Math 131: 2; Math 223: 10; Math 215: 19.)
- Less than once a week: 5. (Math 131: 2; Math 223: 1; Math 215: 2.)

3. How many hours in total did you spend using *Mathematica* during the semester?

Range of responses: 0-30 hours. Averages for each class were

- Math 131: 12.70 hours; Math 223: 9.88 hours; Math 215: 8.30 hours.

4. Did you use *Mathematica* other than to complete an assignment which specifically required the use of the program?

- Yes: 7. (Math 131: 0; Math 223: 1; Math 215: 6.)
- No: 34. (Math 131: 5; Math 223: 12; Math 215: 17.)

5. Overall, would you say that *Mathematica* made a positive contribution to your experiences in class this semester?

- Yes: 29. (Math 131: 4; Math 223: 7; Math 215: 18.)
- Somewhat / Not Too Much: 3. (Math 131: 0; Math 223: 2; Math 215: 1.)
- Not Really: 1. (Math 131: 0; Math 223: 1; Math 215: 0.)
- No: 7. (Math 131: 1; Math 223: 3; Math 215: 3.)
- No response: 1. (Math 131: 0; Math 223: 0; Math 215: 1.)

6. What features of *Mathematica* did you like the most?

- 131:
I really liked the graphing of *Mathematica*-5. It made every thing Dr. Su taught us very easy to understand thus making the course very interesting.
I liked the fact that I could obtain any derivative of a function instantaneously. Also, I liked how the program could graph 3D which my calculator is not capable of.

- 223:
The functions available were amazing.
Being able to perform operations that I cannot do by hand (especially producing graphs.)
That I could figure out 3D things, and see them.
Help Menu.
- 215:
Help menu (which made it possible to plug in all the difficult functions.)
Provided precise pictures and answers.
How clear it was to see through examples, instead of focusing on working out the problem, *Mathematica* does it for you, and you focus more on the concepts.
Being able to figure out complicated questions easily.
It reinforced what we learned in class.
Made ideas more concrete.

7. What features of *Mathematica* did you like the least?

- 131:
I don't like how the error message appears frequently if the notation is not exactly right. Sometimes it's hard to get through an assignment because the message appears often. Also the help option was very complex and it was hard to understand what the problem with the input was and how to fix it.
- 223:
The syntax was no fun. *Mathematica* should be approached like a programming language. It is often tedious and unclear, i.e. when it gives an error message I'm not sure what I've done wrong.
How it would sometimes be difficult and everything had to be 100% correct when typed in.
It was still difficult to find certain commands.

- 215:
Sometimes a little difficult to figure out how to do a certain operation. All the codes I didn't know and the fact spaces & periods have to be just right.
A little frustrating if you don't know where to start, although Help Menu was very useful!
Sometimes it was hard to figure out what functions to use - the Help Index was confusing.

8. Did you experience any recurrent difficulties using *Mathematica*? Were your difficulties resolved?

- 131:
At first yes but Dr. Su was always available to help me out of it. Secondly, there were some computers that were giving trouble and I told Dr. Su about such problems.
All my difficulties were resolved without much of challenge because they usually were just an incorrect typing form of an equation that the program couldn't recognize.
- 223:
Syntax, but other than that no.
The problems I had completing specific assignments were resolved on my own through a trial and error process.
Yes, it is a little difficult to get used to the needed commands, but using the help browser usually resolves this.
Yes, many rules that I didn't know. Dr. Su helped.
- 215:
Difficulties solved by help menu.
It is so picky with the calls that I found it sometimes frustrating but I did always figure it out.
Just little things with spaces and periods. The help browser clears it up.

9. Did you experience any recurrent difficulties accessing *Mathematica* through the labs this semester?

- 131:
Yes (1).
No (4).

- 223:
Yes (0).
No (12).

- 215:
Yes (3).
No (19).
Put it in library!
They should make it available in the library.

10. Do you have any suggestions as to how *Mathematica* could be more successfully used in future courses?

- 131:
It is a very good program and it will do us better as students if we did something in this program every day in class.
The weekly assignments seemed effective although the final project was a bit too difficult.

- 223:
Give an optional class on how to use it, more familiarity would help.
Students should be given more preparation as to how to enter equations into the program.
Mathematica software should also be in the library computers.
I don't really know how to make it more simple to use, but that's the main thing that would help.

- 215:
 Incorporate a lab/recitation to the class for 1 hour a week, making the class 4 credits, and the lab time being spent in computer labs learning about *Mathematica*.
 If the functions were explained in greater detail in class.
 No, it's incorporated the right way & amount.
 No, I think students just need to get used to it.

11. Overall, would you say that *Mathematica* made a positive contribution to your experiences in class this semester?

- 131:
 Certainly I would say. In addition to that it helped me because Dr. Su was always available for questions and to help when ever help was needed.
 I would say that *Mathematica* made a positive impact on my experiences in class because it offered an alternative way to learn. The technology was amazing and I was able to use features that was unknown to my calculator. I found it to be a creative way of solving a problem. It's always good to explore different methods of learning.
- 223:
 Yes, it helped to understand the concepts better. Otherwise I would not have been able to see some of the parametric graphs etc.
 I liked it, just wish there was a better explanation of how to use it before I began.
 Not too much because I don't really know how to use it much. Visuals & graphics were very helpful though. Honestly, not really, it confirmed answers but it didn't exactly teach me anything.
- 215:
 Yes it helped my understanding of the material.
 Yes, although it was sometimes time consuming to use, the projects I had gave me a better understanding of the concept.
 Yes, application in larger setting.

Yes, I think now that I'm more familiar with the program I will use it more often.

I would say it didn't make a difference in either direction.

Summary of the Survey Results for Donohoe:⁹

57 Responses: Mth 215 – 23; Mth 110 – 20; Mth 223 – 14.

1. How useful did you find *Mathematica* in your mathematics class this semester?

- Very useful: **11** (Mth 215: 7; Mth 110: 3; Mth 223: 1.)
- Somewhat useful: **32** (Mth 215: 11; Mth 110: 11; Mth: 223: 10.)
- Not useful at all: **14** (Mth 215: 5; Mth 110: 6; Mth 223: 3.)

2. How often did you use *Mathematica*?

- Daily: **0**.
- A few times a week: **6** (Mth 215: 4; Mth 110: 1; Mth 223: 1.)
- Once a week: **13** (Mth 215: 6; Mth 110: 3; Mth 223: 4.)
- Less than once a week: **38** (Mth 215: 12; Mth 110: 17; Mth 223: 9.)

⁹Spring semester classes only.

3. How many hours in total did you spend using *Mathematica* during the semester?

Range of responses: 0-20 hours. Averages for each class were

- Mth 215: 7.3 hours, Mth 110: 3.6 hours, Mth 223: 5 hours.

4. Did you use *Mathematica* other than to complete an assignment which specifically required the use of the program?

- Yes: **8** (Mth 215: 5; Mth 110: 1; Mth 223: 2.)
- No: **49**

5. Overall, would you say that *Mathematica* made a positive contribution to your experiences in class this semester?

- Yes: **28** (Mth 215: 15; Mth 110: 8; Mth 223: 5.)
- No: **13** (Mth 215: 5; Mth 110: 4; Mth 223: 4.)
- No Response: **16**

6. What features of *Mathematica* did you like the most?

- Mth 223:
Fast.
The Help (Menu) and red type that shows what mistake you made.
Graphing surfaces in R^3 .
Three dimensional graphs.
Simplification of complex problems.
Its ability to 3D graph.

It can do double integrals.
The 3 dimensional graphs.
It does a lot of complicated computations for you.
I found it powerful and user-friendly – I like the layout of the program.

- Mth 215:
Very few.
Didn't like using it except for row-reducing so I didn't have to do it by hand.
Easy to use.
Row reducing!!
Quick results, easy to use.
Row reduce and finding the determinant.
It could find inverses & row reduce.
Performed math operations for you.
Row reduction.
Matrix row reduction.
Row reduction.
It's ability to row reduce large matrices (2).
That it could solve complex equations faster than doing them by hand.
I did not like *Mathematica*.
Row reduction of matrices.
Row reduction.
Ability to reduce matrices.
Simplifying calculations.
Row reduce and inverse.
The ability to quickly perform matrix operations.
- Mth 110:
You didn't have to do much.
I liked how you could see the graphs.
It was nice to see the graphs.
3D plots.
Solutions.
Graphing, fast answers.
Nothing.

I liked seeing 3D graphs of functions that were difficult to draw.
The helpful visual graphics (*sic*).
I liked being able to visualize the problems.
Being able to rotate the graphs and view them from a different angle.
Great aide in solving problems.
Visualizations of problems from class.
To see what the equations looked like in 3D.
Visually seeing (*sic*) the 3D images.
Graphs.
The rotation of graphs to see from all angles.
I liked the graphing because it helped me visualise the graphs, especially the one in 3-space.

7. What features of *Mathematica* did you like the least?

- Mth 223:
Hard to use and figure out.
Too picky with the way things have to be typed.
Contour planes.
Hard to input commands.
Too many possible errors in formatting.
Won't work if you type in wrong, hard to find error.
The need for exact commands.
It is too confusing to do and learn, especially when we got into the harder graphing.
It's very picky.
When you cannot figure out a command it is very difficult & frustrating to use the program.
Only available in Sowa & Accino.
- Mth 215:
A lot.
Takes a lot of time to learn to use, not an easy programme.
Gave me error too many times.
I only used Row Reduce and Form Matrix.
Difficult syntax sometimes.

Since I was completely unfamiliar with the programme I found it hard to teach myself how to find different commands and syntax needed. It was confusing at times and the Help Menu didn't provide any useful tips.

Figuring out how to type in what you wanted.

Difficult to input.

Not being able to augment.

It was cumbersome and complicated.

The complicated input system.

It was too confusing and you had to be too precise.

The way you had to enter everything.

Learning to use it.

It gave lots of error & did not seem consistent sometimes.

Row reduction of augmented matrices.

The tricky syntax.

It is not easy to figure out how to do what you want to do.

- Mth 110:

The strict format.

How it was picky; you could understand the math & then *Mathematica* wouldn't work.

It was very difficult to graph, had to follow strict instructions.

Iterating integrals.

Trying to figure it out.

Doesn't tell you how it got answer.

I really didn't like anything about it at all; I've attempted extra-credit assignments on the programme and through frustration gave up. The class needs to spend more time learning how to use it.

I did not like how *Mathematica* is specific with the way you type something in, for example if a letter is capitalized or not.

Placing in all the numbers.

It was very complicated to do a simple problem due to the commands it required.

Figuring out the correct format to plot the graph.

Hard learning curve.

Language is too specific, errors too common.

Confusing to set up the equation.

Error messages.

Technical manner you need to format problems.

How tricky it was to plug things in.

I am not really familiar with the programme and how you are supposed to go about typing in commands but with practice it would have become easier.

8. Did you experience any recurrent difficulties using *Mathematica*? Were your difficulties resolved?

- Mth 223:

No. (6)

Yes; most of the time.

Yes; sometimes they were resolved other times I gave up.

Yes but I tried a few different commands until I got the answer.

Yes and no (I couldn't figure it out).

Commands; yes and no.

- Mth 215:

No (3).

A few; yes.

Yes; no. (2)

Yes; I figured them out. *Mathematica* has a good Help File.

Nothing other than not knowing how to use it.

Yes, I had difficulty getting it to do what I wanted.

Not really any major problems.

Problems with commands; not really.

It was very hard to figure out what to do if you did not know the right command to use.

I did not know how to use most features of *Mathematica*.

Yes; they weren't resolved.

Sometimes equations couldn't be solved.

Yes; somewhat.

Yes; not really resolved.

Nor very recurrent, difficulties always overcome.

- Mth 110:
 No difficulties (4).
 Just in typing in what it wanted.
 Always 'error' message! Took a while to find missing comma or something of that sort.
 Master index helpful.
 I followed examples shown, however I kept getting error messages. It is very frustrating after an hour or so.
 Often times I would type in a command incorrectly and *Mathematica* would tell me it was wrong but not how to fix it specifically, so it took a lot of time and effort to resolve those difficulties on my own.
 Yes but they were eventually solved.
 Yes; difficulty with plotting graphs.
 I had format difficulties.
 N/A.

9. Did you experience any recurrent difficulties accessing *Mathematica* through the labs this semester?

- Mth 223:
 No. (6)
 Sometimes computers with *Mathematica* are hard to access.
- Mth 215:
 No (14).
 The Library doesn't have it! (E-classroom is always closed)
 No although it was hard to get a computer with *Mathematica* on it.
 E-classroom in library was always being used and the other labs were often busy.
 Yes labs were too crowded.
 No, but it should be on all the computers in the library not just the e-classroom, which is only open at night.

- Mth 110:
No (12).
No; always available.

10. Do you have any suggestions as to how *Mathematica* could be more successfully used in future courses?

- Mth 223:
Make it easier to use.
Use it in class.
Make it available in the dorms not just in the labs.
Introductory help sessions or a master list of commands accessible through the library.
Have one class that just teaches *Mathematica*.
Set up lab-time for class to use it at least once a week.
Have a tutorial at the beginning of each semester.
No.(2)
- Mth 215:
Just a little more instruction in the beginning. It took a while to figure everything out.
One class, the professor should show it in a computer lab.
Perhaps a class in the lab becoming familiar with it.
Use for beginning concepts before using it for more difficult ones.
No this was good.
Have a tutorial at the beginning of the class & go over everything we will need to know.
More preparation on how to use it.
I think we should have one class in the lab so that we could all become familiar with the program. It was very difficult trying to learn the program on my own.
Hold a session introducing the command of *Mathematica* where the students can learn with your direct assistance or the assistance of someone who knows how to use it.
Give more row reduction problems or determinant problems.
More assignments on *Mathematica*.

- Mth 110:
 No (1).
 It's helpful when graphing.
 Have more lab time.
 Spend more time on it.
 If it is going to be used for class in any way the professor should spend a class on the techniques and procedures.
 I think to be used successfully *Mathematica* would have to be used more often for students to get a better feel for it.
 More *Mathematica* homework.
 Easier format to use.
 I am not good with computer programs so maybe if there was an extra day to go slower over how to use *Mathematica* it would have been good, but if one is comfortable with computer programs then the lectures on it were fine.

11. Overall, would you say that *Mathematica* made a positive contribution to your experience in class this semester?

- Mth 223:
 No (1).
 Yes (4).
 Yes, but not much.
 I didn't really use *Mathematica* a lot for this class but it could be used more and would be a positive contribution.
 Positive if I could have figured it out.
 Yes, a lot of the topics are difficult to picture in your head.
 Sometimes.
- Mth 215:
 No (2).
 Yes (10).
 Yes, but it could be improved.
 Somewhat, makes the class easier.
 No, it could have if I knew how to use the programme.
 It was ok.

Definitely.

Didn't have much of a contribution.

Yes (but only for one quiz) which did help course overall.

- Mth 110:

No (1).

Yes (2).

Yes, it solidified the information we were working on in class, especially the 3D graphs. Working in 3 space because it was easier to visualize.

Yes, I liked using *Mathematica* I think you should continue using it.

Yes it did help.

Not really.(3)

I would say that *Mathematica* made a positive contribution to my experience in class this semester but it was a very small contribution.

No, I have to say that I strongly dislike the programme. It makes the student even more confused and frustrated at times.

For the most part yes, other than when I failed a take-home quiz on it.

Positive.

Summary of Survey Results from Ishizuka's Students:

114 respondents – MTH 107: 37; MTH108: 20 ; MTH 109: 49; MTH 132: 8

1. How useful did you find *Mathematica* in your mathematics class this semester?

- Very useful: **5**

(MTH 107: 2; MTH 108: 0; MTH 109: 1; MTH 132: 2)

- Somewhat useful: **60**

(MTH 107: 14; MTH 108: 12; MTH 109: 31; MTH 132: 3)

- Not useful at all: **49**

(MTH 107: 21; MTH108: 8; MTH109: 49; MTH132: 3)

2. How often did you use *Mathematica*?

- Daily: **1**

(MTH 107: 1; MTH 108: 0; MTH 109: 0; MTH 132: 0)

- A few times a week: **23**
(MTH 107: 3; MTH 108: 2; MTH 109: 17; MTH 132: 1)
- Once a week: **33**
(MTH 107: 9; MTH 108: 4; MTH 109: 20; MTH 132: 0)
- Less than once a week: **57**
(MTH 107: 24; MTH 108: 14; MTH 109: 14; MTH 132: 7)

3. How many hours in total did you spend using *Mathematica* during the semester?

Range of responses: 0-25 hours. Averages for each class were

- MTH 107: **8.5**, MTH 108: **5.7**, MTH 109: **8.0**, MTH 132: **5.1**

4. Did you use *Mathematica* other than to complete an assignment which specifically required the use of the program?

- Yes: **7** (MTH 107: 3; MTH 108: 0; MTH 109: 3; MTH 132: 1)
- No: **107** (MTH 107: 34; MTH 108: 20; MTH 109: 46; MTH 132: 7)

5. Overall, would you say that *Mathematica* made a positive contribution to your experiences in class this semester?

- Yes: **54** (MTH 107: 16; MTH 108: 12; MTH 109: 22; MTH 132: 4)
- No: **58** (MTH 107: 21; MTH 108: 7; MTH 109: 26; MTH 132: 4)
- Neutral : **2**

6. What features of *Mathematica* did you like the most?

- MTH 107:
Easy to figure out what you did wrong.
Processed equations immediately.

Graphing.
Equation solving.
Matrices manipulations.
Compatibility with ANGEL.
Its easy-to-use nature.
Palettes for mathematical symbols.

- MTH 108:

Help menu.
Graphing.
Solved the problems for you.
3-D graphing.
Evaluating integrals.
Easy to use.

- MTH 109:

Graphing.
Derivatives.
Equation solving.
I liked the quick output and the easy input features.
Cool calculator.
Compatibility with ANGEL.
Easy to use.
Palettes for mathematical symbols.

- MTH 132:

Differentiation & integration.
Compatibility with ANGEL.
Graphing.
Equation solving.

7. What features of *Mathematica* did you like the least?

- MTH 107:

Difficult to use.
Difficult to correct errors.
Strict syntax rules.

Confusing Help menu.
Key setup.
Not available in residential halls.
Time consuming. Matrix manipulation.
Not available in the library.
Not available in my own computer.
Unclear error messages.

- MTH 108

Difficulty to use.
Strict syntax rules.
Sometimes I did the problem and it wouldn't work (it would only output errors), and other times, on the same computer it would work...it was inconsistent.
It doesn't walk you through the problems, so you wonder how it got a certain answer.
Time consuming.
Bad tutorial & help menu.

- MTH 109

Strict syntax rules.
Difficult to use.
Help bar is not helpful.
Unclear error messages.
Having to go to the lab a lot.
I had to open up tables to find little symbols. I also couldn't figure out some features.
Availability on students' own computers.
The $f_{[x]}$ notation.

- MTH 132

Strict syntax rules.
Difficult to use.
Too many commands to learn.
Strange commands.
Unclear error messages.

8. Did you experience any recurrent difficulties using *Mathematica*? Were your difficulties resolved?

- MTH 107

Yes: **23** (Resolved: 8; Not Resolved: 5; No Response: 10)

No: **14**

- MTH 108

Yes: **13** (Resolved: 3; Not Resolved: 2; No Response: 8)

No: **6**

- MTH 109

Yes: **40** (Resolved: 13; Not Resolved: 3; No Response: 24)

No: **9**

No Response: **1**

- MTH 132

Yes: **5** (Resolved: 1; Not Resolved: 2; No Response: 2)

No: **3**

9. Did you experience any recurrent difficulties accessing *Mathematica* through the labs this semester?

- MTH 107

No: **45**

Yes: **9**

Not enough computers in Accino and Koffler.

Not available in the library.

Not available in resident halls.

Labs were too busy.

Inconvenience.

Class reservation.

- MTH 108
No: **15**
Yes: **5**
Not available in the library.
Inconvenient.
Class reservations.
- MTH 109
No: **44**
Yes: **5**
Class reservations.
Not available in the library.
Not available in resident halls.
- MTH 132
No: **5**
Yes: **3**
Busy labs.
Not available in the library.

10. Do you have any suggestions as to how *Mathematica* could be more successfully used in future courses?

- MTH 107
Availability throughout campus.
Availability on students' own computers.
More Lab time & Instruction on Mathematica.
More examples of Mathematica.
Integrate *Mathematica* more with the class.
I do not think that *Mathematica* should be used in lower level Mathematics courses.
I think it would help if students learned how to do more complex problems as well as easy ones.
Don't use it.

Just do the projects instead of putting mathematica in the everyday homework assignments

- MTH 108

Relate it more to the class material.

More lab time & instruction on Mathematica.

Available in the library

I don't think Mathematica is a desperate necessity for students. It is sometimes useful but in reality I think it doesn't really make that much of a difference.

Simplify commands.

Integrate it more with class.

- MTH 109

More lab time & instruction on Mathematica.

Available throughout campus.

Better help menu.

I don't think it is necessary to this course.

Less homework on it.

A better manual

Do not use it in future courses. Get an easier program. My class had no math majors in it and it was deemed unuseful. It was more of an aggravation than helpful.

- MTH 132

Maybe some kind of assignment were the students use it to find the correct answers, then have to show the steps to how to reach said answer.

Do not continue to constitute into hw.

Availability in residence halls.

Explain stuff slower, clearer.

Availability in the library.