Five-Year Assessment and Review of the Mathematics Program

Natural Science Division

Seaver College

Pepperdine University

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I. Introduction and Overview:

A. Internal Context

1. Overview

The Mathematics Program in the Natural Science Division of Seaver College is one of the classic components of a liberal arts college. The program offers two majors, the Mathematics Major leading to the Bachelor of Science degree, and the Mathematics Education Major leading to the Bachelor of Arts degree. The program also offers two minors, the Math Minor and the Applied Math Minor.

The program has been a part of Seaver College from the beginning of the school. Originally only the B.S. Mathematics degree was offered. The Mathematics Minor added in 1991, the Applied Mathematics Minor added in 2004, and the Mathematics Education Major added in 2007.

The Mathematics program exists to prepare students mathematically for lives of purpose, service and leadership. The Mathematics Minors allow students interested in other majors to at least have a fundamental understanding and competency in calculus and other important areas of mathematics. The Mathematics Education Major is meant to prepare students who plan to teach mathematics in high school or advanced mathematics in middle school. The Mathematics Major prepares students for future graduate education in mathematics or other related fields, or for careers in industry, or for teaching in secondary schools.

Mathematics courses are required in most of the sciences, economics, and business, Most of the Business majors will take the two business mathematics courses, Business Calculus and a subsequent course consisting of Probability, Linear Systems and Multivariable Optimization. Some of the Business majors may instead take the regular calculus courses and often complete the applied math minor. The Computer Science/Mathematics Major requires a number of courses in mathematics. In addition, the Mathematics Program offers "Nature of Mathematics", a math course for the General Education program, and Biostatistics for biology, nutrition and sports medicine majors, as well as many of the applied math minors. Most students who enter Seaver College will take a mathematics or statistics course sometime in their undergraduate career.

2. Changes to the Mathematics Program: Curricular revision 2011

Since the last five year assessment, the Mathematics Program instituted a major restructuring, which involved modifying the course requirements for the Mathematics Major, modifying and adding some new courses, and renumbering the courses. These changes, based on previous assessment results, were approved in 2010 and were implemented in 2011. These assessment efforts are described in the previous five-year assessment document from 2011. For the purposes of this document, the new course numbers will be used.

The majority of the effort was to come up with a plan for our majors in order to:
- Better align with curricula at peer institutions.
- Have greater congruence with recommendations from professional associations.
- Be responsive to feedback from graduates and alumni.
- Increase scheduling flexibility to allow majors to graduate on time without having to make normal exceptions.
- Better prepare students for undergraduate research, careers and graduate school.

In addition, we laid out a complete renumbering scheme to:
- Make the class numbers more in line with the year in which the courses are typically taken, including removal of the 500-level courses.
- Align course numbers with their level of difficulty.
- Flag the "sequence courses" by making the second course in the two-term sequence a 400-level course.

We also modified the descriptions on many of the courses so that they would more clearly reflect:
- The current course content.
- Unique descriptions in the two-term courses. (Somehow these had defaulted to the same description of what used to be a single course listing.)
- More clearly note the important parts of our course content for students needing to transfer courses from other colleges.

In developing our revised curriculum, we took account of the course offerings of our peer and aspirational institutions, as well as the "Survey on Preparation for Graduate School" (FOCUS newsletter of the Mathematical Association of America, Volume 8, No. 4, September 1988) and also the CBMS 2005 Survey of Undergraduate Programs[1], and the MAA curricular recommendations, as noted in section II. A. 2. a .

All of these changes have now undergone evaluation over the past five years of annual assessments.

Other changes:
Previous to 2012, placement of students into the calculus classes was based on SAT math score (a score of 600 or higher allowed students to take Math 150; a lower score meant that the student needed to take a remedial subject like Math 103: College Algebra or Math 099: Intermediate Algebra). In 2012, we created an online math placement exam intended to replace the SAT math for these purposes. Students entering in the Fall of 2012 were given this exam but the exam was not

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[1] Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States, American Math Society, copyright 2007.

used for their placement. Starting with Fall 2013, placement of students was based on a weighted average of this exam and the SAT math score. At the same time, Math 099 was discontinued. Data concerning these scores have been gathered and will be analyzed in 2016–2017.

In Fall 2013, Calculus courses no longer included a 1-hour lab.

Credit hours

Comparison of Mathematics (B.S.) curriculum or equivalent program across peer institutions.

Institutions	Units Required for Degree	Calculus	Linear Algebra, Diff Eqns	Real Analysis	Abstract Algebra	Upper Division	Other
Pepperdine University	14/53	2/8	2/8	1/4	1/4	8/32	
Harvey Mudd College	29/61	2/3	7/12	1/3	1/3	15/37.5	
Loyola Marymount University	20/61-62	3/12	2/6	1/3	0/0	10/30	
Occidental College (B.A.)	14-15/52	3/12	1/4	0/0	0/0	8/28	
Santa Clara University	16/71	4/16	2/8	0/0	1/4	7/35	Quarter System

Listed as number of courses/number of units

Comparison of Mathematics Education (B.A.) curriculum or equivalent program across peer institutions.

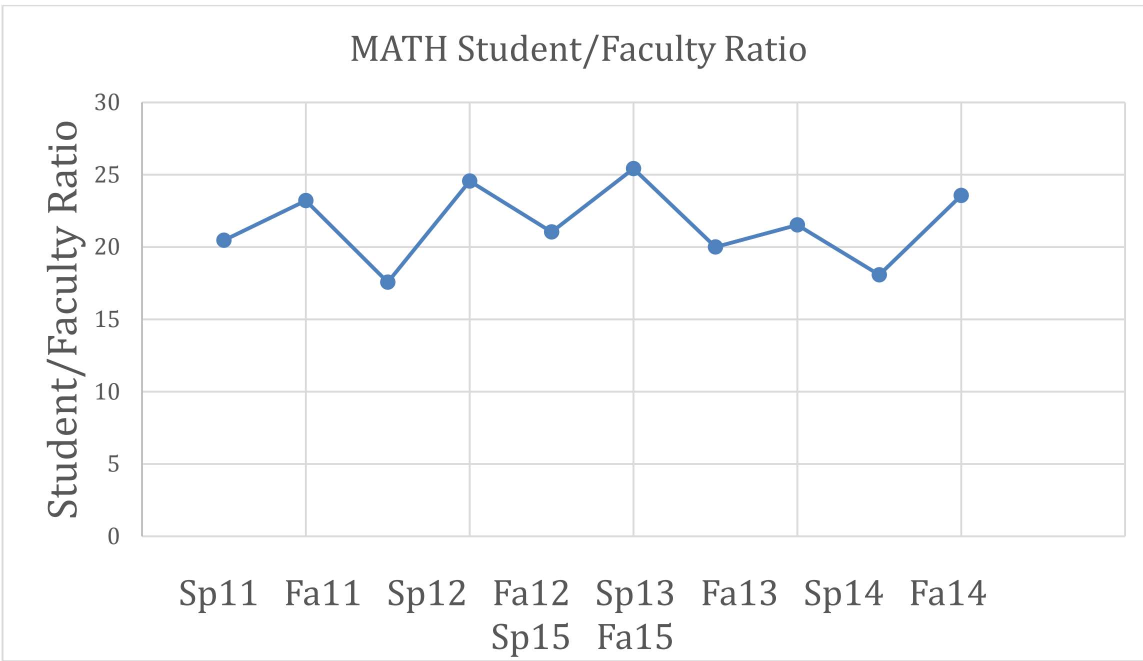
Institutions	Units Required for Degree	Calculus	Linear Algebra, Diff Eqns	Real Analysis	Abstract Algebra	Education Units	Upper Division Math	Other
Pepperdine University	17-20/61-65	3/12	1/4	0/0	1/4	6/20	5/19-20	
Loyola Marymount University	22/67-68	3/12	2/6	0/0	0/0	3/9	9/27	
Occidental College	14-15/52	3/12	1/4	0/0	0/0	0/0	8/28	
Santa Clara University (B.S.)	17/76	5/21	2/8	0/0	2/9	1/5	7/35	Quarter System

Listed as number of courses/number of units

Faculty/Student ratios

Semester	Ratio:
Spring 11	20.46
Fall 11	23.21
Spring 12	17.58
Fall 12	24.56
Spring 13	21.04
Fall 13	25.42
Spring 14	20
Fall 14	21.54

Spring 15	18.08
Fall 15	23.56



B. THE EXTERNAL CONTEXT

Mathematics has always been an important part of a liberal arts education, from the seven classical liberal arts (which include geometry, arithmetic, and logic) through the scientific revolution, where calculus and analytic geometry played a critical role, to the current age, where mathematics is embedded in a wide range of academic areas and industries. In academia, mathematics is a vibrant subject, where exciting discoveries continue to be made. It also informs many areas of not only natural science and engineering but also economics and business. Through statistics, mathematics has had an impact on many subjects, especially in the social sciences. Its use of pure reasoning has also engaged philosophers and theologians about the ultimate nature of truth. In industry, mathematics has influenced decision making through risk analysis and operations research, actuarial projections and finance through mathematical modeling, medicine through statistical research, as well as current advances in computer science and engineering.

The mathematics major program at Seaver College is designed with this wide range in mind. In the tradition of the liberal arts, the program is intended to not only introduce students to the great mathematical ideas in our world heritage, but also develop critical thinking and creative problem solving skills, and clear, logical proof writing. The mathematics major is also designed to prepare students who choose to continue in mathematics study in a masters or Ph.D. program in mathematics or a related field like statistics or actuarial studies. It is also designed for students who wish to apply mathematics to an industrial workplace setting, from computer programming to business analysis. It is hoped that even students who decide to pursue a career that is less explicitly mathematical will find that their mathematical training has proved both useful and enriching. The mathematics education major is specifically designed for students who wish to teach mathematics at the junior high or high school level.

C. MISSION, PURPOSES, GOALS, AND OUTCOMES

1. Mission Statement

Mathematics is *the* language of science – honored for the precision of its concepts, the rigor of its demonstrations, and the certitude of its truth. The Mathematics Program provides students the opportunity to experience modern mathematics as a dynamic and innovative field whose fundamental concepts can be applied to graduate school, teaching, or industry. The Mathematics Major prepares students for success in any career by fostering the ability to solve problems rigorously, creatively, and independently.

2. Institutional Learning Outcomes

Pepperdine University's Institutional Student Learning Outcomes

http://services.pepperdine.edu/oie/learning-outcomes/ieos.aspx

	Knowledge/ Scholarship	Faith/ Heritage	Community/Global Understanding
PURPOSE	**ILO#1** Demonstrate expertise in an academic or professional discipline, display proficiency in the discipline, and engage in the process	**ILO#2** Appreciate the complex relationship between faith, learning, and practice.	**ILO#3** Develop and enact a compelling personal and professional vision that values diversity.

	of academic discovery.		
SERVICE	**ILO#4** Apply knowledge to real-world challenges.	**ILO#5** Respond to the call to serve others.	**ILO#6** Demonstrate commitment to service and civic engagement.
LEADERSHIP	**ILO#7** Think critically and creatively, communicate clearly, and act with integrity.	**ILO#8** Practice responsible conduct and allow decisions and directions to be informed by a value-centered life.	**ILO#9** Use global and local leadership opportunities in pursuit of justice.

3. Program Learning Outcomes

A student who completes a B.S. in Mathematics will satisfy the Mathematics Program Learning Outcomes. A student who completes a B.A. in Mathematics Education will satisfy the Program Learning Outcomes of both the Mathematics Program and the Teacher Education Program. Therefore, we will list our PLO's in two separate formats:

Mathematics Program Learning Outcomes (MPLOS):
A student who completes the mathematics or mathematics education degree should be able to:

MPLO #1	Formulate mathematical proofs that are clear, correct, complete, and logical.
MPLO #2	Demonstrate an understanding of the knowledge and skills central to the discipline of mathematics.
MPLO #3	Demonstrate the ability to apply appropriate mathematical ideas to both abstract and real-world contexts.
MPLO #4	Demonstrate a willingness to serve by having participated in co-curricular activities that are central to the broader mathematical community.

Teacher Education Program Learning Outcomes (TPLOS):
A student who completes the mathematics education degree should be able to:

Knowledge and Scholarship	***Faith and Heritage***	***Community and Global Understanding***

TPLO #1	TPLO #2	TPLO #3
Know the theories of learning for instructional time	Fulfill professional, legal, and ethical obligations.	Plan instruction for all students and teach English learners.
TPLO #4 Know developmentally appropriate teaching practices; demonstrate specific pedagogical skills for subject matter instructions.	**TPLO #5** Monitor student learning during instruction.	**TPLO #6** Know the concept of human engagement and know how to make content accessible.
TPLO #7 Interpret and use assessments and know theories of development for learning about students.	**TPLO #8** Seek professional growth as an educator and lifelong learner.	**TPLO #9** Create a social environment.

I. Alignment of PLOs with Institutional Learning Outcomes

Our program prepares students for lives of purpose, service and leadership by training them in the mathematical thinking, skills, discipline, and service opportunities that are needed in various professions.

Institutional Learning Outcomes	MPLO #1	MPLO #2	MPLO #3	MPLO #4
ILO #1 Demonstrate expertise in an academic or professional discipline, display proficiency in the discipline, and engage in the process of academic discovery.	X	X	X	
ILO #2 Appreciate the complex relationship between faith, learning, and practice.				
ILO #3 Develop and enact a compelling personal and professional vision that values diversity.				
ILO #4 Apply knowledge to real-world challenges.			X	
ILO #5 Respond to the call to serve others.				X
ILO #6 Demonstrate commitment to service and civic				X

engagement.				
ILO #7 Think critically and creatively, communicate clearly, and act with integrity.	**X**		**X**	**X**
ILO #8 Practice responsible conduct and allow decisions and directions to be informed by a value-centered life.				
ILO #9 Use global and local leadership opportunities in pursuit of justice.				

Alignment of TPLOs with ILOs:

	ILO#1	ILO#2	ILO#3	ILO#4	ILO#5	ILO#6	ILO#7	ILO#8	ILO#9
TPLO #1	**X**								
TPLO #2		**X**							
TPLO #3			**X**						
TPLO #4				**X**					
TPLO #5					**X**				
TPLO #6						**X**			
TPLO #7							**X**		
TPLO #8								**X**	
TPLO #9									**X**

II. Curriculum Map for MPLOs

For each course, indicate whether students will be ***Introduced*** *to the PLO (**I**),* ***Develop*** *their skills related to the PLO (**D**), or demonstrate* ***Mastery*** *of the PLO (**M**) by entering* ***I***, ***D***, *or* ***M*** *under the appropriate PLO.*

Course Number	**MPLO 1**	**MPLO 2**	**MPLO 3**	**MPLO 4**
Math 130 – Colloquium in Mathematics				I
Math 151 - Calculus II		I	I	
Math 250 - Calculus III		D	D	
Math 260 - Linear Algebra	I	D	D	
Math 320 - Transition to Abstract Mathematics	I			I
Math 325 – Mathematics for Secondary Education				D
Math 335 - Combinatorics	D			
Math 340 - Differential Equations		D	D	

Math 345 - Numerical Methods			D	
Math 350 – Mathematical Probability	D		D	
Math 355 - Complex Analysis	D			
Math 365 - Automata Theory			D	
Math 370 - Real Analysis I	D	D		
Math 380 - Algebraic Structures I	D	D		
Math 480 - Algebraic Structures II	M	M		
Math 450 – Mathematical Statistics			M	
Math 440 - Partial Differential Equations			M	
Math 470 - Real Analysis II	M	M		
Co-curriculum				M

Curriculum Map for TPLOs
*For each course, an **X** is used to indicate that the TPLO is satisfied.*

	EDUC 251 Human Development	**EDUC 461 Instructional Design**	**EDUC 462 Educational Foundations**	**EDUC 464 Literacy in the 21st Century**	**EDUC 465 Teaching English Learners**
TPLO #1		X		X	
TPLO #2			X		
TPLO #3		X	X	X	X
TPLO #4	X	X		X	X
TPLO #5				X	X
TPLO #6		X		X	X
TPLO #7	X	X		X	X
TPLO #8			X		
TPLO #9		X		X	

Design of the Mathematics major:
A typical math major begins with the three semester calculus sequence. Very frequently, entering first years already have credit for one or two of these through AP or similar credit. Calculus is one of the foundations of the modern scientific and technological age. It relates ideas from classical geometry like area and tangency to dynamical ideas like rate of change and sensitivity to change, and is the basic language of physics and many other areas of science, engineering, and economics. The second and third semester of calculus also build the student's ability to visualize in three dimensions.
During the Spring semester of the first year, math majors and prospective math majors should take Colloquium in Mathematics, a 1 unit seminar where students are exposed to an overview of what the math major is like beyond calculus. Math

faculty present short introductions to different topics that students will encounter later in the major. Along the way, students get to meet many of the math faculty. Students also learn about career options for math majors and learn about other opportunities such as undergraduate research and other programs for math majors.

During the second year, students take the Linear Algebra and Differential Equations courses. These courses mix the largely computational aspects of calculus with the conceptual and abstract thinking of upper division courses. Linear Algebra further develops the mathematics of three (or higher) dimensions, describing linear (straight) objects using tables of numbers called matrices. It lies at the intersection of the geometric and the symbolic approaches to mathematics, as well as the intersection of theoretical and applied mathematics. Differential equations is a course in projecting how a system will behave over time, when various influences on the system are known. In this course, students learn to model real-life problems mathematically, and see how these tools can yield profound insights about the natural world.

During the second semester of the second year, math students typically take Transition to Abstract Mathematics. This is a course that introduces students to the concept of proof. Students learn to understand mathematical proofs and write their own, with an eye not only to logical accuracy but also clarity. The Transition course is a prerequisite for most upper division math major courses.

During the third and fourth year, students will take a range of upper division courses. Two in particular are required of all math majors: Real Analysis I and Algebraic Structures I. These introduce students to abstract and proof-based approaches to continuous and discrete areas of mathematics, respectively. They are the foundation for many areas of advanced mathematics, including many areas of mathematics research. These courses are offered every other year, so students must take Real Analysis I one year and Algebraic Structures I the other year.

Students should have an in-depth year-long experience at the upper division level. Thus they choose at least one of a list of four year-long sequences:

- Real Analysis I and II
- Algebraic Structures I and II
- Differential Equations and Partial Differential Equations, or
- Probability and Statistics.

The idea is for students to be introduced to mathematical ideas in one semester and explore them in depth in another semester. This also allows for learning of remarkable ideas that take some time to develop. The course numbering scheme puts the second semester of each of these courses in the 400 level, and students are required to take at least one 400 level course.

Beyond this, math majors must take three other upper division courses from a range of topics, depending on possible career choices, graduate school preparation, or general interest. For instance, students interested in teaching at the middle school to high school level would benefit from Mathematics for Secondary Education, which fulfills many of the goals set by the National Council of Teachers of Mathematics that are not fulfilled elsewhere in the curriculum. Students pursuing graduate school in pure mathematics would benefit from Real Analysis II, Algebraic

Structures II, Complex Variables, and in general should take a wide range of mathematics courses beyond those required to graduate. Combinatorics is an introduction to discrete mathematics and can lead to many research opportunities here and in graduate school. For those interested in graduate school in applied mathematics, Real Analysis II, Partial Differential Equations, Complex Variables, Numerical Methods, Mathematical Probability, and Statistics would be worthwhile. Automata Theory has connections to Computer Science, Logic and Philosophy, and Linguistics, for students interested in those topics.

Each student's mathematical experience is complemented by courses outside of mathematics. Physics I allows students to experience mathematics applied in a physical science. Introduction to Computer Programming teaches students how to program computers, which is fundamental to much of applied mathematics, and is often the basis for many career options for math majors.

Design of the Mathematics Education major:

A typical math education major begins with the three semester calculus sequence. Very frequently, entering first years already have credit for one or two of these through AP or similar credit. Calculus is one of the foundations of the modern scientific and technological age. It relates ideas from classical geometry like area and tangency to dynamical ideas like rate of change and sensitivity to change, and is the basic language of physics and many other areas of science, engineering, and economics. The second and third semester of calculus also build the student's ability to visualize in three dimensions.

During the Spring semester of the first year, math education majors should take Colloquium in Mathematics, a 1 unit seminar where students are exposed to an overview of what the math major is like beyond calculus. Math faculty present short introductions to different topics that students will encounter later in the major. Along the way, students get to meet many of the math faculty. Students also learn about career options for math majors and learn about other opportunities such as undergraduate research and other programs for math majors.

During the second year, students take the Linear Algebra, normally during the fall semester. This course mixes the largely computational aspects of calculus with the conceptual and abstract thinking of upper division courses. Linear Algebra further develops the mathematics of three (or higher) dimensions, describing linear (straight) objects using tables of numbers called matrices. It lies at the intersection of the geometric and the symbolic approaches to mathematics, as well as the intersection of theoretical and applied mathematics.

During the second semester of the second year, math students typically take Transition to Abstract Mathematics. This is a course that introduces students to the concept of proof. Students learn to understand mathematical proofs and write their own, with an eye not only to logical accuracy but also clarity. The Transition course is a prerequisite for most upper division math major courses. This course is important for math education majors as it requires them to understand the very foundations of mathematics and learn to use them to prove basic results about the

real number system, leading to a deeper understanding of how mathematics builds upon the foundational axioms of our number system.
During the third and fourth year, students will take a range of upper division math courses. Real Analysis I is required of all math education majors. This course introduces students to abstract and proof-based approaches to continuous areas of mathematics. Real Analysis is a foundation for many areas of advanced mathematics, including many areas of mathematics research. Beyond this, math majors must take three other upper division courses from a range of topics.
Each student's mathematical experience is complemented by courses outside of mathematics. Students may take either Physics I or Chemistry 120/120L and 121/121L, which allow students to experience mathematics applied in a physical science.
Beyond the mathematics courses, students are required to take 5 education courses. These courses are Human Development, Instructional Design, Educational Foundations, Literacy in the 21st Century – Single Subject and Teaching English Learners.
Students are NOT required to complete the student teaching courses as we do not want to require students to obtain a teaching credential in the state of California. Our majors come from across the country and may wish to complete the requirements of a different state in order to teach in a different place.

III. Alignment of PLOs with Core Competencies

Place a check mark to indicate which PLOs develop each of the Core Competencies.

	MPLO#1	MPLO#2	MPLO#3	MPLO#4
Critical Thinking	X	X	X	
Information Literacy		X	X	
Oral Communication			X	X
Written Communication	X		X	
Quantitative Skills		X	X	

The Mathematics program as a whole lends itself extremely well to the development of many, if not all, of the Core Competencies.
Critical Thinking: The study of mathematics at all levels leads students to develop sharper critical thinking skills. In all classes, students are asked to analyze a given set of conditions or a given set of data and use that information to draw conclusions that are logically consistent. In order to solve problems or apply mathematics to various real world situations, students must be able to recognize what information is necessary to solve the problem and what information is not needed. When

writing a proof, students must learn how to string together arguments that can be logically supported and which follow directly from the given information.
Information Literacy: This core competency is a critical part of the math major as a whole and plays in important role in many of our classes. Students must be able to assess information that is given and be able to interpret that information in the mathematically correct way. In our GE classes and lower division courses, we often discuss examples from newspapers, the news, the internet, and other popular culture outlets where numbers or statistics are given and we discuss whether the conclusions drawn by the media are mathematically correct and logically sound (and often they are not!). In our upper division Statistics and Differential Equations courses, students work with real world data and must use mathematics to draw conclusions. This again requires students to be comfortable interpreting a given data set and to analyze the potential weaknesses of that data set.
Oral Communication: We strongly encourage each of our math majors to give an oral presentation about a mathematical topic in a public forum before they graduate. We run a weekly colloquium, called the Tuesday Tea at Three, which involves 20 minutes of refreshments followed by a 20-30 minute mathematical talk. Most of our seniors will give a talk in the Tuesday Tea at some point during their undergraduate career (in the 2012-2013 year 100% of our Math majors gave a talk). Many of our majors have given a mathematical talk at a local conference (primarily the Pacific Coast Undergraduate Mathematics Conference – a southern California conference that draws roughly 500 participants each year) or at a national meeting, such as Mathfest (the summer national conference of the Mathematical Association of America). (Again, in the 2012-2013 year, 100% of our Math majors gave a talk or poster at a professional conference.) In addition, each year we generally have several students give a poster at the Joint Mathematics Meetings (the largest national math conference of the year). In each of these forums, students are developing their ability to communicate mathematics to other mathematicians and non-mathematicians.
Written Communication: Our math majors must be able to communicate mathematical ideas clearly, concisely and correctly. Our MPLO #1 directly addresses the ability of our students to write proofs and this written communication is critical to their success in the mathematics program. Our Math 320 class (Transition to Abstract Mathematics) is primarily an introduction to proof-writing course in which the main focus of the course is on teaching students how to write proofs. In our calculus courses, students are asked to solve many problems and explain their reasoning, which are pre-proof writing skills, but are rarely asked to develop a proof on their own. Math 320 is the bridge course to our upper division courses in which students are often asked to write proofs and must have the ability to understand complicated proofs and also analyze a given proof for correctness or possible logical errors. Upon graduation, students often report that they have seen enormous growth in their ability to set out their mathematical ideas in a clear and concise manner.
Quantitative Skills: We do not have any math classes that do NOT develop quantitative skills! Students must be able to assess data, reason mathematically,

solve problems, think critically about given information and in general use quantitative reasoning to solve a variety of problems.

IV. Assessment Schedule

This is the schedule of assessments that were done in the past 5 years.

Direct evidence *arises from performance-based evaluations such as observation and student work samples.* ***Indirect evidence*** *arises from measures of perceived value such as surveys or questionnaires.* ***Authentic evidence*** *arises from measure of a student's ability to apply his or her learning and knowledge in real world applications*.

MPLO Number	Assessment Schedule	Direct Evidence	Indirect Evidence	Authentic Evidence
SLO1	**Fall 2011**	**380 Final Exam**	**Graduate Survey**	
SLO2	**Fall 2012**	**ETS – MFT Math**	**Alumni Survey**	**ETS test, UG Research**
SLO3	**Spring 2013**	**340 Project**	**Alumni Survey**	**UG Research**
SLO4	**Fall 2015**	**List of Talks, Service Participation**	**Graduate Survey**	

V. Assessment of MPLO1

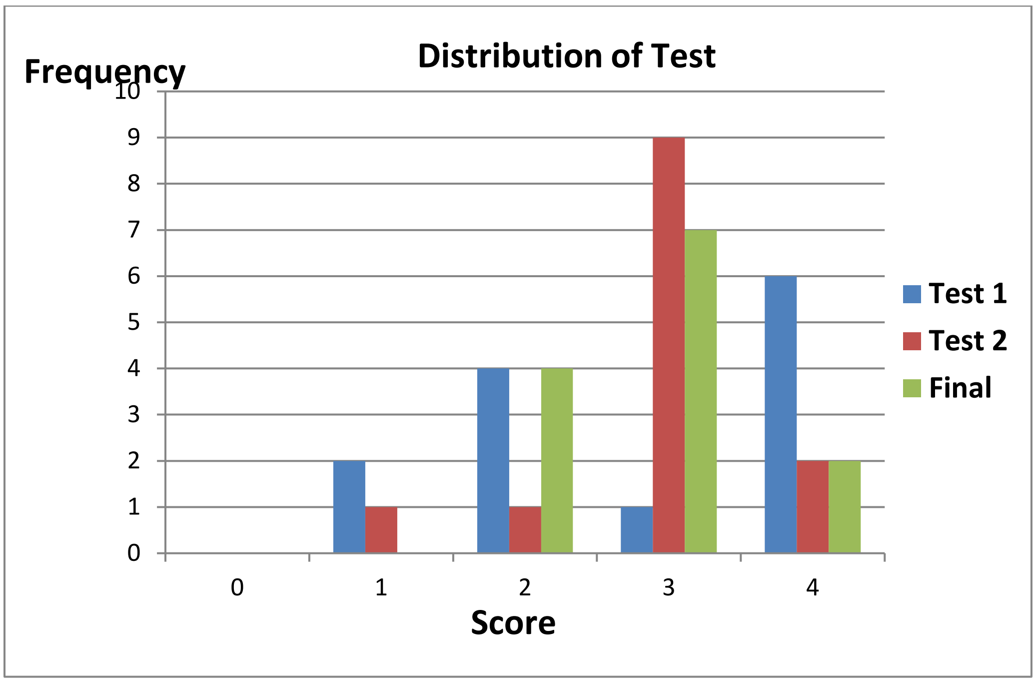
Homomorphisms & Isomorphisms: Proof-writing in Abstract Algebra

By Don Thompson, Kevin Iga, Brian Fisher, and Don Hancock

Algebraic Structures is a course in the mathematics major that requires its students to master sophisticated content that forms the foundation of pure mathematical thought. Algebra (from Arabic al-jebr meaning "reunion of broken parts") is the branch of mathematics concerning the study of the rules of operations and relations, and the constructions and concepts arising from them, including terms, polynomials, equations and algebraic structures. Together with geometry, analysis, topology, combinatorics, and number theory, algebra is one of the main branches of pure mathematics. Central to all of mathematics is the ability to read and write mathematical proofs. Without these skills, mathematical maturity will never occur and students will be unable to advance past the trivial stages of mathematical computation. Proof-writing is especially critical within pure mathematics because it represents the primary way in which the field is rigorously advanced. It is a recognized component of one's membership in the guild of mathematics. Indeed, it is rooted in the work of Pythagoras, Euclid, and Aristotle, as it represents rigorous critical thinking and expression. Moreover, writing-intensive courses within the mathematics curriculum equate with those courses that demand proof-writing expertise.

Proof-writing, as with all writing, is a function of content. One writes in order to solve a problem or present an argument, both of which are completely driven by the material at hand. For Algebra, one of the central concepts that students study is that of "mapping", which frequently takes the form of isomorphism or homomorphism, depending on the nature of the map and its domain and range structures. Thus, our assessment focused on proof-writing with respect to these two common forms of mapping that are found within the mathematical field of Algebra.

We analyzed the proof-writing expertise among the thirteen students who were enrolled in Math 380 in the Fall 2011 term. We selected one problem on each of the three major exams in the class. Each problem was a sophisticated mathematical proof of a mapping concept involving groups, rings, or fields. We did a check on inter-rater reliability, after which each member of our four member panel read the pre-chosen problem on each of the three exams for each student. We used the following rubric to evaluate the mathematical writing: poor (0), marginal (1), good (2), very good (3), or outstanding (4). For each problem and each student, we determined the modal score of our individual scores. The graph below indicates the number of students who received the indicated modal score on each of the three exams.



Statistically, the Test 1 Problem had a mean of 2.85, mode 4; the Test 2 Problem had a mean of 2.93, mode 3; and the Final Exam Problem had a mean of 2.85, mode 3.

After our team read and evaluated each of the three problems for each of the thirteen students, we met for discussion of our results. We drew the following primary conclusion:

- Overall, the results were very good. For example, on the final exam 9 out of 13 were scored as very good or excellent, and the remaining 4 were scored as good, i.e., no poor or marginal.

- Over time, because the content of each test increases in difficulty, our students do improve significantly in their proof writing skills. This means they are learning how to write proofs AND master increasingly complex material. This is very encouraging to us because they are improving in two ways – (1) mastering one of the primary learning outcomes: proof-writing and (2) maturing as mathematical thinkers, being able to apprehend monotonically increasing sophisticated mathematical content. Finally, this gives us confidence in the greatest learning outcomes we can hope for: deep learning. See the important article by Halpern & Hakel:

http://dt.pepperdine.edu/projects/wasc/Applying%20the%20science%20of%20learning.pdf

Closing the Loop

We would be more pleased if the number of students earning a score of three or four on each proof were higher, so, we see a number of next steps that we will consider pursuing in the coming years with our students:

- Spending time in advanced mathematics classes demonstrating
  - How to evaluate proof quality
  - Best practice in proof-writing
  - Common proof-writing errors
  - Covering proofs outside the particular course content, thereby requiring students to transfer their skills to other domains
- Development of a proof writing lab component in select advance courses.
- Sharing these findings with our students themselves, thereby making this assessment both summative and formative.
- Focus more on content mastery and less on pedagogy. We are convinced that mathematics is really more about focused time on content than it is about the latest technology or pedagogical innovation. After all, to master Immanuel Kant, one must simply read and study his work. There is no substitute and no shortcut.

Assessment of MPLO2

A. Proof-Writing Ability: Assessment of final exam questions on proof-writing.

- **Fall 2012 – Math 260, Linear Algebra (Dr. David Strong)**

  Math 260 Linear Algebra is a course required for mathematics and a variety of science majors, as well as the applied mathematics minor. It is generally taken by sophomores and juniors. Some have no experience in reading and writing proofs, while others have more extensive experience from other mathematics courses. This wide range of students' backgrounds makes our treatment of proof-writing in class a bit more complicated: should I risk boring the more advanced students with the basics of proof-writing, with which they are already comfortable, or do I risk losing the weaker students by considering more complicated proofs in class and in homework assignments?
  The proof question on the final exam that was analyzed for all students is:

Given an $n \times n$ matrix A, we are interested in fixed conditions on $\vec{b}$ that will result in the set $S = \{\vec{x}: A\vec{x} = \vec{b}\}$ being a subspace of R^n. (Note: what we are interested in is *whether* S is a subspace, not what it is a subspace *of*.) Recall that both of the following conditions must be met in order for S to be a subspace of R^n:

(i) $\vec{u}, \vec{v} \in S \Rightarrow \vec{u} + \vec{v} \in S$
(ii) $\vec{u} \in S \Rightarrow c\vec{u} \in S$

Under what condition(s) on $\vec{b}$ is (i) true? Prove/explain this.

Under what condition(s) on $\vec{b}$ is (ii) true? Prove/explain this.

Using your results of (a) and (b), under what condition(s) on $\vec{b}$ is $\{\vec{x}: A\vec{x} = \vec{b}\}$ a subspace of R^n?

What is special about this space, if it meets the condition(s) you found in (c)?

This problem was to some extent to test student's ability to write a proof, and to some extent a test of their ability to reason and derive conditions that must be met for the given result to be true, as opposed to being given a set of conditions with which to prove a certain result.
23 students took the exam. This question was worth 10 points out of a total of 135 points. The average and median scores were both approximately 7/10. All but two of the scores were between 3 and 10, inclusive.
The wide range of scores was not a huge surprise, for three main reasons: (1) aside from this class, some students have no background whatsoever in proof-writing, while some have taken multiple other proof-focused courses; (2) many students are majoring in fields other than mathematics, and thus do not have the same general mathematical background as the math majors (the math majors tend to be more adept in reading and writing proofs); (3) while proof-writing is a component of this course, it is not our main focus.
It is important to note that we have indicated that MPLO #1 is introduced in Math 260 and students are not expected to have developed competence or mastery of this difficult skill at this time.
With this in mind, I would hope that at least half of the students would score at least a 70% (that is, a C–, the grade required to move on to other courses for which Math 260 is a prerequisite) on this question. This is more or less the case. Of course, most students tended to do better on the non-proof questions, and thus more than half of the students scored 70% or better on the entire final exam. In spite of the struggles of some students (mostly the non-math majors), overall I am pleased with the overall performance of the students in this class. We believe that the course has satisfied the goal of introducing students to proof-writing techniques and that students develop a satisfactory level of proof-writing in this course.

- **Fall 2012 – Math 335, Combinatorics (Dr. Kendra Killpatrick)**

Math 335 – Combinatorics is an upper division elective course that is taken by junior and senior math majors. It was taught during the Fall 2012 and an important component of the course is to teach students how to write combinatorial proofs,

which differ in spirit and details from the algebraic or geometric proofs that students learn to write in other courses. The proof question on the final exam that was analyzed for all students is:
Give a combinatorial proof that:

$$\sum_{k=0}^{m} \binom{m}{k}\binom{n}{r+k} = \binom{m+n}{m+r}.$$

This question was worth 8 points on a 200 point final exam. Out of 7 students in the course, 6 students received a perfect score of 8 points and one student did not attempt the problem (his paper was blank) and thus received a score of 0. Combinatorial proofs are quite different in nature than the proofs that students learn to write in other courses and it is a safe assumption that no student in the class is able to write a combinatorial proof (or even knows what such a proof might look like) when the class begins. In light of this fact, these results are quite good and the Math Department is very pleased with them. The student who received a 0 did express that he did not feel that he had enough time to finish the exam so it is possible that the reason he did not attempt this problem is because he ran out of time.
In light of these results, we feel that the Math 335 class is doing an excellent job of teaching students how to write a combinatorial proof. The next time the class is taught, the professor will give a pre-test that asks students to write a combinatorial proof and then will repeat that test at the end of the semester (or possibly as part of the final exam) to obtain some pre and post data on the ability of students to write combinatorial proofs.

- **Fall 2012 – Math 370, Real Analysis I (Dr. Don Hancock)**

As part of the ongoing assessment of our math majors' ability to write mathematical proofs, we analyzed one proof question on the final exam for each student in the required upper division course Real Analysis I (Math 370), which was taught by Professor Hancock in the Fall. Here is the question that we assessed: "Prove the Mean Value Theorem for Integrals, which says that if f is a continuous function on [a,b], then $\int_a^b f(x)dx = f(c)(b-a)$, for some c in [a,b]". This 10-point question was one of 9 proofs asked for on the exam, and was considered to be somewhat above average in difficulty. We chose this question to assess for this report in part because the proof can be approached in a couple of distinct ways, it ties together several key ideas from the course, and it is neither excessively long nor technically demanding. Our hope and expectation was that at least 70% of the students would earn 8 or more points on this problem, which translates into "B" or higher work. (For comparison purposes, when we assessed proof-writing last year in the comparable-level abstract algebra course, about 70% of the students earned a rating of "B" or higher.) The actual grading of the problem was performed solely by Professor Hancock.

Before grading the problem Professor Hancock developed a rubric for assigning the 10 possible points: 3 points were possible for the student who properly used key properties of continuous functions (Extreme Value Theorem and Intermediate Value Theorem, or Fundamental Theorem of Calculus and Mean Value Theorem for Derivatives, depending on the approach used); up to 3 points were dependent on

the student correctly applying comparison and monotonicity properties of the integral; the remaining 4 points were tied to logical correctness of the student's proof (including recognition of the hypothesis and conclusion) and a suitable level of detail. Of the 22 students who took the final exam, 10 of the students earned full credit and wrote basically flawless proofs, while 3 others had a very minor flaw resulting in a one-point deduction. Thus, 13 students wrote what we consider to be "A" level proofs. There were 3 other students who demonstrated solid logic and proof-writing skills, but they failed to fully address how the continuity hypothesis of the function f fit in. These 3 students earned 8 points on the problem, regarded as B-level work. This means that nearly ¾ of the class wrote proofs of "A" or "B" quality, which somewhat exceeds our original expectations.
However, the work of the remaining 5 students on this problem was of very poor quality. One student, earning 5 points, started the proof in a legitimate way by introducing an integral function, but failed to then make the key connection to either the Fundamental Theorem of Calculus or the Mean Value Theorem for Derivatives. Four other students wrote severely flawed arguments, attempting to use the definition of the integral as a limit of Riemann sums; each earned 3 points. The remaining student left the problem blank, having no idea how to begin. It should be noted that 4 of these 5 students did very poorly on the entire test, including all computational problems and ones asking for examples. We believe that their poor performance is due to a lack of effort and failure to comprehend even the most basic concepts from the course; thus, it is difficult to blame their poor performance simply on poor proof-writing skills. It is worth noting that the analysis course is only offered every other year, and is populated by students with significantly varying levels of experience writing proofs. Coupled with the fact that real analysis is viewed as one of the most challenging undergraduate math courses, this helps explain why student performance in Math 370 is traditionally more diverse than in some other math classes. Overall, we are pleased with the results of our assessment and do not recommend changes at this time, particularly since this course is not one in which students are expected to have mastered MPLO #1, but are developing competence in this area.

- **Spring 2013 – Math 260, Linear Algebra**

Math 260 – Linear Algebra is a class taken by freshmen and sophomores majoring in Mathematics, Mathematics Education and Math/Computer Science as well as students who are minoring in Mathematics or Applied Mathematics. The course is one of two courses in our curriculum where students are *introduced* to MPLO #1 and the difficult skill of proof-writing. Those students in the class who have already taken Math 320 – Transition to Abstract Mathematics (the other course in our curriculum where MPLO #1 is introduced) or who are concurrently taking Math 320 tend to be far superior at proof-writing than their peers who have not taken this course, often leading to a somewhat bi-modal distribution in the ability of students in Math 260 to write proofs.
The question analyzed on the Spring 2013 final exam was:
Prove that the function T: $R^3 \to R^2$ given by

$$T\left(\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}\right) = \begin{bmatrix} x_1 - 5x_2 + 4x_3 \\ x_2 - 6x_3 \end{bmatrix}$$

is a linear transformation.

When proving a function is a linear transformation, there are two main things to prove. Each of these two things was worth 5 points if the student completed them successfully. A student received 2 points for simply correctly stating which two things needed to be proved, and then earned the remaining points by proving them correctly.
Out of 12 students in the class, 5 students earned a perfect 10 points on this question, one student earned 9 points, one student earned 5 points, one student earned 2 points, and 4 students earned 0 points. Of the students who earned 5 points or below, none had taken Math 320 or were concurrently enrolled in it. These results were somewhat disappointing and lower than expected for this question. I would have expected 7 out of 12 students to have been able to score 7 points or more on this question, so the class was below expectations. In the future when teaching this course, it will be important for the professor to spend a little more time working on introducing proper proof-writing technique, particularly for those students who have not taken a proof-writing course before. However, with the four students scoring a zero, it is difficult to determine if they simply did not understand what a linear transformation is or if their difficulty was in the proof-writing itself since there was not enough information on their exam to determine where the difficulty was for them.

- **Spring 2013 – Math 320, Transition to Abstract Mathematics (Dr. Brian Fisher)**

Problem: Assume that $f: A \to B$ is an injective function and let A_1 and A_2 be subsets of A. Prove that $f(A_1) \cap f(A_2) \supseteq f(A_1 \cap A_2)$.
Nine students completed this problem on their final exam and they were graded out of ten points. In particular, I looked at 5 components while grading these proofs:

- Did the proof use correct logical arguments?
- Did the student select an appropriate method of proof?
- Did the student use relevant definitions and theorems correctly?
- Was the proof complete or did it lack essential details?
- Was the proof written in a manner that conveys the details of the proof to the reader?

The scores for the proof can be roughly placed into the four categories below:

Classification	Score	Description
Outstanding	10	Student wrote a complete and correct proof using appropriate methods for the problem. The writing used all definitions and theorems appropriately and clearly conveyed the elements of the proof to the reader
Good	7 – 9	Student wrote a proof that was complete and correct using an appropriate method of proof containing some minor errors. The writing of the proof may contain minor jumps in logic, slight misuse of terminology, or potentially misleading notation.
Marginal	5 – 7	Student wrote a potentially correct proof using a potentially correct method containing moderate logical flaws and/or lacking needed details. The writing of the proof may contain moderate

		errors in its use of definitions and theorems and may misuse terminology/notation in a way that would be distracting to readers.
Poor	0 – 4	Student wrote a proof that contained significant logical errors and/or missed significant details. The student may have chosen an inappropriate proof method or misused definitions and theorems. The writing of the proof may contain significant mistakes that misrepresent the mathematics involved.

<u>The scores for this problem were:</u>
10 – Two students
9 – Four students
8 – Two students
4 – One student

<u>Personal reflection on the results:</u>

The role of Math 320 within the mathematics curriculum is to introduce students to formal proof writing allowing them to engage in mathematics in a more meaningful manner, thus equipping them for success in upper-division mathematics courses. From an assessment perspective, Math 320 is chosen to be one of the two courses in the curriculum (along with Math 260) that *introduces* students to the a*bility to formulate clear, correct, complete, and logical mathematical proofs.* From this viewpoint, it is my opinion that students who have obtained an introductory understanding of proof-writing would be able to achieve a score of "good" or "outstanding" (scoring 7 – 10 points) on this problem. Given this measure of success, I was very pleased that 8 of the 9 students enrolled in the course succeeded on this problem. This supports my confidence that these students are prepared to move along in the mathematics curriculum and develop their understanding of proof-writing even further.

As with all small-scale assessments, this positive result needs to be understood in the context of all the assessments given throughout the semester and through the curriculum. For example, the one student who earned a score of "poor" on this assessment happened to be the top scoring student in the class throughout the semester.

- **Spring 2013 – Math 355 – Complex Variables (Dr. Tim Lucas)**

  Complex Variables is an upper division elective course that is taken by sophomore, junior and senior mathematics majors. Professor Lucas taught this course during the spring term of 2013. An important theme in the course is to extend results from calculus and analysis on the real line to the complex plane. For example, students are asked to use their understanding of the definition of sequence convergence for real numbers to define sequence convergence for complex numbers. For the final exam we chose to analyze the following related proof:
  "Use the epsilon – N definition of a limit to show that a sequence of complex numbers converges if and only if the real and imaginary parts of the sequence converge."
  Before grading the problem, Professor Lucas developed a rubric to assign the 10 possible points. For simplicity, we will label A as the statement that a sequence of complex numbers converges and B as the statement that both the real and imaginary parts of the sequence converge. The students received one point for

recognizing that they must show that A implies B and B implies A. The proofs that A implies B and that B implies A were worth 4 points each. Within each of these proofs students received one point for correctly stating the assumptions and conclusions, one point for stating the correct definition of a limit of a sequence, and two points for applying the appropriate bounds to show that the required sequences converge. The final point was awarded for a technical issue that involves correctly specifying an arbitrary epsilon > 0 and choosing a positive integer N that specifically depends on that epsilon. Our expectation is that 75% of the students would receive 8 out of 10 points which translates onto "B" level or higher work.
Of the 11 students in the course, 3 students received 10 points, 3 students received 9 points, 3 students received 8 points and 2 students received 5 points. In total, 9 out of 11 students (82%) received a score of 8 or higher. All students recognized that they must show A implies B and B implies A and were able to correctly state the definition of sequence convergence. Both of the students that received 5 points were able to prove that B implies A, but had difficulty with the logic in proving that A implies B. Overall we are pleased with the results of this assessment. The students demonstrated an understanding of basic proof techniques that were introduced in Math 320: Transition to Abstract Mathematics and demonstrated by many of the students in Math 370: Real Analysis. The 8 students that did not receive 10 points had difficulty with the technical issue described above. Although Professor Lucas did address this issue when grading a similar proof about limits of complex functions on the first exam, in future semesters the class would benefit from reminding the students about the importance of using the correct logic in writing proofs about limits.

- **Spring 2013 – Math 470, Real Analysis II (Dr. Don Hancock)**

Continuing the assessment of our majors' ability to write mathematical proofs, one proof question was analyzed from the in-class portion of the final exam for Real Analysis II (Math 470), which was taught in the Spring semester by Professor Hancock. The assessed question asked the students: "Prove that if f is a summable function on [0,1], and $g_n(x) = x^n f(x)$ for all x in [0,1] and every natural number *n*, then $\lim_{n\to\infty} \int_{[0,1]} g_n \, dm = 0$". This 9-point question was one of 9 proofs asked for on the exam, and was considered to be average in difficulty. We chose this question to assess for this report in part because it ties together several key ideas from the course, namely convergence and Lebesgue integration, and it is neither excessively long nor technically demanding. Our hope and expectation was that at least 75% of the students would earn 7 or more points on this problem, which translates into "B-" or higher work. (For comparison purposes, when we assessed proof-writing in the prerequisite Real Analysis I course the previous semester, about 75% of the students earned a rating of "B-" or higher.) The actual grading of the problem was performed solely by Professor Hancock.

Before grading the problem, Professor Hancock developed a rubric for assigning the 9 possible points: 3 points were possible for the student who showed that each g_n is a measurable function and is uniformly dominated by a summable function; 3 points were tied to showing that the sequence $\{g_n\}_{n=1}^{\infty}$ converges to 0 almost everywhere on [0,1], and 3 points were dependent on properly applying the Lebesgue Dominated Convergence Theorem to reach the desired conclusion that the limit of the integrals is 0.

Of the 9 students who took the final exam, 4 of the students earned full credit and wrote basically flawless proofs, while the remaining 5 had a minor flaw resulting in a one-point deduction. In each case, the flaw was either in not fully justifying why each g_n is measurable, or in omitting a needed absolute value sign somewhere. Thus, all the students wrote what we consider to be "A" or "B+" level proofs, which exceeded our expectations. It is worth noting that, in fact, all students demonstrated solid logic and proof-writing skills throughout the exam, which is reflected in the fact that the mean score was 85%. Overall, we are extremely pleased with the results of our assessment and do not recommend changes at this time.

B. Applications of Mathematics: Math 340 Projects

By Dr. Courtney Davis, Dr. Tim Lucas and Dr. David Strong

For the past 4 years we have assigned a semester-long project in Math 340: Differential Equations that is designed to give students experience in applying mathematics in real world contexts (MPLO #3).

The instructions for the project on the Math 340 syllabus are as follows.

Final Project: Each group of two to three students will choose a model or differential equation beyond those discussed in class to thoroughly analyze. For each project I expect you to do the following analysis when appropriate to your project.

- Discuss the background and history of your particular model or differential equation.
- Discuss the existence and uniqueness of solutions to ordinary differential equations.
- Plot slope fields or phase planes and discuss the behavior of solutions with various key initial values.
- Discuss the sensitivity of solutions to initial conditions and/or boundary conditions.
- Solve the equations analytically using techniques learned in class if possible.
- Discuss steady-state and transient solutions if applicable.
- Consider linearizations of nonlinear differential equations or systems.
- Compute numerical solutions using techniques learned in class.
- Analyze solutions in the context of applications of the differential equation or system.

Each group will present their project on a poster that contains the relevant analysis of a real-world application outlined above. A poster session will be held on during the final exam period for the course. Members of the Natural Science faculty will assist in judging the posters.

The students are given a list of suggested topics from a variety of differential equations and mathematical modeling texts or are encouraged to choose an application they find interesting. The students are given deadlines to encourage them to work on the project throughout the semester and produce results with sufficient mathematical content and applicability.

The learning outcomes for this project are that students should be able to:

1. Formulate a mathematical model that describes a real-world problem and report results of the mathematical analysis that are relevant to the broader context or application.
2. Conduct appropriate mathematical analysis by examining the form of the equations, interpreting slope fields or phase plane diagrams, identifying and classifying equilibria, and finally solving the equations algebraically or approximating solutions.
3. Present the model and mathematical analysis in a clear, organized manner on a conference-quality applied mathematics research poster.
4. Demonstrate a thorough understanding of the model and mathematics when presenting the poster and respond appropriately to questions from experienced mathematicians and scientists.

Dr. Davis, Dr. Lucas and Dr. Strong met together to create a rubric that addresses these learning outcomes. The rubric is split into four categories that mirror the learning outcomes and each category is scored on a four-point scale: (4) Excellent, (3) Sufficient, (2) Insufficient, (1) Poor.

Categories	Criteria	Rating
Mathematical Analysis	Correctness of mathematical analysis Breadth and depth of DE analysis DE analysis appropriate to context Use of relevant graphics Understanding of the mathematics Overall mathematical analysis	
Modeling Application and Context	Clearly defined questions Clearly defined terms Quality of results Understanding of real-world context Understanding of the role of DEs in context Overall background and results in context	
Poster Writing	Defined sections and headings Flow to assist the reader without help Explanation clarity Writing errors Labeling and readability of graphics Overall finished product	
Oral Presentation	Involvement of all members Verbal explanations by group as a whole Group's understanding of overall project Thoughtful and clear answers to questions Overall oral presentation	

Our expectation is that 75% of the projects will receive a score of 3 or higher in each category indicating that the project represents a sufficient level of proficiency for each learning outcome.

Our assessment of the Math 340 projects includes 23 projects that have been completed over the past four years. These projects have addressed applications in biology, chemistry, physics, economics and finance. Many members of the Mathematics and Natural Science faculty have been invited to evaluate posters during final presentations over the past four years. These include Dr. Courtney Davis, Dr. Brian Fisher, Dr. Timothy Lucas, Dr. David Strong and Dr. Don Thompson from Mathematics as well as Dr. Stephen Davis from Biology and Dr. Ken Henisey from Physics. The two instructors for Math 340, Dr. Lucas and Dr. Davis, met after final presentations this spring to assess each of the past 23 projects and determine a consensus score for each category in the rubric. Below is a chart that gives the distribution of scores for the projects.

Score	Application	Analysis	Poster	Writing
4 Excellent	10	14	9	12
3 Sufficient	10	5	10	8
2 Insufficient	1	2	2	2
1 Poor	2	2	2	1
Average	**3.22**	**3.35**	**3.13**	**3.35**

Over 80% of the projects received a 3 or 4 in every category, and the overall average across categories for the posters was 3.24. Overall, we are pleased with the results of this assessment. The students in Math 340 have made great progress in demonstrating their ability to apply their knowledge of differential equations to a wide variety of real-world applications. We recognize that these projects are an effective method for students to engage in the discipline of applied mathematics by using the tools developed in class to investigate real-world problems.

Although we are pleased with the results, we recognize that some improvements can be made to the structure of the semester-long projects so that more groups can produce excellent work. The greatest obstacle that students face in completing these projects is the time required throughout the semester to investigate their models. Although the students are given deadlines to meet throughout the semester, we believe that a more detailed list of achievable deadlines will help motivate groups to use the entire semester to work on their projects. We propose expanding the list of deadlines as follows, with dates to be assigned at the discretion of the instructor.

1. Project topic
2. Annotated Bibliography with three sources outside the textbook.
3. Draft of background research for the poster.
4. Draft of model explanation and justification for the poster.
5. Detailed outline of techniques that will be used to analyze the model.
6. Draft of entire poster.
7. Final poster due.

8. Final presentations.

Each of these deadlines is also an opportunity to meet with the instructor and discuss the expectations for the project. By incorporating and enforcing these expanded deadlines we believe that the overall quality of the projects will improve.

Student Assessment of the Differential Equations (Math 340) Projects, Spring 2014

In an effort to get more students involved in providing feedback of the assessment process, we surveyed the students in the Math 340: Differential Equations class to obtain their thoughts regarding the projects done throughout the semester. We asked the students five questions:

1. What was useful about the project? What was useful about the poster presentation?
2. Do you have any suggestions for improvements?
3. Did the projects help you to understand topics or applications in Differential Equations beyond what you learned from other coursework; if so, what?
4. Has the experience of developing and presenting a poster for this class made you more comfortable with the idea of presenting a poster or talk at a departmental/university level or conference?
5. Do you have any other comments relative to the effectiveness of the projects and poster presentations on your learning?

19 students submitted anonymous responses. The responses to these questions were widely positive, with the few negative comments being mostly constructive, as described below.

Nearly every student shared more praise than critique for the projects. The most common answer to #1 and #3 was that the projects and presentations helped to solidify class concepts by applying those methods to real-world questions. For example, "It helped to learn how to…see a problem and figure out what we could say about it with what we know"; "It helped me to connect what we learned in class to real world applications…we were proud of the work we did"; "It really seemed to summarize the whole class"; "I think discussing and presenting the concepts forced us to understand them better." Furthermore, some students noted how much they learned about the applications: "I have done more economic research in this project than I have done in my four years at Pepperdine"; "[I now] know details about HIV dynamics [and] other modeling"; "I spent many hours on theoretical models and actual data and feel that I understand this [competition of species] very well."

The constructive critiques received in #2 often focused mostly on logistics rather than on the format or content of the projects and presentations. A number of student survey responses included the desire for each student to have seen every poster presented. Unfortunately, this is contingent upon class size if group sizes remain small. This year, it was impossible in the time allotted with seven posters (21 students); however, in 2013, with five posters (15 students), all students were able to see all posters presented. Students who chose projects using concepts

taught in the last month of class wished that mathematical techniques commonly used by many projects, such as nonlinear system analysis, be presented earlier in the course material. Also, one student asked that more guidance be given about how much mathematical work is sufficient. These projects are intentionally open-ended, but with expectations and a detailed grading rubric given from the start of the semester; this open-ended nature was welcomed by many, but not, all students. The fourth question of this survey presented an opportunity to get students to consider whether the projects affected their confidence in making presentations. In total, 15 students responded yes, 3 were tentative, and 1 responded "No, I already was." Comments included: "It made me more comfortable with the making of the poster and learning what a poster presentation looks like"; "I feel very comfortable being able to replicate this process and it was a huge help in the learning curve of this type of presentation"; "I have never spoken about math like this…I am much more comfortable presenting mathematical posters but not quite confident enough to speak at a higher level yet." [emphasis theirs]
Overall, the student feedback supported our observations that the Differential Equations projects are highly effective in creating and solidifying student learning. Furthermore, a student called these projects "more useful than a cumulative final" at getting the students to understand and work with the mathematical concepts in depth. We will continue to welcome student input and will continue to work on refining the projects, presentations, instructions, and timing to strengthen the Differential Equations projects and course as a whole.

MPLO #4

Pi Mu Epsilon enrollments

PME Enrollments

Fall 2011:
Michelle Barnum
Brittany C Beck
Leah Whitaker

Spring 2012:
Ashley Broadwell
Joshua Thornton

Fall 2012:
Dylan Stuart Bury
Shannon Courtney
Leonard Fletes III
Wancen Jiang
Danial Lander

Junyuan Lin
Steven Lou
Gerard Rothfus
Gifford Leon Tompkins III
Noah BC Webster

Fall 2013:
Jesse Robert Aston
Mitchell A. Bennett
Bryan M. Carter
Chloe Cheung
Erika Ordog
Thomas Shifley
Anna Tramutolo
Dayna Mann

Spring 2014:
Nathan Daniel Boettcher
Hanna Kristensen
Sara Tandon

Fall 2014:
Ben Drozdoff
Jane Lee
Jordan Emalea Weaver

Fall 2015:
Lauren Courtney
Max Ginnell
Joshua C. Haug
Marjorie Teel Jones
Kade Shoemaker

Tuesday Tea at Three talks

Tuesday Tea at Three – Spring 2011

1/18/11	Alex White	"Hungary" for Mathematics in Budapest
1/25/11	Darlena Kern Mark Allenby	Summer Programs in Math
2/1/11	Dr. Killpatrick	Test of Mathematical Content Knowledge
2/8/11	Wendy Jiang	The 4th Dimension
2/15/11	Leah Whitaker	Fibonacci Numbers and Linear Algebra
2/22/11	Roxy Galstyan	NCTM: A Cinderella Story
3/8/11	Wendy Jiang	Love Code
3/15/11	Noah Webster	Multi Variable Limits
3/22/11	Garrett Johns	Ecology Model of Chaparral Plants in Response to Wildfire
3/29/11	Jon Burke	Banach Limits and Asset Price Bubbles
4/5/11	Leo Fletes	The Monty Hall Problem
4/12/11	Stephen Lou	?
4/19/11	Josh Thornton Gifford Tompkins	Fun With Fractals

Tuesday Tea at Three – Fall 2012

9/11/12	Joshua Thornton	A Combinatorial Representation of Pattern Avoiding Involutions
9/18/12	Ashley Broadwell	Generating Functions for Pattern Avoiding Involutions
9/25/12	Leo Fletes	Off the Chain
10/16	Noah Webster	The Man Who Loved Only Numbers
10/23		Pumpkin Pi painting
10/30		Quiz Within a Quiz
11/20		Thanksgiving Tea
12/4		Secret Santa Reveal Party

Tuesday Tea at Three – Spring 2013

1/15/13		Panel Discussion on Conferences for Undergraduates
1/22/13	Zack Reed	A Probability Question
1/29/13	Leah Whitaker	Pascal's Triangle
2/5/13		Panel Discussion on Summer Opportunities
2/12/13	Dr. Killpatrick	Budapest Semesters in Mathematics
2/19/13	Wendy Jiancen Noah Webster	Summer REU research on chaparral
3/5/13	Dr. Fisher	Mathematics of Juggling
3/12/13		Pi Day festivities and pie eating contest!
3/19/13	Dr. DeLong	Taxicabs and Elliptic Curves
3/26/13		Easter Ellipsoid Coloring

Tuesday Tea at Three – Fall 2013

Tuesday Tea at Three – Spring 2014

1/14/14	Dr. Killpatrick	Budapest Semesters in Mathematics program
1/21/14	Dr. Strong	
1/28/14	Dan Lander	Supervised SIM Imaging Segmentation of Self-Assembled Molecule Layers
2/11/14	Joanne Lin	A Model of Plane Evacuation
2/18/14	Jane Lee	Farkle
3/4/14	Erika Ordog	Harmonographs: The Math of Music
3/11/14		Pi Day festivities and pie eating contest
3/18/14	Tom Shifley	Weird Dice
3/25/14	Zack Reed	Graduate School
4/1/14	Hanna Kristensen	To Infinity and Beyond: the Riemann Zeta Function
4/8/14	Dr. Naiomi Cameron	The Inversion Statistic on Consecutive Pattern Avoiding Perms
4/15/14		Easter Ellipsoid Coloring

Tuesday Tea at Three – Fall 2014

9/2/14	Erika Ordog	Pattern Avoidance and Inversion Polynomials
9/9/14	Sara Tandon	Tribonacci Tableaux and Inversion Polynomials
9/16/14	Dayna Mann	
10/7/14	Benjamin Drozdoff	
10/14/14	Dr. Stephen Robertson	
10/21/14	Dr. Matt Highfield	
10/28/14		Pumpkin pi painting
11/4/14	Dr. Talithia Williams	Modeling and Statistics
11/11/14	Jane Lee	
11/18/14	Dr. Derek Wise	
11/25/14		Thanksgiving Tea
12/2/14	Naomi Uyeno	

Tuesday Tea at Three – Spring 2015

1/20/15	Dr. Killpatrick	Guarding an Art Gallery
1/27/15	Dr. Josh Bowman	
2/3/15	Dr. Kevin Iga	
2/10/15	Dr. Killpatrick	Budapest Semesters in Mathematics
2/17/15	Dr. Tim Lucas	Point Processes
2/24/15		Math Games
3/10/15		Pi day festivities and pie eating contest
3/17/15		St. Patrick's Day tea
3/24/15	Jane Lee	
3/31/15		Easter Ellipsoid Coloring
4/7/15	Erika Ordog	
4/14/15	Scarlett He	
4/21/15	Erika Ordog and Hanna Kristensen	

Conference talks and posters

Mathfest talks
Mathfest 2012
Josh Thornton "A Combinatorial Representation of Pattern Avoiding Involutions"
Ashley Broadwell "A Generating Function for Inversion on Pattern Avoiding Involutions"
Won a prize for Outstanding Student Talk.

Mathfest 2014
Erika Ordog "Inversion Polynomials for Pattern Avoiding Permutations"

Sara Tandon "Pattern Avoiding Permutations and Tribonacci Tableaux"

Mathfest 2015

Jordan Weaver "A Combinatorial Proof for a Fibonomial Coefficient Description"

PCUMC Talks – 2011

Joshua Thornton and Gifford Tompkins "Fun with Fractals"
Gerard Rothfus "Squaring the Circle"
Noah Webster "Understanding Multivariable Limits"
Janet Kim "Ganita Sara Samgraha"
Leah Whitaker "The Fibonacci Sequence and Linear Algebra"
Wancen Jiang "Love Code – Love You More Than I Can See"
Mark Allenby "A Point Process Model for Simulating Gang Violence"
Darlena Kern "Fast Approximation of Derivatives Using LU Factorization of Vandermonde Matrices"

PCUMC Talks – 2012

Janet Kim and Ayden Smalling "Arnold's Cat Maps"
Wancen Jiang and Garrett Johns "Chaparral Population Models in Response to Wildfires"

PCUMC Talks – 2013

Zachary Reed "Did Penn and Teller Tell a Lie? Comments on the Bias of a Spinning Penny"
Wancen Jiang and Noah Webster "Spatial Simulation of Chaparral Vegetation Response to Frequent Wildfire"

PCUMC Talks – 2014

Erika Ordog	“Harmonographs: Visualizing the Mathematics of Music”
Thomas Shifley	“Weird Dice: An Application in Algebraic Combinatorics”
Jane Lee	“Farkle”
Kade Shoemaker	“Quants: The Mathematicians of Wall Street”

PCUMC Talks – 2015

Jane Lee	“Logarithmic Spirals”
Hanna Kristensen	“Applications and Mathematical Challenges of Digital Image Mosaicking”
Erika Ordog	“Digital Image Mosaicking: The Algorithm and Its Challenges with Color Images”
Dayna Mann	“An Individual-based Model of Chaparral Response to Frequent Wildfires”

C. Senior Surveys

The math department sends a survey to all of the senior Math and Math Education majors each spring to gain valuable feedback on the mathematics program. This year, we sent the survey to 5 Mathematics majors and 2 Mathematics Education majors and received responses from 4 of the Math majors and both of the Math Education majors. In the past, we have seen strong trends in the student comments regarding the flexibility of the major and the course offerings and these comments motivated us to make some major changes to the mathematics curriculum. The new curriculum and requirements went into effect with the incoming class of 2011-2012, but all of our current senior math majors have chosen to complete the new requirements rather than the old ones (they were given the option because the old requirements are technically the catalog year they came in under). In the past two years, we have not seen flexibility of the major come up in the student comments and have been pleased to see that the number of comments regarding the number of course offerings has also significantly dropped.

The first set of survey questions were grouped according to the Mathematics MPLO’s and students were asked to rate four or five different questions regarding to each MPLO on a Likert scale with options being Very Effective, Slightly Effective, Neither Effective nor Ineffective, Slightly Ineffective, and Very Ineffective. Our expectations were that 80% of the scores for each questions relating to our MPLO's would be either Very Effective or Slightly Effective.

For MPLO #1 (Roughly titled "Reading and Writing Proofs"), 2 of the 4 questions had 4 responses in the Very Effective category and 2 in the Slightly Effective category and 2 of the 4 questions had 3 responses in the Very Effective category, 2 in the Slightly Effective category and 1 in the Slightly Ineffective category.

For MPLO #2 ("Acquisition of knowledge and skills that are central to the discipline"), 2 of the 4 questions had 4 responses in the Very Effective category and 2 in the Slightly Effective category, 1 question had 3 responses in the Very Effective category and 3 in the Slightly Effective category, and 1 question had 2 responses in the Very Effective category, 3 in the Slightly Effective category and 1 in the Slightly Ineffective category.

For MPLO #3 ("Analysis of abstract and real-world problems and application of appropriate mathematical methods to obtain solutions."), we had 5 questions. 2 of the 5 questions had 3 responses in the Very Effective category and 3 responses in the Slightly Effective category, 2 of the questions had 2 responses in the Very Effective category and 4 responses in the Slightly Effective category, and 1 question had 2 responses in the Very Effective category, 3 responses in the Slightly Effective category, and 1 response in the Slightly Ineffective category.

For MPLO #4 ("Understanding the profession of mathematics and participation in the mathematical community."), we had 2 questions. On one question, we had 3 responses in the Very Effective category, 1 response in the Slightly Effective category, 1 response in the neither Effective nor Ineffective category and 1 response in the Slightly Ineffective category. The other question had 3 responses in the Very Effective category, 1 response in the Slightly Effective category and 2 responses in the Slightly Ineffective category.

Closing the Loop: We were quite pleased with the responses to the sets of questions regarding our first 3 MPLO's as these all seemed within the realm of our expectations. We were particularly pleased to see that in response to the question asking students to rate the "Development of your confidence to write proofs", 4 students replied Very Effective and 2 students replied Slightly Effective. We wanted to specifically address how students felt about their ability to write proofs in this survey and feel that we are doing an adequate job at building their confidence in proof-writing with these results. The scores on MPLO #4 were somewhat lower, however when we looked at the wording of the questions we could see that the students may have not known about some of the professional organizations listed and this may have resulted in a lower rating. Other questions on the survey indicated that 5 out of 6 students joined a professional mathematics organization or mathematics honor society, 4 out of 6 students attended a professional conference in mathematics, 4 out of 6 students gave a talk at a professional conference, 5 out of 6 students gave a talk in our departmental colloquium, 3 out of 6 participated in a summer mathematics program of some sort (away from Pepperdine) and 4 out of 6 students participated in undergraduate research while at Pepperdine. We are extremely pleased with these overall numbers and will continue to work to encourage all of our majors to participate in undergraduate research and in giving talks at local and national conferences.

Teacher Education TPLO

Math Education major assessment:

In the 2013-2014 academic year, our goal was to formulate an assessment plan for the Math Education major. The B.A. in Math Education began in the year 2007-2008 and we had not done any assessment of this program since it began. During the 2013-2014 year, we collaborated with the Teacher Education program to obtain PLO's for the B.A. in Math Education (5 of the classes that students take are education courses). We made a curriculum map for the courses required of the Math Education majors by combining the curriculum maps for the math classes and the education classes. At the end of the 2012-2013 academic year we met with four students who were either math education majors or planning on teaching math and discussed the math education program. In addition, in 2013-2014 we sent an informal survey to the alumni of the math education program to obtain indirect evidence of the efficacy of this program. Our intention is to assess the math education program once every five years on a rotating basis with the assessment of each of our Math PLO's. We will continually be gathering data to assess the Math Education major by surveying our graduating seniors each year and surveying our alumni once every five years.

We have attached a copy of the survey questions that we asked the graduating seniors at the end of last year and sent to the alumni this year. We have a small number of majors which makes for a small set of survey data (received feedback from four students last year and one alumni this year), but it has been helpful to discuss the major with them as we are hoping to see growth in this program over the next five years.

We asked the students which math classes and which education classes did they feel had been the most helpful in preparing them for teaching and the overwhelming feedback was that they wanted more instruction in both the specific math content they would be teaching and in different ways that they could teach that particular content. This is primarily the content of our Math 325 course (which is an elective course for Math Ed majors), but since this course is only offered on an every other year basis and did not have enough enrollment the last time it was offered to run, none of these students had taken it. We are in the process of making changes to the Math Education major to require this course of Math Education majors.

Students reported feeling like they were doing two majors – math and education. Their feelings did not stem from feeling like the content of the two departments was too much, but like they had separate advising and separate peer groups. Most students reported feeling more at home and connected to the math department than to the teacher education department. In response, we believe our math faculty need to work more closely with the teacher education faculty to make the major as seamless as possible and to make sure the advising is consistent.

The students did report feeling confident in their ability to teach all levels of high school math, including calculus. They also felt well prepared to answer deeper mathematical questions that strong students may have.

Assessment of AP Calc Placement
One question that continually has been raised is "Is the score of 3 or better on the AP Calculus AB credit sufficient for a student to succeed if placed directly into Calculus II. Analyzing data from the Fall 2008 and Fall 2009for students who came in with AP Calc AB credit, it was determined that a score of 3 was not a detriment to obtaining a passing grade in Calc II, and in fact some of those students did quite well. AP Calc scores of 4 or better tended to have better grades as well, although that was not uniformly true. Similarly, students with a grade of 3 or better on the AP Calc BC exam were generally able to successfully complete Calc III. Thus we concluded that our current policy is sufficient.

Assessment of Math 103 Effectiveness
Math 103, College Algebra, has two prime purposes:

- Prepare students for Math 210, Calculus I
- Satisfy a requirement for the Nutrition major

In addition, some students take it to better prepare for Math 214, Calculus for Business and Economics.

In a study that extended from Spring 2005 through Fall 2009, it was found that 186 students attempted the Math 103 course, of which 129 were declared science majors (some nutrition, some required to take Math 210). Of the 186, there were 137 that ended the course with a grade of C- or better, which would allow them to enter Math 210. Of these, 19 successfully completed Math 210 with a grade of C- or better (including 3 A's), 6 more had a grade of some sort of D, which may have satisfied their major requirement. Of those, only 4 went on to successfully complete Math 211 with a grade of C- or better. In addition, there were 6 who went from Math 103 to Math 214 and successfully completed that course with a grade of C- or better (including 2 A's).

This is the data. We have not yet had time to decide what it means or what we should do about it. The effectiveness of Math 103 seems questionable when almost 74% of the Math 103 class completed the course successfully, but only 14% of those successfully completed Math 210.

Quality: In meaning of the degree student learning outcomes and curriculum matrixes were used to define the degree. Now please describe the processes used to ensure the quality of the program.

1. Describe the practices which enrich the learning experiences such as co-curricular experiences (How are they integrated in the curriculum? Are they assessed?)
   a. Service learning
   b. Research opportunities
   c. Internships
   d. High-impact practices

2. Co-curricular: How intentional are the co-curricular experiences offered by student affairs and how are they integrated into the curricular plan?
   a. Academic and career advising programs and resources
   b. Tutoring, supplemental instruction, and teaching assistants
   c. Orientation and transition programs
   d. Financial support for obtaining scholarships, fellowships, teaching assistantships, etc.
   e. Support for engagement in the campus community
   f. Support for emotional and psychological variables of success
   g. Spiritual development programs and opportunities
   h. Multicultural opportunities which support diversity
   i. Plays, musicals, art exhibits, and lectures
   j. the Sophomore Experience
   k. Study Abroad

3. What is the profile of students in the program and how does the profile relate to or enhance the purpose and goals of the program?

   Please explain your student success data (enrollment and retention data). Evidence should include student retention and graduation rate trends (disaggregated by different demographic categories such as race, gender, first-generation students, etc.).

   OIE provides this data annually and houses the reports on the OIE website and LiveText site.

4. Please present your student and alumni survey data examining student attitudes, satisfaction levels and dispositions. OIE will provide the data in tables and graphs in their Educational Effectiveness Report. Programs are responsible for explaining the survey results. Survey data includes: UCLA/CIRP satisfaction survey data, alumni data.

5. Please describe evidence of students' research and publications, awards and recognition, professional accomplishments

Integrity: In meaning of the degree (#1) student learning outcomes and curriculum matrixes were used to define the degree. Now please describe the processes used to ensure the rigor of the program.

6. Are the graduates achieving the student learning outcomes at the expected level? How was the

threshold determined? How do you know your expectations are appropriate? Do you use comparisons based on national standards or benchmarking? How have your assessment findings supported this?

7. Is there assurance that students consistently meet the standards of performance that the major has established? What happens to students that don't meet the standards?

8. Please present an integrated analysis of the data collected from the assessment of direct learning and indirect learning (survey data, focus group, alumni data, and authentic evidence). Please report on the findings from the last comprehensive program review. In summary please explain how the program has achieved a holistic evaluation of the students' educational experience.

9. How does the program ensure that graduates meet the WASC FIVE CORE COMPETENCIES? Present your findings of measurements you have done of the core competencies (may be less than 5).

Faculty:
The math faculty as of December 2015 include 8 regular (tenured or tenure track) faculty, including one joint appointment with Great Books (Don Thompson) and one Associate Dean (Kendra Killpatrick). There was 1 visiting (non-tenure-track) faculty. There is also one faculty (Eric Hamilton) from GSEP (Pepperdine's Graduate School of Education and Psychology) who taught one course in the Fall. Sometimes adjunct professors are hired to cover courses. One adjunct professor was hired in the Fall of 2015 to teach one class.

The faculty members in the math discipline are active in one or more of the major mathematics organizations such as the American Mathematics Society (AMS), the Mathematical Association of America (MAA), the Society for Industrial and Applied Mathematics (SIAM), and others.

Joshua Bowman
Assistant Professor of Mathematics (tenure track)
Ph.D. Mathematics, Cornell University 2009
Research field: Dynamical systems

Courtney Davis
Assistant Professor of Mathematics (tenure track)
Ph.D. Mathematics, Univ. Utah 2010
Research field: Mathematical Biology

Eric Hamilton
Professor of Education (at GSEP, tenured)
Ph.D. Mathematics, Northwestern
Research field: Mathematics Education

Don Hancock
Professor of Mathematics (tenured)
Ph.D. Mathematics, UC Santa Barbara 1979

Research Field: Real Analysis
Howard A. White Teaching Award 2015

Kevin Iga
Professor of Mathematics (tenured)
Ph.D. Mathematics, Stanford Univ. 1998
Research field: Differential Topology and Mathematical Physics

Kendra Killpatrick
Professor of Mathematics (tenured)
Associate Dean 2015–present
Ph.D. Mathematics, University of Minnesota 1998
Research field: Combinatorics
Howard A. White Teaching Award 2005
AMS Programs that Make A Difference 2015 (for PCUMC conference)
Seaver Regents Program director
Associate Director, Budapest Semesters in Mathematics

Timothy Lucas
Associate Professor of Mathematics (tenured)
Ph.D. Mathematics, Duke University 2006
Research field: Mathematical Biology

David Strong
Professor of Mathematics (tenured)
Ph.D. Mathematics, UCLA 1997
Research Field: Numerical methods in Linear Algebra

Don Thompson
Professor of Mathematics and Great Books (joint appointment) (tenured)
Ph.D. Mathematics, Univ. Arizona 1979
Visiting scientist at Hughes Research Laboratories
Research field: Applied Mathematics, Great Books, Vocation

Elizabeth Thoren
Visiting Professor of Mathematics (non-tenure-track)
Ph.D. Mathematics, UT Austin 2009
Research field: Mathematics Education

Facilities – describe adequacy of the following:
The Natural Science Division at Seaver College is housed in two main areas, the first to fourth floors of the Keck Science Center (KSC) and the first floor of the Rockwell Academic Center (RAC). The total space allocated to the division is 39,037.5 ft^2, and square footage within this space includes offices for faculty and staff, storage areas, support facilities, research and teaching laboratories, and classrooms. There is no immediate space allocated specifically for studying by students, but students are allowed access to

empty classrooms during the day as well as the RAC lobby, which is decorated with adequate furnishings. In addition, students are in easy walking distance to the Payson Library.

Of the space allocated to the Natural Science Division, 943 ft^2 is used for the main office, stockroom, and tech support. In addition, there is approximately 1,401 ft^2 that includes space for office equipment, a break room, adjunct office space, a conference room, and the lobby. Storage space consist of 1,159 ft^2. In addition, approximately 1,751 ft^2 is used for a vivarium, autoclaves, the stockroom, a cold room, chemical storage, and washroom.

Classrooms for all courses taught by programs in the division are scheduled by the Office Administrator of the Natural Science Division. Currently, the division has access to 9,801.5 ft^2 that is used as classroom space, with classrooms distributed throughout the RAC, KSC, CAC (Cultural Arts Center), and the Plaza. In addition, PLC102, a classroom adjacent to the Payson Library, is used to teach several classes in mathematics. The following is a list of classrooms by student capacity: 1) 50 students – Plaza 188 and KSC 130; 2) 30 students – CAC 124, CAC 125, and RAC 175; 3) 24 students – KSC 100, KSC 110, RAC 170; 4) 16-22 students – KSC 210, KSC 300, KSC 320, KSC 360, RAC 138, RAC 178. Four (KSC 210, KSC 300, KSC 320, KSC 360) of these classrooms are used as teaching laboratories as well as classrooms.

Faculty members have assigned lab space that is used for both research and teaching. Programs most of the laboratory space include Biology, Chemistry, Physics, and Sports Medicine. Collectively, this amounts to approximately 9,788 ft^2. Laboratory space utilized primarily for teaching includes 14,956 ft^2.
Office space for faculty is located in the RAC and totals 4,240 ft^2. In addition, one visiting professor in mathematics and the Coordinator of Nutrition's post-baccalaureate program for students interested in becoming Registered Dietitians.

Office Space for Mathematics

RAC 105	132.00	Lucas Office
RAC 144	125.00	Bowman Office
RAC 115	108.00	Hancock Office
RAC 116	132.00	Strong Office
RAC 118	126.00	C. Davis Office
RAC 121	120.00	Thompson Office
RAC 124	135.00	Killpatrick Office
RAC 129	94.50	Iga Office
Total	972.50	

Graduates of the program serve as high school teachers, have careers in industry, or are graduate school students oftentimes serving as teaching assistants. Faculty and majors have participated in math or science nights at some local schools. Some of the math faculty members have served as MAA officers or committee members, leaders in the Semester in Budapest program, and as referees for journal papers.

f. Faculty review and evaluation process
All fulltime and visiting faculty in the Natural Science Division are asked to complete an Annual Faculty Activity Form. This form asks each member of the faculty to outline his or her activities in the areas of scholarship, teaching, and service. The Divisional Dean of the Natural Science Division reviews each of these annual reports and assesses student teaching evaluations of courses taught by each member of the faculty. After evaluating each report, the Divisional Dean provides written feedback of the faculty member's teaching and achievement, and the faculty member is asked to provide any written comments related to the evaluation. In addition, the Divisional Dean has one on one conversations with any faculty member needing further follow-up to the evaluation.

For fulltime members of the faculty, each rank (e.g. Assistant, Associate, and Full Professor) has three steps. Based on information related to a faculty member's scholarship, teaching, and service, the Divisional Dean can recommend a step increase within a particular rank to the Dean of Seaver College, who makes the final decision regarding the step increase. Promotion to a higher rank, such as Assistant Professor to Associate Professor or Associate Professor to Full Professor, requires an evaluation by the Rank, Tenure, and Promotion (RTP) Committee, which consists of voting tenured representatives from each division in Seaver College as well as a non-tenured professor. For promotion in rank, the faculty member must provide information on Teaching Effectiveness, Scholarly Activity, and Service (professional, university, division, community). With the approval of the Divisional Dean, the candidate for promotion is asked to designate five peer reviewers, who will be asked to evaluate the information provided by the candidate. Each of these designated reviewers will provide a formally written response to each of the major categories, and the Divisional Dean will provide an independent response that includes details of the faculty member's teaching evaluations submitted by students. The RTP committee evaluates the evidence and makes a recommendation to the Dean of Seaver College, who has independently evaluated all of the evidence submitted on behalf of the candidate. The Dean's recommendation is then sent to the Provost and President.

The above outlined procedure is basically the same used for an individual submitting for tenure and promotion. All members of the faculty considered tenure-track receive a pre-tenure review that uses the same criteria as those outlined for tenure and promotion. This review occurs mid-tenure and is designed to provide constructive feedback concerning teaching, scholarship, and service. It also allows for the college to determine whether or not the faculty member should continue. If the evaluation suggests no reappointment, the faculty member is allowed to stay the following year prior to termination. If the reappointment is approved, the Divisional Dean and faculty member will go over the RTP report and decide the best course of action to address any identified weaknesses.

After tenure, each member of the faculty receives a five-year evaluation. The basic procedures are similar to those outlined for tenure and promotion, except only three designated peer reviewers are required. The RTP committee makes a recommendation to the Dean of Seaver College, and the Dean decides the appropriate merit raised based on the outcome of the evaluation.

Appendix: 2010 proposal for curricular revision (abridged)

Proposal for Adoption
Seaver College Academic Council

I. NATURE OF THE REQUEST: Revision of the requirements for the Bachelor of Arts in Mathematics Education, Bachelor of Science Degree in Mathematics, Mathematics Minor and Applied Mathematics Minor.

II. BE IT MOVED:

That page(s) 311-314 of the Seaver College catalog be changed as follows: [all deleted material to be stricken through; all added material to be underlined.]

Bachelor of Arts in Mathematics Education and Bachelor of Science in Mathematics

The courses in mathematics are designed to:

- Provide an opportunity for liberal arts students to explore the nature of mathematics.
- Provide specialized training for various scientists who will use mathematics as a tool.
- Prepare the mathematics major for employment in industry, teaching, or admission to graduate school.
- Provide information about modern mathematics as a dynamic and creative field with applications in business and in the physical, biological, and social sciences.

To enroll in any mathematics course which lists prerequisite courses, a student must earn a grade of "C-" or above in all mathematics prerequisites. A student may not enroll in a mathematics course that is a prerequisite for another mathematics course for which credit has already been received.

Course Requirements—Bachelor of Arts in Mathematics Education

~~A student must earn a grade of "C-" or better in any courses that are prerequisites for mathematics courses. A student may not enroll in a mathematics course that is a prerequisite for one for which credit has already been received.~~

Required Lower-Division Mathematics Courses: ~~18-20~~ 22-25 units

MATH ~~110~~ 130 Colloquium in Mathematics .... (1)
MATH ~~210~~ 150 ~~Analytic Geometry and~~ Calculus I (GE) .... (4)
MATH ~~211~~ 151 ~~Analytic Geometry and~~ Calculus II .... (4)
MATH ~~212~~ 250 ~~Analytic Geometry and~~ Calculus III .... (4)
MATH 260 Linear Algebra .... (4)

Choose one of the following:
PHYS 210 Physics I (GE) (5)
or
CHEM 120 General Chemistry I (GE) (3)
~~**and**~~
CHEM 120L General Chemistry I Lab (GE) (1)
and
CHEM 121 General Chemistry II (3)
CHEM 121L General Chemistry II~~.~~ Lab (1)

Required Upper-Division Mathematics Courses: ~~22-24~~ 19-20 units
~~MATH 330 Linear Algebra (4)~~
MATH ~~360~~ 320 Transition to Abstract Mathematics (WI, RM. PS) (4)
MATH ~~530~~ 370 Real ~~and Complex~~ Analysis I (4)

Choose three of the following:
MATH 316 Biostatistics (GE) (3)
MATH ~~420~~ 325 Mathematics for Secondary Education (4)
MATH 335 Combinatorics (4)
MATH 340 Differential Equations (4)
MATH ~~510~~ 350 Mathematical Probability ~~and Statistics I~~ (4)
MATH 355 Complex Variables (4)
MATH ~~430~~ 380 Algebraic Structures I (4)
MATH ~~511~~ 450 Mathematical ~~Probability and~~ Statistics ~~II.~~ (4)
Note: Students cannot count both MATH 316 and MATH ~~511~~ 450.

Required Teacher Education Courses: 20 units
EDUC 351 Child Development (4)
EDUC 561 The Teaching-Learning Process (4)
EDUC 562 The School and Society (4)
EDUC 564S Reading and Language Arts in Content Areas—Single Subject (4)
EDUC 570 Culture, Language, and Learning (4)

In order to earn a California teaching credential, students will be required to pass the CSET Single Subject Mathematics Exam and complete their student teaching requirement (EDUC 566, EDUC 581, EDUC 582). Students should refer to the Teacher Education Professional Sequence Requirements listed in the Humanities and Teacher Education Division section for further information.

Course Requirements—Bachelor of Science in Mathematics
~~To enroll in any mathematics or computer science course which lists prerequisite courses, a student must earn a grade of "C-" or better in all the prerequisites. A student may not enroll in a mathematics course that is a prerequisite for one for which credit has already been received.~~

~~A mathematics major must complete the following:~~

Lower-Division Courses: ~~26~~ 21 units

COSC 105 Introduction to Programming (3)
MATH ~~110~~ 130 Colloquium in Mathematics (1)
~~MATH 210 Analytic Geometry and Calculus I (GE) (4)~~
MATH ~~211 Analytic Geometry and~~ 151 Calculus II (4)
MATH ~~212 Analytic Geometry and~~ 250 Calculus III (4)
MATH 260 Linear Algebra (4)
PHYS 210 Physics I (GE) (5)
~~PHYS 211 Physics II (5)~~

Upper-Division Courses: ~~27-28~~ 32 units

~~MATH 330 Linear Algebra (4)~~
MATH ~~360~~ 320 Transition to Abstract Mathematics (WI, RM, PS) (4)
MATH 340 Differential Equations (4)
MATH ~~430~~ 380 Algebraic Structures I (4)
~~MATH 431 Algebraic Structures II (4)~~
MATH ~~530~~ 370 Real ~~and Complex~~ Analysis I (4)
~~Choose two additional upper-level mathematics courses with the approval of the advisor. Most of the upper-division courses will be offered on an alternate-year basis. (7-8)~~

Choose four of the following courses, at least one of which must be at the 400 level:

MATH ~~420~~ 325 ~~Foundations of Mathematics~~ Mathematics for Secondary Education (4)
MATH 335 Combinatorics (4)
~~MATH 340 Differential Equations (4)~~
MATH 345 Numerical Methods (4)
~~MATH 420 Foundations of Mathematics (4)~~
MATH ~~510~~ 350 Mathematical Probability ~~and Statistics I~~ (4)
MATH 355 Complex Variables (4)
MATH 365 Automata Theory (4)
MATH 440 Partial Differential Equations (4)
MATH ~~511~~ 450 Mathematical ~~Probability and~~ Statistics ~~II.~~ (4)
MATH ~~530~~ 470 Real ~~and Complex~~ Analysis II (4)
MATH ~~431~~ 480 Algebraic Structures II (4)
~~MATH 540 Introduction to Numerical Analysis (4)~~

~~Freshman~~ First Year Program

The mathematics major ~~(B.A. or B.S.)~~ should enroll in the general education program and include MATH ~~110~~ 130~~,~~ ~~MATH 210,~~ and MATH ~~211~~ 151 or MATH 250 in the ~~freshman~~ first year.

International Programs

Mathematics students wishing to participate in the international programs are advised to do so during the summer term.

Mathematics Minor

Six courses are required:
MATH ~~210~~ 150 ~~Analytic Geometry and~~ Calculus I (GE) .... (4)
MATH ~~211~~ 151 ~~Analytic Geometry and~~ Calculus II .... (4)
MATH 250 Calculus III .... (4)
MATH ~~360~~ 320 Transition to Abstract Mathematics .... (4)

~~**Choose one of the following:**~~
~~MATH 212 Analytic Geometry and Calculus III .... (4)~~
~~MATH 330 Linear Algebra .... (4)~~

Choose two additional upper-division of the following:
MATH ~~420~~ 325 ~~Foundations of Mathematics~~ Mathematics for Secondary Education .... (4)
MATH 335 Combinatorics .... (4)
MATH 340 Differential Equations .... (4)
MATH 345 Numerical Methods .... (4)
~~MATH 420 Foundations of Mathematics .... (4)~~
MATH ~~510~~ 350 Mathematical Probability ~~and Statistics I~~ .... (4)
MATH 355 Complex Variables .... (4)
MATH 365 Automata Theory .... (4)
MATH ~~530~~ 370 Real ~~and Complex~~ Analysis I .... (4)
MATH ~~430~~ 380 Algebraic Structures I .... (4)
MATH 440 Partial Differential Equations .... (4)
MATH ~~511~~ 450 Mathematical ~~Probability and~~ Statistics ~~II.~~ .... (4)
MATH ~~530~~ 470 Real ~~and Complex~~ Analysis II .... (4)
MATH ~~431~~ 480 Algebraic Structures II .... (4)
~~MATH 540 Introduction to Numerical Analysis .... (4)~~

The Math Minor is not available for the Computer Science/Mathematics Major.

Applied Mathematics Minor

Required courses: 23 units
MATH ~~210~~, ~~211~~, ~~212~~ 150, 151, 250 Calculus I, II, III (GE) .... (4,4,4)
MATH ~~330~~ 260 Linear Algebra .... (4)
MATH 316 Biostatistics (GE) .... (3)
MATH 340 Differential Equations .... (4)

The Applied Math Minor is not available for the Computer Science/Mathematics Major.

Note: For Economics majors and minors, ECON 310 may be substituted for MATH 316.

Brief background:
Over the years, mathematics courses have been added, deleted, or modified in response to changing student backgrounds, student needs, and national developments in mathematics. We have also added an additional major, the Math Education major, as well as an additional minor, the Applied Math minor. However, the curriculum as a whole has not essentially changed since it was transported from the Vermont campus.

The proposed revisions are required to bring the mathematics into alignment with curricula at peer institutions and congruence with recommendations from professional associations. Further, the proposed changes are responsive to feedback from graduates and alumni and increase scheduling flexibility for students as they progress through the mathematics major. Most importantly, the curricular revisions will better prepare our students for undergraduate research, careers and graduate study.

The proposed curricular revision is outlined below.

- Three new courses will be added to the mathematics curriculum.
  - MATH 335 (Combinatorics),
  - MATH 440 Partial Differential Equations, and
  - MATH 470 (Real Analysis II).
- Two courses will be revised to become intermediate level so as to offer students more elective course options.
  - MATH 345 (Numerical Methods)
  - MATH 355 (Complex Variables),
- MATH 340 (Differential Equations) currently an elective course will be required for all mathematics majors.
- The number of upper-division elective courses required of mathematics majors will increase to four courses. To fulfill this requirement and provide students curricular flexibility, four two-semester upper division sequences will be created. (Currently our mathematics majors have a single option for the year-long depth requirement, Algebraic Structures I and II.)
  - MATH 340 Differential Equations, MATH 440 Partial Differential Equations
  - MATH 350 Mathematical Probability, MATH 450 Mathematical Statistics
  - MATH 370 Real Analysis I, MATH 470 Real Analysis II
  - MATH 380 Algebraic Structures I, MATH 480 Algebraic Structures II
- The first mathematics course in the new curriculum will be MATH 151 (Calculus II) since almost all mathematics majors now enter with AP credit for MATH 150 (Calculus II).
- Students will no longer be required to take PHYS 211 because they will see many applications of mathematics in MATH 340 (Differential Equations).

As noted briefly in the introduction, we propose these curricular modifications for several reasons. We expand on each of these rationale in the following sections.

Recommendations from the Mathematical Association of America (MAA):
According to a survey of 102 mathematics graduate programs (Survey on Preparation for Graduate School, FOCUS newsletter of the Mathematical Association of America, Volume 8, No. 4, September 1988) the two most important courses for those planning on graduate study in mathematics are a second semester of Real Analysis and a course on Partial Differential Equations. Neither of these courses has been offered at Pepperdine. The third most important course recommended by the MAA was Differential Equations which is currently an elective. *The proposed curricular add new courses in both Real Analysis and a course on Partial Differential Equations.*

Response to feedback from graduates and alumni:
As a component of our ongoing program review, we have regularly surveyed mathematics graduates and alumni. In 2009 we administered an on-line survey to all former mathematics majors who graduated between 1998 and 2008. Additionally, we have surveyed all graduating seniors from 1997. The results of both of these surveys have been carefully studied by the mathematics faculty and have played a large role in shaping the proposed new mathematics program.

One of the most useful questions on the alumni survey asked each student to provide 3 specific recommendations as to how the Pepperdine mathematics program could be improved. The major areas of alumni concern are listed below. All of these areas of concern are addressed by the proposed curricular revision.

1. Widen the range of courses offered (including adding advanced analysis or topology, combinatorics, and more applied courses);
2. Offer a pure and applied emphasis within the major; and
3. Allow for more flexibility in the required courses (such as allowing Algebraic Structures II to be replaced by a second semester of probability/statistics).

In addition to the recommendations made by the alumni, recent senior surveys have noted some additional concerns:

1. Drop the second semester of physics as a requirement;
2. Enhance the use of computers within the major, and
3. Reduce the Algebraic Structures requirement to one semester.

Our revisions to the program respond to all the primary concerns of the alumni and recent graduates.

Comparison of current and proposed curriculum to that of our peers:
Our proposed changes will help to bring Pepperdine's mathematics program more in line with those at our peer and aspirational schools. Partial Differential Equations is taught at all 8 of our peer and aspirational schools. Real Analysis II and Combinatorics are both taught at 7 of the 8 peer schools. Indeed, all three courses are regularly taught at most American colleges. We note that there are still other

courses that are regular parts of many mathematics programs, including most of our peer and aspirational schools, that we are *not* proposing to add to our curriculum.

Increased flexibility for students to complete the major:
There are several significant ways in which the new program offers increased flexibility to students.

- First, there are additional mathematics electives to choose from, such as MATH 335 (Combinatorics), MATH 440 (Partial Differential Equations) and MATH 470 (Real Analysis II).
- Second, there are now more electives, such as MATH 335 (Combinatorics), MATH 345 (Numerical Methods) and MATH 355 (Complex Variables), that can be taken by sophomores rather than just juniors or seniors.
- Third, with the old program the year-long upper level depth requirement could only be satisfied in one way (with the Algebraic Structures I and II sequence), whereas the new program offers three additional choices. In particular, our students will have more freedom in choosing which path to pursue within the major. These paths include pure mathematics, applied and computational mathematics, and probability and statistics. Not only is this attractive to students because they can choose to study areas of mathematics of greatest interest, it also makes it much easier for students to graduate on time. For example, previously, depending on their year of entry, a student not completing Algebraic Structures II by the spring of their junior year could not graduate in less than 5 years. Under the new program, two different staggered year-long sequences will be available every year.

Students who fall behind lack in their degree progress or who enter the major late or attend an international program will now have a much better opportunity to graduate "on time".

Enhanced preparation of students for graduate school and careers:
The additional courses, and the fact that some courses can now be taken earlier, should enable our students to achieve higher scores on the mathematics GRE subject exam. The mathematics alumni survey showed 31% entered graduate school the first year after graduation, but that 89% eventually attended (or still plan to attend) graduate school. As for career preparation, the increased emphasis and availability of applied courses, such as MATH 345 (Numerical Methods) and MATH 440 (Partial Differential Equations, will make it easier for students to directly enter the workforce in mathematics-related fields.

Better preparation for undergraduate research:
The proposed changes to the mathematics major will greatly increase both the preparations of and the opportunities for our students to do undergraduate research. By offering a course in Combinatorics, a mathematical area that is rich in problems that are solvable at the undergraduate level and Dr. Killpatrick's area of expertise, students will be prepared to participate in summer undergraduate

research programs both at Pepperdine and at other institutions. Also traditionally accessible to undergraduates for research are various areas in applied and computational mathematics. By lowering the implied level of courses such as Complex Variables and Numerical Methods, which is part of our renumbering strategy, students will be able to learn that material earlier in their undergraduate career; thus, they will then be prepared at an earlier stage of their studies to undertake undergraduate research in those areas. Also, by requiring all students to take Differential Equations and by offering a new elective in Partial Differential Equations, our students will have more frequent and more valuable experiences in undergraduate research projects in these areas with Dr. Strong and Dr. Lucas**.**

Benefits for Mathematics Minors:
In general, a wider array of mathematics courses will benefit all students from any discipline taking mathematics courses. Students with a mathematics minor will have more courses from which to choose to satisfy the requirements of the minor. Examples of mathematics minors, or other students who simply want more mathematics courses to complement their major, include:

- Chemistry majors, who may benefit from taking Partial Differential Equations
- Economics or finance majors, who may benefit from taking Real Analysis II
- Biology majors, who may benefit from taking Combinatorics

Student recruitment:
With a curriculum offering greater depth and breadth, coupled with enhanced flexibility to aid degree progress, we will likely attract stronger students to Pepperdine to study mathematics and mathematics-related disciplines. Currently, based on both anecdotal evidence and our own assessment of Pepperdine's mathematics curriculum, our current curriculum is lacking and has resulted in high-quality students choosing to study mathematics at other colleges and universities. Our proposed changes should help to reverse this trend.

Renumbering strategy:
We completely redesigned the numbering scheme of the courses to:

1. Align course numbers with their level of difficulty and the year in which students *should* enroll.
2. More explicitly detail the four upper division year-long sequences by numbering both course sequentially (340 & 440; 350 & 450; 370 & 470; and 380 & 480)
3. Remove all 500 level courses.

Change in course descriptions:
All course descriptions were revised. These changes:

1. Allow the course descriptions to more effectively communicate the course content;
2. Provide unique descriptions for both courses in the year-long sequence; and

3. More clearly note our course content for students who may wish to transfer a course from another college.

Frequency of Course Offerings:
Lower division courses for mathematics majors and minors will continue to be offered every semester with the exception of Linear Algebra which is offered only in the Fall. Among the upper division courses, MATH 316 Biostatistics will continue to be offered every semester, while MATH 320 Transitions to Abstract Mathematics and MATH 340 Differential Equations will continue to be offered every spring. All other upper division courses will be offered once every other year as demonstrated in the following sample schedule.

Fall 2011		Spring 2012		Fall 2012		Spring 2013	
260	Linear Algebra	320	Transition to Abstract Mathematics	260	Linear Algebra	320	Transition to Abstract Mathematics
325	Mathematics for Secondary Education	340	Differential Equations	440	Partial Differential Equations	340	Differential Equations
380	Algebraic Structures	345	Numerical Methods	370	Real Analysis I	470	Real Analysis II
350	Mathematical Probability	450	Mathematical Statistics	335	Combinatoric s	355	Complex Variables

Possible student schedules depending on interest:
As described previously students will choose at least one of four two-semester upper-division sequences. Below are four sample schedules for students whose interests correspond to one of these two-semester sequences (**in bold**). Each schedule contains four upper division electives. Note that students will not take more than two classes for the mathematics major during a semester.

For students interested in Pure Mathematics:

Year	Fall Semester		Spring Semester	
First Year	151	Calculus II (GE)	251 COSC 105	Calculus III Introduction to Programming
Soph.	260 PHYS 210	Linear Algebra Physics I (GE)	320 355	Transition to Abstract Mathematics Complex Variables
Junior	380 350	Algebraic Structures Probability	340	Differential Equations
Senio r	**370** 335	**Real Analysis I** Combinatorics	**470**	**Real Analysis II**

Year	Fall Semester		Spring Semester	
First	151	Calculus II (GE)	251	Calculus III

Year			COSC 105	Introduction to Programming
Soph.	260 PHYS 210	Linear Algebra Physics I (GE)	320 355	Transition to Abstract Mathematics Complex Variables
Junior	380 350	**Algebraic Structures** Probability	480	**Algebraic Structures II** Differential Equations
Senio r	**370** 335	Real Analysis I Combinatorics		

For students interested in Applied Mathematics:

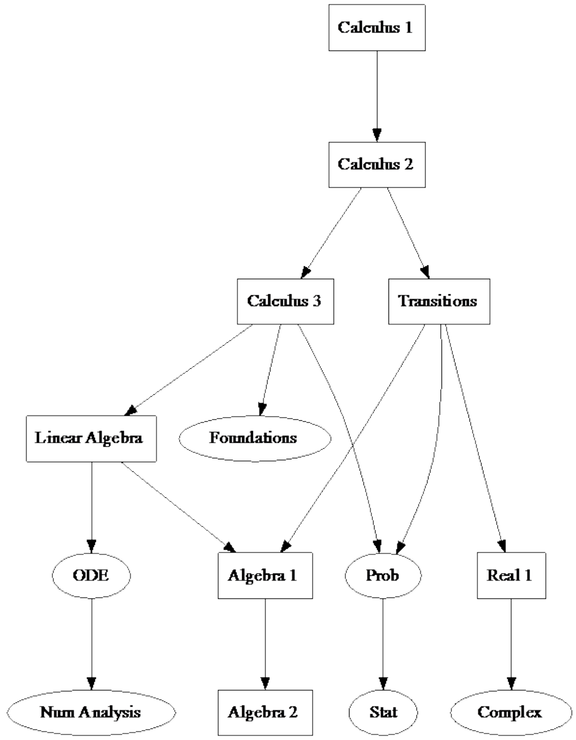
Year	Fall Semester		Spring Semester	
First Year	151	Calculus II (GE)	251 COSC 105	Calculus III Introduction to Programming
Soph.	260 PHYS 210	Linear Algebra Physics I (GE)	320 340	Transition to Abstract Mathematics **Differential Equations**
Junior	380 350	Algebraic Structures Probability	345	Numerical Methods
Senio r	**370** **440**	Real Analysis I **Partial Diff. Eqns.**	355	Complex Variables

For students interested in Probability and Statistics:

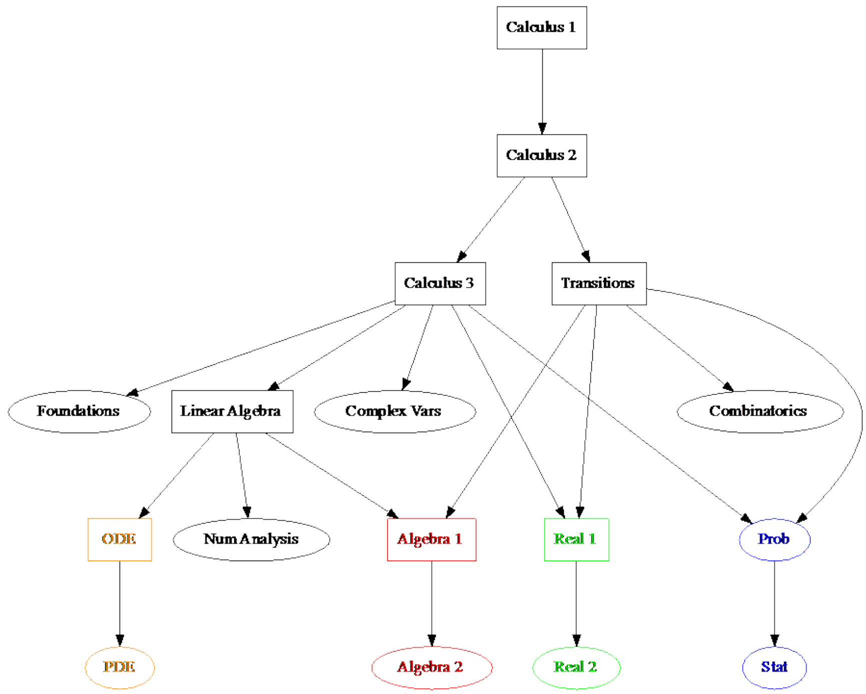
Year	Fall Semester		Spring Semester	
First Year	151	Calculus II (GE)	251 COSC 105	Calculus III Introduction to Programming
Soph.	260 PHYS 210	Linear Algebra Physics I (GE)	320 340	Transition to Abstract Mathematics Differential Equations
Junior	380 **350**	Algebraic Structures **Probability**	450	**Statistics**
Senio r	**370** 335	Real Analysis I Combinatorics	355	Complex Variables

Altered Prerequisite Structure:

Currently, the mathematic curriculum is rigid with a highly prescribed perquisite structure. The current prerequisite structure is shown in the following figure; in this figure, rectangles are required courses and ovals are elective course. As noted in the figure, in the current curriculum, students have limited choices after completing only MATH 212 (Calculus III) and MATH 360 (Transition to Abstract Mathematics).



In the proposed new curriculum (shown below), students will have a wider variety of options after completing only MATH 250 (Calculus III) and MATH 320 (Transition to Abstract Mathematics). There are more upper division electives and four options to fulfill the year-long sequence requirement. In the following diagram, rectangles denote required courses, ovals indicate elective course and hexagons indicate course in one of the four two-semester sequences.



Summary:
In summary, the proposed curriculum enhances the mathematics program in four areas:

Best Practice
The additional courses, MATH 335, MATH 440, MATH 470, are consistent with the recommendations of the Mathematical Association of America. Our proposed changes will help to bring Pepperdine's mathematics program more in line with those at our peer and aspirational schools. We believe that these courses belong to a viable undergraduate mathematics program.

Response to Alumni
Our revisions to the program will respond to the primary concerns of the alumni and recent graduates with respect to breadth and depth of course coverage and flexibility.

Undergraduate Research:
The additional courses in our proposal provide our students with the opportunity to sequentially prepare to carry out undergraduate research with our mathematics faculty.

Student Recruitment
Over the last ten years, we have increasingly attracted a larger population of strong mathematics students. With a curriculum offering greater depth and

breadth, coupled with enhanced flexibility to aid degree progress, we are providing these students with a richer academic experience, thereby preparing them for professional work in the discipline.

V. RELATIONSHIP TO THE CHRISTIAN MISSION OF THE SCHOOL

As a Christian university, Pepperdine University fulfills its Mission by preparing students for lives of purpose, service, and leadership. Seaver College contributes to the fulfillment of the University Mission by developing within its graduating students a number of academic and personal characteristics. These include

- ***The ability to continue the quest for knowledge and insight*** and to adapt to constant changes spurred on by the excitement of discovery and aided by an understanding of the nature and techniques of intellectual research.
- ***The ability to think*** clearly, logically, independently, and critically – to synthesize and integrate knowledge, not simply to accumulate it.
- ***The ability to communicate*** and to understand the communication of others: to read, to listen, to speak, and to write effectively.

The mathematics program described in this proposal is designed to nurture the development and enhance the expression of these traits in its graduates in three ways. First, mathematics is concerned with the ongoing pursuit of truth. At its core, mathematics is a process of discovering and verifying truth. Its methods are based on rigor and the ability, in the words of Descartes, to know "clearly and distinctly". Thus, the study of mathematics prepares its disciples (its students and professors) with the means to continue to search for and apprehend that which is real and true. Accordingly, because the pursuit of truth is a goal of the Christian faith, mathematics follows a Christian path.

Second, the study of mathematics is founded on a metaphysics that is born of logic that is built upon a rigorous foundation of axiomatic and rational discourse. Therefore, mathematics students continually refine their thinking skills, by examining a number of classical mathematical problems, in order to think well. This allows its students to learn to use their minds in order to obey the words of Christ in Matthew 22:37, calling for us to love God with our minds.

Finally, because mathematics, like any discipline, calls for its disciples to learn to communicate its ideas, the study of mathematics calls for the ability to read and understand mathematical works carefully, listen to and speak clearly about mathematical ideas, and to express the findings of mathematical study through the classic methods of proof writing and explication. Thus, mathematics students are able to read and analyze not only mathematical work, but are also given the skills to read and analyze sacred text such as the Bible, thereby providing them with the ability to discern meanings associated with faith.

In these ways, then, the liberal arts discipline of mathematics lies within the center of the academy and at heart of the Christian framework, both of which are celebrated at Pepperdine University and Seaver College.

VII. BUDGETARY REQUIREMENTS

[Specify any impact the proposal may have on the budget such as need for adjunct faculty, new faculty, new operating budget dollars, etc.]

In order to determine the budgetary impact of the proposed curriculum review, we computed the estimated faculty workloads for all courses taught in the proposed revised mathematics curriculum. This information is shown in the following table:

Course Type	Fall Courses	Fall Faculty Workload Units	Spring Courses	Spring Faculty Workload Units	Annual Faculty Workload Units
Lower Division	099 – 1 section 103 – 1 section 104 – 1 section 120 – 5 sections 140 – 5 sections 141 – 4 sections 150 – 2 sections 151 – 1 section 250 – 1 section 270 – 1 section	84	103 – 1 section 120 – 5 sections 130 – 1 section 140 – 3 sections 141 – 5 sections 150 – 1 section 151 – 1 section 250 – 1 section 271 – 1 section	69	153
Upper Division (Odd Years)	260 – 1 section 316 – 1 section 325 – 1 section 350 – 1 section 380 – 1 section	19	316 – 1 section 320 – 1 section 340 – 1 section 345 – 1 section 450 – 1 section	19	38
Upper Division (Even Years)	260 – 1 section 316 – 1 section 335 – 1 section 370 – 1 section 440 – 1 section	19	316 – 1 section 320 – 1 section 340 – 1 section 355 – 1 section 365 – 1 section 470 – 1 section	22	42
Total Units (Odd Years)		103		88	191
Total Units (Even Years)		103		91	194

Presently, the Natural Science Division has 8.17 full-time equivalent faculty in mathematics. Thus, the average workload for mathematics faculty in "odd" years will be 23.4 units (191/8.17) and the average workload for mathematics faculty in "even" years will be 23.8 units (194/8.17). As the contracted workload for all Seaver College faculty is 24 units, the Natural Science Division will be able to implement the proposed curriculum without the need for additional faculty. *The Natural Science Division has adequate staffing to cover all proposed mathematics courses; no additional faculty are required to implement the proposed curriculum.*

Implementation of the proposed mathematics curriculum will require no new instructional resources; thus no additional financial expenses are expected.