

## FACULTY DEVELOPMENT PLAN - 2018

Name  
DEPARTMENT OF MATHEMATICS

### TEACHING

**Self-assessment.** In Winter 2017 I taught one section of Math 313, and one large section of Math 113. I had taught both classes before, although this was the first time I had taught a large section of any course. The section of Math 313 went well; my student ratings were high, and I was able to implement minor tweaks to the course from observations and assessments I had made in previous semesters. Because I had taught this course numerous times, I had a good idea of areas the students were likely to struggle in, and I addressed those areas proactively. For example, I created interactive software files that allowed students the opportunity to explore geometric concepts outside of class, before discussing them in class. I also created extra typed notes which contained fully worked-out solutions to supplemental problems and examples in the course. Students responded favorably to these extra efforts, and indicated they were helpful in the midcourse survey I sent out close to the end of the semester.

The large section course of Math 113 proved to be a bit more challenging. While I did a good job overall (and my student ratings support this), it was a challenge to find ways to keep the students engaged in a class of that size. It also required that I adjusted how I prepared for class each day. When teaching Math 113 previously (a small section) there was much more flexibility in the material I presented in class. When students asked questions it was possible to take slight detours in the discussion to address them. It was also easier to assess when students were understanding the material, and when they were not, by asking careful questions throughout. While I think that the class went well overall, the next time I teach a large section class I would like to focus on ways to engage the students more, and find ways to assess their understanding throughout the lecture in a more effective way.

In Fall 2017 I taught a graduate course, in which I involved the students by having them present topics from the course. These topics were sometimes ones that were included in the learning outcomes, but other times were ones the students selected out of their own interest. Students responded favorably to this structure, and reported a positive experience in their student evaluations.

Finally, in Winter 2018 I taught two sections of Math 290, which introduces students to logic and formal proofs. The challenge I found with this course was again finding ways to actively engage students during class time. I encouraged participation by giving students proofs to work on, before having them propose their solutions to the class. When working on proofs together, I always asked for students to suggest possible strategies, which we then followed to complete the

problem. While this helped involve the students, I feel that there may be more creative ways to create an active learning in that course.

### Teaching Goals.

- (1) Before each semester, carefully craft course plans for each class I am teaching, identifying specific course objectives and learning outcomes, and ensure that the lectures that semester follow these plans.
- (2) Identify one or two new ideas per semester which can be implemented during the semester to better foster active learning and participation in class.
- (3) For each new course component implemented, ask for student feedback in the middle of the semester using the MidCourse Evaluation website, to assess its effectiveness.
- (4) When teaching another large section course, contact more experienced instructors to discuss strategies for increasing student participation in class, as well as more effective means to assess students' understanding. The semester before I teach, attend a few large section classes taught by successful instructors to glean strategies and ideas.

### SCHOLARSHIP

**Self-assessment.** 2017-2018 was a good year for research. As a visiting faculty member until 2017, my future employment plans made it look likely that I would be leaving academia and finding a job in private industry. Because of this my research focus shifted in 2016 to more applied topics in machine learning and data science, and less time was spent working on research in topology. This in turn meant that I had less projects coming to fruition in 2017-2018 as a result. Despite this, my new focus on machine learning has proven to be quite beneficial, as it has allowed me to apply new tools to studying topological problems, and has opened up a new line of research which I am very excited about. It has also given me an avenue to participate in very interesting research with undergraduates. One of the downsides is that this research has also required a large investment of time to scale up. While I believe that these efforts will pay off with interesting research and results, they did represent a considerable investment of time.

I had some definite research successes in 2017 and 2018. I began and completed a new project with Seungwon Kim on immersed Mobius bands in the complements of knots, and representability of  $\mathbb{Z}_2$  homology classes in orientable manifolds. I also began a promising project with Nick Castro on using trisections of 4-manifolds to construct branched coverings over  $S^4$ . While this is an ongoing project, I am confident it will yield interesting results. There are a few other projects in various stages of development that also came about in 2017 (quasipositivity detection, isotopy of simple surface braids, and using annular Khovanov homology to find counterexamples to the generalized slice ribbon conjecture, to name a few). Another exciting problem that I began working on in 2018 with Seungwon Kim and Maggie Miller was to prove that all Gluck twists on  $S^4$  are standard, using recent work on the 4-dimensional unknotting conjecture.

One of the things I have realized throughout this past year is the importance of fostering collaborative relationships with other topologists. I have also realized the importance of spending time developing research at all levels throughout the year.

Often I find that I become so involved in solving a single problem, or writing up a result, that I neglect the process of finding new problems and working on projects that are in earlier stages of development.

I also spent a good deal of time working with undergraduates in research. While it was generally a very positive experience, I think we struggled to find good problems for the students to work on. I tried to give the students a lot of freedom to select problems which they found interesting, and would be motivated by. While my intention was to help them find projects that they would be motivated to work on and feel a sense of ownership of, it seemed to result in them finding problems which were disconnected from my main research and expertise. This meant that I was not able to provide as much help and guidance as I would have liked in the research process. We also ended up getting bogged down in technical issues, such as gathering, cleaning, and formatting data, and did not spend as much time on implementing and understanding algorithms. From this I have learned that when working with undergraduates I need to direct them to problems that are directly connected to things I am working on in my research, so that I can offer more guidance and expertise.

**Scholarship Plans.** The underlying theme of my scholarship activities during the next 18 months will be to understand knotted curves and surfaces in 3- and 4-manifolds, and related applications to problems in low-dimensional topology. This work will be divided into three main streams. The first will be understanding knotted surfaces in 4-manifolds, in particular knotted spheres in  $\mathbb{C}\mathbb{P}^2$ . These spheres are directly related to Gluck twists and exotic 4-spheres, and hence provide a way to study the smooth 4-dimensional Poincaré conjecture. In recent work my collaborators and I reduced the Gluck conjecture to a question about ribbon surfaces in  $\mathbb{C}\mathbb{P}^2$ , which provides a new path towards proving the conjecture. We will continue to attack this problem, by focusing on interesting subclasses of surface knots, and developing tools to handle the general case.

The second stream of scholarly activities will be understanding knotted curves in 3-manifolds. This research will focus on understanding quasipositivity, and detecting it from a given braid representative of a knot. Algorithms to do this are known in the special case of 3-strand braids, though none is known for general  $n$ -strand braids. In earlier work I conjectured that such an algorithm can be found using the Dehornoy ordering on the braid group. I will continue to work to develop this algorithm, attempting to prove that it indeed detects positive band factorizations in a given braid work.

My third and final stream of scholarly activities will be to apply techniques and algorithms from reinforcement learning to problems in low-dimensional topology. I have already had success applying techniques of machine learning to computing knot invariants. In my current work I am trying to train reinforcement learning algorithms to construct explicit solutions to certain problems, including finding minimal genus slice surfaces. Other natural problems to study using this approach involve finding sequences of Reidemeister moves between two given knot projections, and the related problem of finding Kirby moves between diagrams of 3- and 4-manifolds. Success in applying reinforcement learning algorithms to the latter problem would be very practical, providing a tool for researchers to quickly find diffeomorphisms between manifolds presented by different diagrams. I will continue to involve undergraduates as I pursue this program of research.

**Scholarship Goals.**

- (1) Schedule and spend 30 minutes to 1 hour each day during Fall and Winter, and 2 hours in Spring and Summer performing research at the following levels:
  - (a) Early stage research - reading new research papers, discussing problems with colleagues, looking for interesting questions.
  - (b) Mid stage research - working directly on solving a problem identified in the previous stage, coding algorithms, etc.
  - (c) Final stage research - writing research papers, submitting papers to journals, etc.
- (2) At each conference I attend, identify one new research idea (which may be vague initially) and one person I can speak to about it at the conference, in the hopes of starting a new research collaboration. Discussions will focus on whether my techniques can be used to solve problems they are thinking about, or whether their techniques can be applied to answer questions I am interested in.
- (3) Select problems for undergraduate research that have a clear connection to my own research, and which either supplement or are supported by the research I am doing independently.
- (4) Give four to six talks this year, either in seminars, conferences, or AMS meetings.

**CITIZENSHIP**

**Self-assessment.** During 2017 and 2018 I had several service assignments in the Mathematics Department. During Winter 2017 I was the coordinator for Math 313, and was additionally responsible for coordinating the exams (formatting and processing them for electronic tablet grading). In May 2017 I was then assigned to the Calculus Committee, where I assisted in redesigning the calculus courses, which included implementing new online homework, new content, and a new schedule. This also involved spending considerable time coordinating and processing exams.

I also tried to support the department in a number of other areas. For example, I prepared and gave talks at the Timpview High School Career Fair, the BYU Math High School Banquet, the BYU Summer Math Camp, BYU Math Undergraduate Banquet, as well as teaching Math Circles several times. I served as the BYU Data Science Club faculty advisor (and spoke at their meeting), wrote and graded the topology PhD qualifying exams, served as a judge during the annual CPMS Student Research Conference, co-organized and ran the TA training for incoming graduate TAs, and organized the department writing group.

Additionally I have been involved as a referee and reviewer for Mathematical Reviews. I was involved in planning a conference in May 2018, and have begun work on organizing a different one in 2019.

**Citizenship Goals.**

- (1) Make plans to organize another conference or AMS special session, beyond the two conferences I'll be working on in 2018 and 2019.
- (2) Schedule 1 hour each week to performing professional service, such as refereeing or reviewing a paper, or organizing one of conferences mentioned above.

- (3) Continue to assist the Mathematics Department where needed, including assisting with the overhaul of Math 313.

# Learning Centered Syllabus

Math 290: Fundamentals of Mathematics  
Sections 1 and 2  
Syllabus: Winter 2018

**Instructor:** Name  
**Office:** 324 TMCB  
**Phone:** 801-422-7416  
**Email:** [hughes@mathematics.byu.edu](mailto:hughes@mathematics.byu.edu)  
**Office Hours:** TBA

**Class Time:**  
Section 1 - MWF 9:00am – 9:50am  
Section 2 - MWF 10:00am – 10:50am

**Location:** TMCB 136

**Text:** *A Transition to Advanced Mathematics* by Darrin Doud and Pace Nielsen, available for free download at <https://math.byu.edu/~doud/Transition/>.

**Prerequisite:** Successful completion of Math 112 or its equivalent with a grade of C- or better or concurrent enrollment.

**Course Purpose:** Students will become fluent in the language of logic and proof, allowing them to approach a variety of mathematical and real-world problems. In the process they will learn to reason logically through mathematical problems, re-evaluating and altering their approaches when necessary.

**Core Learning Objectives:**

1. Student will be able to analyze and interpret mathematical and logical statements.
2. Students will be able to make sound logical deductions from clear premises.
3. Students will be able to plan, structure, and write clear and concise proofs of basic statements in set theory, number theory, and real analysis.

**Schedule:** See the last page of the syllabus for the course schedule.

**Assessment:** We will participate in a number of activities to assess your understanding of the content and ideas throughout the course of the semester. Some of these activities will be used to determine your grade at the end of the course, while other activities will be used to help me assess your understanding so that I can tailor the course to the needs of the students. Ungraded assessments will consist of pre-lecture reading quizzes and classroom activities, while graded assessments will consist of homework assignments, midterms, and the final exam.

**Pre-lecture Quizzes:** Students will be responsible for reading the textbook section before class each day, and answering a short quiz on Learning Suite before attending class so that I can identify areas which may need special attention in class. While your performance on these

quizzes will not directly factor into your final grade, students who complete 90% of the quizzes will have 2 extra lowest scoring homework assignments dropped from their final grade.

**Classroom Activities:** Classroom activities will consist of reviewing material from the readings as a class, paying special attention to areas which cause difficulty on the pre-lecture reading quiz. We will then extend the ideas in the reading, with further examples and applications. Students will work individually, in groups, and together as a class to solve these additional examples. Students will often be invited to present their solution to the class, and classmates will be given the opportunity to solicit feedback from their fellow classmates on their solutions.

**Homework:** Daily homework will be assigned, which will be due two days after the class in which the material was covered (for example, questions from the topic covered on Monday will be due the following Wednesday). These assignments will be listed on Learning Suite under the Assignments page, and will be designed to solidify ideas and concepts discussed in class and in the reading assignment.

Homework may be turned in on the due date at 324 TMCB (under the door), and will also be accepted in class. **Hand-written homework is due on the date listed on the schedule before 4:00PM. Typed homework using LaTeX may be submitted electronically via Learning Suite any time before midnight on the due date. Late homework will not be accepted.** The lowest three homework scores will not be figured into your final grade. This accommodates for minor illnesses or others disruptions to your regular schedule that might prevent you from turning an assignment in on time.

**Please indicate your section number (01 or 02) at the top of your HW, along with your first and last name, and BYUID.** Solutions should be clearly labeled and in order. The style of your written solutions should be very much like that of a textbook example; solutions should contain enough explanation so that one of your classmates would be able to easily understand what you have done.

You are strongly encouraged to study together and work together on homework assignments. However, you each must submit your own assignment. Everything you turn in should be in your own words and you should thoroughly understand everything you write down. The homework grader will only grade selected exercises. Therefore it is important for you to solve each one.

**LaTeX Typed Homework:** There are multiple programs available for typesetting mathematical expressions. Simple GUI-based formula editors are included with many word processors. However, there are other options as well. Perhaps the most versatile and widely-used is PDFLaTeX, which compiles a LaTeX script into a PDF file (similar to the way a web browser takes an HTML document and displays a web page). This is used not only in mathematics, but many of the physical sciences, engineering, and other fields that involve a fair amount of mathematical expressions. Moreover, there are free, web-based LaTeX compilers (such as ShareLaTeX), which means no special software needs to be installed on your personal computer. As mentioned above, typed homework may be submitted through Learning Suite later than the 4PM deadline for hand-written homework. Note that a scanned copy of hand-written homework does **NOT** qualify for the midnight deadline!

**Midterm Exams:** Three midterm exams will be given during the course. They will be designed to assess your understanding of the material covered in the corresponding chapters of the book. While they will focus on specific chapters, they will be cumulative in the sense that later topics in the book naturally build on earlier chapters. The midterms and final exams will be designed to test problems similar to the homework assignments. In addition, practice midterms and solutions will be distributed roughly a week before each midterm, and the final exam.

There will be three midterm exams on the following dates:

- Midterm I – February 7, 8 (late day on the 9<sup>th</sup>)
- Midterm II – March 7, 8 (late day on the 9<sup>th</sup>)
- Midterm III – April 4, 5 (late day on the 6<sup>th</sup>)

Each midterm will be held in the Testing Center.

**Final Exam:** The final exam will be similar in format to the midterms, and practice final exam. It will be cumulative, but will be weighted more heavily towards sections 32-36 of the textbook. The final exam will be held at

- **Section 1:** Monday April 23, 11:00am-2:00pm in TMCB 136
- **Section 2:** Tuesday April 24, 7:00am-10:00am in TMCB 136

**Grading:** Your final grade will be determined based on the following three weighted components:

35% Homework Assignments and Reading Quizzes  
40% Midterm Exams (3 total)  
25% Final Exam

**Preventing Sexual Harassment:** Title IX of the Education Amendments of 1972 prohibits sex discrimination against any participant in an educational program or activity that receives federal funds. The act is intended to eliminate sex discrimination in education and pertains to admissions, academic and athletic programs, and university-sponsored activities. Title IX also prohibits sexual harassment of students by university employees, other students, and visitors to campus. If you encounter sexual harassment or gender-based discrimination, please talk to your professor; contact the Equal Employment Office at 801-422-5895 or 1-888-238-1062 (24-hours), or <http://www.ethicspoint.com>; or contact the Honor Code Office at 801-422-2847.

**Students with Disabilities:** BYU is committed to providing reasonable accommodation to qualified persons with disabilities. If you have any disability that may adversely affect your success in this course, please contact the University Accessibility Center at 422-2767. Services deemed appropriate will be coordinated with the student and instructor by that office.



## Math 290 Schedule Winter 2017

Date	Lecture	Topic	Homework Due Date
Jan 8, 2018	Section 1	Sets, subsets, and set operations	01/10/18
Jan 10, 2018	Section 2	Products of sets and indexing sets	01/12/18
Jan 12, 2018	Section 3	Statements	01/17/18
Jan 15, 2018	MLK Holiday		
Jan 17, 2018	Section 4	Open Sentences	01/19/18
Jan 19, 2018	Section 5	Multiple quantifiers and negating sentences	01/22/18
Jan 22, 2018	Section 6	Direct Proofs	01/24/18
Jan 24, 2018	Section 7	Contrapositive Proof	01/26/18
Jan 26, 2018	Section 8	Proof by Cases	01/29/18
Jan 29, 2018	Section 9	Proof by Contradiction	01/31/18
Jan 31, 2018	Section 10	Proofs in Set Theory	02/02/18
Feb 2, 2018	Section 11	Existence Proofs and Counterexamples	02/05/18
Feb 5, 2018	Section 12	Set proofs in logic	02/07/18
Feb 7, 2018	Review for Exam		
<b>Exam 1: February 7 to February 8 in Testing Center</b>			
Feb 9, 2018	Section 13	Mathematical Induction	02/12/18
Feb 12, 2018	Section 14	More examples of Induction	02/14/18
Feb 14, 2018	Section 14	Strong Induction	02/16/18
Feb 16, 2018	Section 16	The binomial theorem	02/20/18
Feb 19, 2018	Presidents Day Holiday		
Feb 20, 2018	Section 17	Divisibility	02/21/18
Feb 21, 2018	Section 18	The extended Euclidean algorithm	02/23/18
Feb 23, 2018	Section 19	Prime Numbers	02/26/18
Feb 26, 2018	Section 20	Properties of relations	02/28/18
Feb 28, 2018	Section 21	Equivalence relations	03/02/18
Mar 2, 2018	Section 22	Equivalence classes and partitions	03/05/18
Mar 5, 2018	Section 23	Integers modulo $n$	03/07/18
Mar 7, 2018	Review for Exam 2		
<b>Exam 2: March 7 to March 8 in Testing Center</b>			
Mar 9, 2018	Section 24	Defining functions	03/12/18
Mar 12, 2018	Section 25	Injective and surjective functions	03/14/18
Mar 14, 2018	Section 26	Composition of functions	03/19/18
Mar 16, 2018	Spring Break Holiday		
Mar 19, 2018	Section 27	Additional facts about functions	03/21/18
Mar 21, 2018	Section 28	Definitions regarding cardinality	03/23/18
Mar 23, 2018	Section 29	More examples of countable sets	03/26/18
Mar 26, 2018	Section 30	Uncountable sets	03/28/18
Mar 28, 2018	Section 31	Injections and cardinalities	03/30/18
Mar 30, 2018	Section 32	The Schroder-Bernstein theorem	04/02/18
Apr 2, 2018	Review/Makeup		
Apr 4, 2018	Review for exam		
<b>Exam 3: April 4 to April 5 in Testing Center</b>			
Apr 6, 2018	Section 33	Sequences	04/09/18
Apr 9, 2018	Section 34	Series	04/11/18
Apr 11, 2018	Section 35	Limits of functions	04/13/18
Apr 13, 2018	Section 36	Continuity	04/16/18
Apr 16, 2018	Additional topics/Review		
Apr 18, 2018	Review for Final Exam		

Final Exam in Class at the scheduled time.

## GOALS FOR SECOND SEMESTER TEACHING

Name  
DEPARTMENT OF MATHEMATICS

Goals for second time I teach Math 290.

- (1) For each class session, plan one active learning activity before hand to hold during the lecture. This may include an interactive quiz, breaking into groups to have them strategize about a new type of problem, compare and share work session, etc. These may be short but should engage the students and complement the topics being discussed in class that day.
- (2) Learn all of the students' names within the first week of class.

## TEACHING GRANT PROPOSAL

Name  
DEPARTMENT OF MATHEMATICS

I will spend the \$300 teaching grant on registration fees for the Joint Mathematics Meetings in January 2019. During these meetings I will attend talks and workshops on active learning in mathematics, and apply strategies I learn there in my classes the following semester.

## SCHOLARSHIP STRATEGIES PROJECT

Name  
DEPARTMENT OF MATHEMATICS

**Scholarship Plans.** The underlying theme of my scholarship activities during the next 18 months will be to understand knotted curves and surfaces in 3- and 4-manifolds, and related applications to problems in low-dimensional topology. This work will be divided into three main streams. The first will be understanding knotted surfaces in 4-manifolds, in particular knotted spheres in  $\mathbb{C}\mathbb{P}^2$ . These spheres are directly related to Gluck twists and exotic 4-spheres, and hence provide a way to study the smooth 4-dimensional Poincaré conjecture. In recent work my collaborators and I reduced the Gluck conjecture to a question about ribbon surfaces in  $\mathbb{C}\mathbb{P}^2$ , which provides a new path towards proving the conjecture. We will continue to attack this problem, by focusing on interesting subclasses of surface knots, and developing tools to handle the general case.

The second stream of scholarly activities will be understanding knotted curves in 3-manifolds. This research will focus on understanding quasipositivity, and detecting it from a given braid representative of a knot. Algorithms to do this are known in the special case of 3-strand braids, though none is known for  $n$ -strand braids. In earlier work I conjectured that such an algorithm can be found using the Dehornoy ordering on the braid group. I will continue to work to develop this algorithm, attempting to prove that it indeed detects positive band factorizations in a given braid work.

My third and final stream of scholarly activities will be to apply techniques and algorithms from reinforcement learning to problems in low-dimensional topology. I have already had success applying techniques of machine learning to computing knot invariants. In my current work I am trying to train reinforcement learning algorithms to construct explicit solutions to certain problems, including finding minimal genus slice surfaces. Other natural problems to study using this approach involve finding sequences of Reidemeister moves between two given knot projections, and the related problem of finding Kirby moves between diagrams of 3- and 4-manifolds. Success in applying reinforcement learning algorithms to the latter problem would be very practical, providing a tool for researchers to quickly find diffeomorphisms between manifolds presented by different diagrams. I will continue to involve undergraduates as I pursue this program of research.

### Scholarship Goals - by February 2019.

- (1) Find unknotting strategies for various special classes of knots in  $\mathbb{C}\mathbb{P}^2$  (e.g. roll spun knots).
- (2) Complete the details of the quasipositivity detection algorithm.
- (3) Complete the programming foundations of the Reidemeister sequence construction project, and apply deep Q-learning algorithms toward solving it.
- (4) Form one new research collaboration.

**Scholarship Strategies.**

- (1) Schedule and spend 1.5 hours each week doing research at the following levels:
  - (a) Early stage research - reading new research papers, discussing problems with colleagues, looking for interesting questions.
  - (b) Mid stage research - working directly on solving a problem identified in the previous stage, coding algorithms, etc.
  - (c) Final stage research - writing research papers, submitting papers to journals, etc.
- (2) Begin writing at the beginning of the project, to keep track of ideas and approaches I've tried.
- (3) At each conference I attend, identify one new research idea (which may be vague initially) and one person I can speak to about it at the conference, in the hopes of starting a new research collaboration.
- (4) Select problems for undergraduate research that have a clear connection to my own research, and which either supplement or are supported by the research I am doing independently.
- (5) Give six talks this year, either in seminars, conferences, or AMS meetings.

**Assessment.** I will evaluate my success with these goals by keeping a weekly journal tracking the time I devote to research at these various stages. Following each conference I will record in my research journal brief records of research conversations I had with other people, including ideas we discussed and potential future collaborative projects. These notes will be reviewed regularly to make sure I am engaging in the scholarship strategies outlined above.

## CITIZENSHIP PROJECT PROPOSAL

Name  
DEPARTMENT OF MATHEMATICS

The citizenship goals outlined here are chosen to complement the goals outlined in my Faculty Development Plan.

### **Collaborating with Colleagues Outside of BYU.**

- (1) Make time to attend the weekly “Trisectors” Skype meeting to build collaborative relationships with colleagues outside of BYU.
- (2) Invite one visitor to BYU for a visit during the summer, and at least one during the Fall 2018 semester.

### **Collaborating Teaching Activities.**

- (1) Observe classes from two colleagues who are strong teachers, and discuss teaching strategies with them afterwards.

### **Service Activities.**

- (1) Organize department “Writing Group” for junior faculty to meet weekly to share their writing and feedback on their current research.