As a young student, I found success in one-on-one tutoring. At the time, this gave me the impression I was only a few skill sets (i.e., classroom management and exposition) shy of being an excellent instructor. As inaccurate on many levels as this was, it was the beginning of my journey toward excellence as an instructor. I have since found that this is not necessarily an attainable goal; rather, the willingness to adapt and grow are keys to being an effective instructor.

In the meantime, I have identified a global shift in my approach to teaching that has gradually moved me from a young instructor-center teacher to a classroom leader who empowers students as the focus in the classroom. To learn mathematics, students must do mathematics, so an effective instructor must get the students to actively engage with the course material in as many ways as possible. Section 1 describes my teaching philosophy through the experiences that led me down this path. Section 2 outlines my experience with the science of teaching and learning. Lastly, my plans for growth as a teacher are laid out in Section 3.

## 1 EXPERIENCE: FLEXIBILITY IN PRACTICE

Given a group of people, there are a few distributions one could consider: learning preferences, majors, backgrounds in mathematics, etc. However, there is also a a less tangible quality; every class has its own personality. As a result, one encounters the deeply frustrating reality that given success with methods X, Y and Z in class A, there is no reason to expect success with the same methods in class B. It is extremely difficult to abandon a method that has served you well, so it was with frustration as a young instructor, I admitted the most important skill an effective instructor can develop is the ability to adapt.

For a classroom experience to turn traditional learners into **independent, thoughtful members of the academic community**, the student must be engaged and interacting [4]. With undergraduate students, this is often one of the greatest challenges. Inquiry-based learning (IBL) and the flipped classroom [6, 2] both seek to remedy this. In a flipped classroom, students are responsible for immersing themselves in the material in advance (using online videos, guided lecture notes, etc.), and the class time is spent working through problems with the instructor. Combinations of these two methods in varying degrees have driven my drift toward student-centered instruction.

### 1.1 Classroom Experience

I have had a lot of opportunity to develop and adjust these techniques, teaching at The University of Akron, Indiana University Purdue University Indianapolis (IUPUI), and The University of Arizona (UA) and in my involvement with the NSF GK-12 program. Having taught in several different settings has given me the chance to learn to quickly adapt these techniques as well. Most recently, while maintaining a 3-3 teaching load at the University of Arizona, I have also become adept at adapting while managing time effectively. I will give a few brief examples of my teaching techniques at work. A list of courses for which I was the primary instructor can be found on my CV, but concisely, it ranges rom Intermediate Algebra and Finite Mathematics to various ODE's courses and Real Analysis and all the things in between.

I have been part of a collaborative effort to incorporate MATLAB into Linear Algebra and Differential Equations course. The series of MATLAB projects we have used so far give deep insight into applications and very practical technical skill; they have also been very popular with the students. I have also had the pleasure of **mentoring multiple undergraduate teaching assistants** (UTA's), mentoring multiple graduate teaching assistants (GTA's) and **coordinating the UTA program** for the department.

The most aggressive flipped classroom I've done was a Discrete Mathematics course at IUPUI. For supplemental material, I generated a series of **guided notes** and saw a great deal of success in student outcomes. This course has large sections with roughly 75 students that are a highly diverse in both motivation and background, and despite these challenges, student attitudes about the course were very good at the end of the semester. As described in Section 2.1, I have also been experimenting with **gentler ways to flip the classroom** and have very promising data that seems to validate the benefits of active reading before class.

Besides the flipped classroom, I've also made extensive use of IBL techniques. In Linear Algebra courses, I've found students tend to struggle with the idea of vector subspaces. Armed with only the definition (which is typically algebraic), students in my section **explored the geometry** of various vector subspaces and as a result developed a stronger intuitive sense for what they are and how they are used. Another of my favorite IBL opportunities is the presentation of applications. In a Supplemental Instruction for Precalculus course, we spent the entirety of class time working in groups on sets of practical applications of the material.

Regular, timely, constructive feedback is fundamental to the learning experience. Assessment takes student and instructor time, and if for no other reason than efficiency, **assessment should be a learning experience** as well. To be thoroughly satisfied with my understanding of student development, I need to have a comfortable understanding of each students' **procedural understanding** (row reduce this $n \times n$ matrix), **conceptual understanding** (describe geometrically how this matrix acts on $\mathbb{R}^n$), and their ability to **apply the material** (use this matrix to find a hypersurface that best fits a set of data). Finally, and arguably most importantly, students' ability to effectively communicate the mathematics they have learned must also be assessed. Well-crafted exam and homework questions can assess a couple of these at a time, but mixing up the format of evaluation is key to achieving all of these goals. I like to work in a couple **essay-style questions** or ask for soft "proofs" in assessments; the word "**explain**" at the end of a question can functionally alter an otherwise simple question.

Every course is a story. It is my duty to impress upon students the importance of the material, how it is all tied together, and how it is relevant outside the course. In general, the first five minutes of class recaps **previous material as motivation** for the new material, and the last five minutes set up the "cliff-hanger." If done well, students won't be able to wait until the next lecture and will be compelled to look at the new material in advance. I am consistently surprised how much story continuity can also motivate student attendance. Moreover, leaving them with something to think about can be like a **flipped classroom warmup** for the next class meeting [1]. This too facilitates **group discussion**.

I am currently developing an on-line version of UA's Real Analysis course with Joceline Lega. Making use of the techniques I've gathered in my classroom experience in a **virtual environment** is providing a fun challenge. More information about this can be found in Section 3.

### 1.2 Experience Outside the Classroom

My Teaching Postdoctoral (TPD) position at UA has afforded me many opportunities to grow as an instructor. At UA, the Mathematics Instruction Colloquium has provided a lot of inspiration and literature to guide me. Also at UA, the Center for Retention and Recruitment of Mathematics Teachers has allowed me to **work directly with both pre-service and in-service mathematics educators**. Besides giving an invited lecture at Mathematics Teacher Appreciation Day in Tucson, AZ, I will be conducting a **content-based professional development workshop** for in-service teachers on the connection between visualizing the geometry and manipulating the algebra of conic sections and quadric surfaces.

I spent the 2012-13 year as an NSF **GK-12 Fellow**. The GK-12 program places graduate students working on their research into K-12 classes to introduce students firsthand to modern research. I was placed in a fully IBL 6th grade general science class, and this allowed me to evaluate my teaching skills from a much broader perspective. I was also able to develop my understanding of IBL and how it can be used in mathematics classrooms. I was able to present exponential growth of error to the students in a length measurement lab that also reinforced several aspects of the scientific method. This experience heightened my awareness of my audience and improved my ability to quickly adapt my teaching to suit them as needed. I've spent the last several years practicing the explanation of my research to undergraduates, but after this experience, I am confident that I can explain the function and process of mathematical research to anyone.

### 1.3 Undergraduate Research

I've been very fortunate to lead two very different undergraduate research projects. The first involved complex dynamics in a single variable and was recently submitted for publication. In the other, we are investigating variations of the Ising Model of magnetization from a dynamical/combinatorial point of view.

The details of both of these projects can be found in my research statement. These projects have been very exciting for both the students and myself.

## 2 THE SCIENCE OF TEACHING AND LEARNING

If there is no one consistently successful method of mathematics instruction, where can one turn? Fortunately, (and much to my delight) there is a vast field of research dedicated to this question. Recently, I've been experimenting with ways to deliver the impact of the flipped classroom without the full implementation. The inspiration came from chaotic dynamics: perhaps a small change in instruction can produce large, positive changes in student learning.

### 2.1 Active Reading in Mathematics

A lot of interesting research has been done touting the benefits of **active reading before class** [5, 3]. In spring and summer sections of Linear Algebra, I had the students read the section to be presented the next day, and before each lecture, email me a question about the section. It could have been a conceptual question, perhaps something they didn't quite understand. It could also have been a quiz-style question. The motivation for students is that at least half of my quiz questions came from the questions they generated. Not only did their questions help me make my lectures more focused on what the students needed, there was a noticeable bump in the grades of the students most actively participating that improved over the semester quicker than those who participated less. I will continue to gather data throughout the fall semester.

### 2.2 Communication Skill as a Learning Tool

I recently **submitted an NSF grant proposal** to acquire the funding to develop the University of Arizona Mathematics Department UTA Program into more of an **apprenticeship that focuses on exposition and communication** of mathematics. The hope is that empowering younger undergraduate students with these skills will also impact their academic career as a whole.

## 3 PLANS FOR THE FUTURE

UA has made **internal funding** available for instructors willing to develop on-line versions of their courses. I will also be writing a grant to continue to develop our department's **Real Analysis course for on-line implementation** in Summer 2015. There is a lot of enthusiasm around this project as no upper division School of Science courses at UA have been attempted on-line. Many of our math majors need Real Analysis to graduate, and it is only offered in the fall. This summer offering will provide students who did not pass in the fall (and whose graduation may otherwise be held up) a second chance. This course will feature interactive web-applets, small video lectures, and extensive solutions and explanations for homework exercises.

My active reading program, described in Section 2.1, does demand organization and time to keep track of email interaction with students, especially with more than one class. In a project with an undergraduate student and Joshua Lioi (a fellow TPD), we are designing a web-based interface to facilitate the submission of questions for students. Besides helping students keep their questions organized, this will allow them a better option for typesetting mathematics (like matrices and integrals) and allow more efficient sharing of questions and the ensuing discussions. We hope to have an operational version ready for spring semester.

Besides the perpetual tweaking of strategies I have tried, I have several new classroom strategies I am looking forward to trying. After the success with MATLAB in Linear Algebra and ODEs, I plan to continue experimenting with **Project-based learning**. Specifically, I will be continuing the effort to incorporate MATLAB into other classes. Also, while teaching Real Analysis in Several Variables this spring, I plan to have the students work together (taking turns as brain-stormers, writers, and editors) to generate a comprehensive solution guide to all of the homework problems I assign. Lastly, I've planned for some time to generate a series of videos for a fully **flipped classroom**.

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