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A decade of undergraduate research for all East Tennessee State University mathematics majors

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This paper offers a brief history of an experiment begun in 2002, namely, the institutionalization of undergraduate research (UGR) in the mathematical sciences as a semester-long requirement for *all* mathematics majors at East Tennessee State University, a public, regional school. We describe the early, middle, and later years of this ten-year journey; assessment methods; and other aspects. Technical aspects of the student projects are limited to those in the authors' fields of expertise, as captured by the MSC secondary classifications for this paper.

1. Introduction and overview

East Tennessee State University (ETSU) is a regional, state-supported institution with a current undergraduate and graduate enrollment of 15,133 students. ETSU is managed by the Tennessee Board of Regents, an education system that ranks number six in size at a national level. Over 100 years, ETSU's mission has evolved from serving initially as a normal school into a multifaceted university conferring undergraduate, graduate and professional degrees.

ETSU is located in the eastern part of Tennessee, adjoining the southern Appalachians. The main campus of ETSU is housed in Johnson City, TN, while satellite campuses operate across the tri-cities (Bristol, Johnson City, Kingsport). ETSU is located near the state lines of Tennessee, Virginia, and North Carolina, with some proximity to the state lines of Kentucky, West Virginia, and South Carolina. Approximately 47,000 alumni of ETSU reside within a 100 mile radius of Johnson City (out of 84,000 graduates since 1911). Approximately 70% of the currently enrolled students are from the three neighboring counties (Carter, Sullivan, Washington).

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As of 2011–12, the ETSU student population includes the following demographics: 86% white; 6% black; 3% Asian/Hawaiian/Pacific Islander; 2% Hispanic; 3% other (multiracial or with unknown race). This demographic composition is somewhat consistent with that of the tri-cities region, having a predominantly white population in this part of the state of Tennessee.

The undergraduate population of ETSU (12,539 as of 2011) has a five-year average of 44% male versus 56% female students. The age distribution of the undergraduate body includes three main age cohorts (with average percentages over 2007–11):

age 22 and younger:	64.80%
age 23–24:	10.60%
age 25 and older:	24.80%

The number of undergraduate mathematics majors was 60 in 2002, and has risen to about 100 (an average of 92 students over 2007–11) at the present time.

Faculty expertise in the Department of Mathematics and Statistics (as it is now officially known) was, and continues to be, in discrete mathematics, statistics, and applied mathematics, with undergraduate and graduate (MS) concentrations under consideration in statistics. Faculty research, as measured by publications (if not funded grants), has always been high; when the second author came to ETSU in 2000 and initiated a subscription to MathSciNet, both he and the agent at AMS were surprised to note that we were being charged the second-highest rate in the state, indicating the second-highest volume of published papers per faculty member per year in the state. Since then, we have attracted significant Infrastructure and Research funding from NSF, including the following grants: NSF-STEP ($1M), NSF-ATE (co-PI; $1.2M), NSF-GK12 (co-PI, $3M), NSF-Noyce ($1M), NSF-UBM (2 awards, $750K), NSF-IGMS ($50K), and NSF-REU-RET (4 awards, $1M). Two other REU programs exist on campus, in the biological sciences and physics and astronomy, and the campus-wide involvement of students in undergraduate research, including that by students in the Quillen College of Medicine and Gatton College of Pharmacy, is very high. Additionally, the Honors College of ETSU has an office dedicated to undergraduate research affairs, which fosters creative efforts advancing student knowledge. They promote efforts in composing music, sculpturing, laboratory bench research, and theoretical research. One of the accomplishments of this office is to keep up a number of research discovery positions, funded through a federal work-and-study program. All these components constitute backdrop and context for our experiment.

2. What we replaced

Until 2002, ETSU mathematics majors (in each of four tracks: mathematical sciences, mathematics education, statistics, and quantitative modeling) had always

been required to take a two-credit-hour freshman seminar, MATH 1090, and a two-credit-hour junior seminar, MATH 3090. These courses were consistent with the recommendations in [MAA 2004]. Each of these classes was both oral and writing intensive, and blessed by the University Intensive Course Committee as satisfying the criteria for being labeled thus. They were taught by different faculty, who gave the classes a different slant at each offering, with the common thread being writing assignments and oral presentations. In 2000, Godbole came to ETSU as chair and taught the junior seminar for the first time in 2002 as an undergraduate research class. It made sense for him to do so, given his active involvement in undergraduate research through REU site direction, editorship of the *CUR Quarterly*, etc. It was, moreover, just intended to be a one-semester, one-time variation of a class that had seen many variations. Students in the small class of about 12 students worked in teams with no more than three students, and their work was impressive. In one of the partnerships, Jamie Howard, who went on to get a PhD in mathematics education, and Re'el Street, who obtained an MBA from Georgia Tech, worked on the "chicken king project", an area that has connections to Seymour's second neighborhood conjecture and kings in tournaments, both notions in graph theory. Their work was never published, but it is good enough to be accepted in a medium-level refereed journal. Even the not-so-motivated students in the class did creditable work, and each proved *something* original. It was enough to make one think, particularly while editing *CURQ* articles on how far the reach of undergraduate research could extend.

In 2003 we went to a 120-credit-hour curriculum, and massive curricular changes were made by the departmental curriculum committee headed by Jeff Knisley and Janice Huang. Among many changes:

- the four tracks assumed their present names;
- we eliminated a 6-hour programming (C++) requirement;
- we replaced the freshman seminar MATH 1090 by MATH 2090 (math computing, comprising, at the time, instruction in LaTeX and Maple); and
- we replaced MATH 3090 by MATH 4010 (undergraduate research), the class that we describe in this paper.

The timing of the last move was fortuitous; 2003 was still part of Godbole's honeymoon period, the first new external funding was being obtained, and the department said "yes" to the changes with little protest. The new courses stayed technology intensive (MATH 2090), and oral and writing intensive (MATH 4010), with instructors of record submitting annual reports to the overseeing university committee. Godbole's ability to suggest research projects in statistics/probability, education, discrete math, and analysis helped, and he was able to accommodate a

wide variety of research interests among the students in the first two offerings of the class. He began to give talks at the Joint Mathematics Meetings with titles such as "Undergraduate research for all math majors: feasible or a pipe dream?", which culminated, years later, in [Godbole 2011].

3. Early years

During the first three years that we offered MATH 4010 — namely, 2003–04, 2004–05, and 2005–06 — ETSU averaged 75 mathematics majors with an average time to graduation of between 5 and 6 years. We thus saw a class size of between 10 and 15 students each fall, since the class was initially offered once a year. The first year had a single advisor, Godbole, so that the instructor of record was the sole advisor. Everything moved smoothly at first; he just considered this an extension of the summer REU, with him directing between four and six groups, with the time-frame being dilated, and with the demands on students and expectations of scientific achievement being lesser.

A few students were also in the Honors Program, and we found that they had to also fulfill an Honors Thesis requirement. During the early years, such students were *occasionally* permitted by both parties to use their hard-earned MATH 4010 project as a "double-dipped" Honors project. This was soon discouraged and prohibited.

MATH 4010 became part of the Academic Quality Initiative (AQI) in 2004, a university-wide project launched in response to the 2003 site accreditation visit by the Southern Association of Colleges and Schools (SACS). AQI was part of the larger Quality Enhancement Plan (QEP) that each institution must submit to SACS as part of its reaffirmation process. It allowed for systematic outcomes-based assessment for several courses across campus, and we were happy to enter MATH 4010 as a participating course. As part of this scrutiny, we formalized the oral and writing requirements as follows: students would submit 5-, 10-, 15-, and 20-page reports at regularly scheduled intervals; the longer reports would be an enhancement of earlier versions. Also, submission of each report would be accompanied by oral presentations that would be attended by all students.

This worked well during the first and second years. Two more advisors were added in 2004–05; they would turn grades in to Godbole, who would submit them along with the grades of his own advisees. The course was offered twice in 2005–06, and even more advisors entered the fray. It became difficult to monitor whether or how the intensive requirements were enforced by other people, or perhaps Godbole just didn't do his job well! The diversity of projects grew as advisors in graph theory, mathematics education, geometry, and statistics began to supervise projects. The students' sense of ownership became evident through AQI assessment and folklore tales. AQI assessment was conducted by a committee chaired by Edith

Seier, and the committee reports were submitted to the University AQI committee. Aspects that were assessed were the oral presentation quality, quality of the final report, and scientific quality.

4. Middle years: the multiple mentors model

The three years 2006–07, 2007–08, 2008–09 were the years when the momentum of the course definitely lessened. Godbole did not enforce the writing/oral requirement too stringently. There were two other instructors of record: Teresa Haynes and newcomer Robert Beeler, who joined us in 2007. The tendency to let advisors "quietly do their own thing" grew, certainly after AQI ended in 2007. It became clear that we needed new blood.

5. New faculty, the reemergence of structure in the present time

Ariel Cintrón-Arias (henceforth Cintrón-A) joined the faculty ranks in 2009, and Michele Joyner came on board in 2010. Cintrón-A immediately became the MATH 4010 instructor of record on several occasions, together with Michele Joyner, who did the job once. Cintrón-A had been to MTBI in 1998 as an undergraduate participant, and had past experience at MTBI (at both Cornell and Arizona State) as a PhD student and at SAMSI-CRSC Undergraduate Modeling Workshop as a postdoc. He had worked extensively with Carlos Castillo-Chavez, who was his PhD advisor. Michele Joyner was H. T. Banks' PhD student and has mentored students at the NCSU REU. It was evident that our undergraduate research strengths had grown, and in new directions, as students began research in the mathematical modeling of complex phenomena such as epidemics, rumors, and antibiotic resistance. Here is an example of how the landscape changed: Cintrón-A ran a summer-fall undergrad research program in mathematical epidemiology; all his students participated in a poster session during the NSF-CBMS Regional Research Conference, alongside graduate students and postdocs from ASU, NCSU, Purdue, etc. His students attended/received offers from summer REUs at MBI-OSU, ASU, UMBC, and NCSU; Joyner's student went to the REU at NCSU. Over the last four years, Cintrón-A set in place a method of ensuring that course objectives are met. Technical reports have to be submitted by preassigned deadline dates, no matter who is the advisor; these still follow the 5-, 10-, 15-, 20-page format. Dates are set for oral presentations as well, and a final capstone talk is attended by all students and their advisors. Students receive LaTeX templates for their papers and copies of books/papers by Higham, Gallian, etc. on how to write mathematics well, how to give good talks, and so forth.

6. Expectations, goals, outcomes

To steal a line from the NSF-REU announcement, one of our goals has always been "to lead the participants from a relatively dependent status to as independent a status as their competence warrants." Correspondingly, we expect all students to produce work that is commensurate with their abilities, and even perhaps to recalibrate their understanding of their own abilities. This is even more critical at an across-the-board UGR than at a summer NSF-REU where often many students are quite independent to begin with. We find, in fact, that the same advisor often has two students who understand/undertake/accomplish similar projects at substantially different levels. Secondly, oral and written communication of mathematics is the most visible/fundamental common thread of the class, and our goal is to ensure that common criteria lead to all students satisfying our stated criteria. We are accountable to the University Intensive Course Committee, especially when SACS comes to town for a site visit. Most students get excited about the sense of ownership they feel, and we look upon quantifying this excitement as a valuable outcome. In a similar fashion, we consider poster presentations, talks at conferences, and possible publication as most desirable outcomes.

7. Replicability: pros, cons, specific issues

Ours still appears to be one of the few across-the-board UGR curriculum requirements in the US; substitutions are never made, and students cannot ask for a substitution because the class "isn't offered": MATH 4010 is now available each semester and sometimes in the summers too. How does one institute such a requirement at another school? Certainly, something has to be given up, as we did with the freshman and junior seminars, so that interested schools might start with the question of "what can we eliminate from the curriculum?" Likewise, our ETSU faculty had widespread UGR experience, and this helped enormously. A school interested in starting a UGR program for all its majors might thus either have the depth of faculty or be willing to invest in building such depth. Other questions we asked ourselves, and which are relevant anywhere: How do students juggle other classes with UGR? How do we empower even our weakest students? How do we give credit for teaching this class? For instructors of record? For advisors?

8. Students' accomplishments

8.1. ***Other programs and departmental involvement.*** This paper has been written from the viewpoint of the authors and details their experiences. However, the ETSU Department of Mathematics and Statistics has a rich and deep involvement with

Faculty member	Research area
Anahita Ayasoufi	thermodynamics
Robert Beeler	graph theory, number theory, combinatorics
Robert Gardner	combinatorics, graph theory, analysis
Teresa Haynes	graph theory
Michel Helfgott	mathematics education, mathematics history
Michele Joyner	mathematical modeling
Debra Knisley	graph theory, nucleotide analysis
Jeff Knisley	applied mathematics and analysis
Yali Liu	statistics
Yared Nigussie	graph theory
Rick Norwood	knot theory
George Poole	geometry and mathematics education
Jamie Price	mathematics education
Robert Price	statistics
Edith Seier	statistics
Daryl Stephens	mathematics education

Table 1. Faculty members who have supervised undergraduate research in MATH 4010.

undergraduate research, much of it funded. Table 1 displays faculty members who have supervised undergraduate research in MATH 4010.

In fact, the only tenure-track persons who have *not* directed undergraduate research projects are faculty without the terminal degree, or those who specialize in the teaching of developmental mathematics. Furthermore, Table 1 includes two persons who are not tenure-track/tenured! But this is not all. Over the years we have built an impressive record of funded activity that supports undergraduate research, as seen by the list below. Such cognate activity only enhances the quality of our MATH 4010 class:

- Robert Beeler and Jeff Knisley are on the leadership team for an NSF-Noyce grant in which students do UGR-like projects at various stages.
- Ariel Cintrón-Arias and Anant Godbole were PI and co-PI on an NSF-CBMS grant at which Cintrón-A's students gave poster presentations describing their UGR projects alongside graduate students and postdocs.
- Anant Godbole's NSF-REU site grant has run since 1991 with two years taken off. Six ETSU students have participated at various times, two of whom have published refereed papers.

- Anant Godbole was PI on an NSF-STEP grant in which 45 students did undergraduate research in quantitative biology, at ETSU and at external REUs. Two students participated in his summer REU with STEP support.
- Michele Joyner and Edith Seier are co-PIs on an NSF-UBM grant that features *long-term and sustained* UGR in quantitative biology.
- Debra Knisley ran an NSF-SUMMA REU program for three years, targeted at underrepresented students.
- International agreements such as the ESTU-NCUT Bridge Program with the North China University of Technology were attractive to the Chinese administrators primarily because of the ETSU UGR class. Likewise, a Cameroonian student began doing UGR "long distance" with ETSU faculty, and eventually got an MS degree from ETSU and PhD from Duke; and
- Jeff Knisley was PI on an early round NSF-UBM grant that was based on UGR in quantitative biology (see [Karsai et al. 2011]).

8.2. ***Godbole and discrete math/probability.*** The second author has supervised the research of about 30 students in MATH 4010 over the years, in combinatorics, graph theory, probability, and statistics. Six novel sequences have been submitted to *The Online Encyclopedia of Integer Sequences*, one of which was labeled "nice" by Neil Sloane. Five refereed papers have appeared in *Congressus Numerantium (2), The Mathematical Scientist, Journal of Combinatorial Designs*, and *Lecture Notes of the London Mathematical Society*. Several other students' work is definitely publishable. Most students' work ended at the modest original contributions made in their technical reports.

8.3. ***Cintrón-Arias and mathematical epidemiology.*** From July 25–29, 2011, a regional lecture series was hosted by ETSU. This event promoted some mathematical methods employed to better understand the underlying dynamics of epidemics. The lecture series was led by two principal lecturers who are leaders in the field of compartmental models of infectious diseases: Fred Brauer and Carlos Castillo-Chavez. In what can be considered a celebration of the tenth anniversary of their textbook *Mathematical Models in Population Biology and Epidemiology*, both Brauer and Castillo-Chavez delivered ten lectures, from introductory formulations of epidemic models through survey topics of current interest, including illustrations relating to influenza, HIV, rotavirus, and tuberculosis.

The Conference Board of the Mathematical Sciences funded this lecture series through a research grant by the National Science Foundation, with Godbole and Cintrón-A as principal investigators. A total of 59 participants attended this CBMS lecture series known as *Mathematical Epidemiology with Applications*, of which 14 were undergraduate students.

In an effort to anticipate the specialized technical level of these lectures, Cintrón-A organized a mini-REU prior to this CBMS conference. Four weeks before the lecture series began, Cintrón-A launched a special session of MATH 4010 (with some additional students joining but enrolled in an independent study), focusing on infectious disease modeling. During the first three weeks, students attended lectures and worked in class activities that included numerical simulations. The following topics were studied:

(1) single-outbreak SIR (susceptible-infective-recovered) model;
(2) final epidemic size;
(3) equilibrium points and stability conditions;
(4) SIR model with vital dynamics;
(5) interpretation of basic reproductive number;
(6) the effect of quarantine in the dynamics of an SIR model;
(7) reduction of state variables and nondimensionalization;
(8) ordinary least square estimation of parameters from longitudinal prevalence data;
(9) stochastic epidemic models;
(10) payoff matrices and stable strategies of evolutionary games;
(11) prisoner's dilemma and hawk-dove games;
(12) replicator equations of evolutionary games;
(13) next-generation operator approach.

This special session of MATH 4010 required students to give a poster presentation at the CBMS lecture series with preliminary results of their research project, thus fulfilling oral-intensive requirements. To complete writing-intensive requirements, students continued working on their manuscript through Fall 2011. Table 2 shows the titles and authors of the posters presented by MATH 4010 students.

Four technical reports originated from these six posters; below we include the abstracts of these reports.

(a) Jordan Angel and Sam Peters, *Game theory analysis of vaccination uptake and risk perception*. In populations with voluntary vaccination policies, it is possible that the vaccination coverage achieved is not the coverage level that would be optimal for the population. We use a game theory model in combination with epidemic modeling to analyze what differences exist in vaccination uptake when individuals act in self-interest compared to the coverage that is best for the group. We define player strategies that reflect individuals acting in self-interest as opposed to the group's interest. Our results characterize the difference in vaccination uptake and

Authors	Title
J. Angel and S. Peters	*Game theory analysis of vaccination coverage with epidemic modeling*
C. Brewer and J. Lunsford	*Prevalence of infection in seasonally forced compartmental models*
S. Cameron	*Prisoner's dilemma implementation on Watts–Strogatz networks and real networks*
S. Peters	*Game theory and evolutionary dynamics*
B. Roland and C. Shimberg	*Analysis of influenza-like illness outbreaks at ETSU*
C. Shimberg	*Parameter selection for ordinary least square estimation of contact processes*

Table 2. Titles and authors of the posters presented by MATH 4010 students.

the increased cost to a population due to suboptimal coverage. Additionally, we will investigate a model when individuals vaccinate based on perceived risk of vaccination versus a perceived risk of infection.

(b) Chris Brewer and Jessica Lunsford, *Seasonal infection modeling: a look at the different parameters and their effects upon the prevalence of infection*. Seasonal infection modeling is used to describe the qualitative behavior of infection during various seasonal cycles within a fixed population. We use ordinary differential equations to achieve an understanding of the behavior of each aspect of infection and transmission that is assigned to each equation. We carry out with graphical data based upon calculated sensitivity equations that are compared over time for each of the parameters involved in the model.

(c) Sharon Cameron, *A study of prisoner's dilemma on real social networks*. Prisoner's dilemma is a game theory model used to describe altruistic behavior seen in various populations. Biologically, prisoner's dilemma is important in describing why a seemingly unsuccessful strategy does persist and spread throughout a population, although it seems to not benefit the player. Spatial prisoner's dilemma brings to light certain requirements that must be met in order for the cooperating or altruistic strategy to spread throughout the population with social network structure. Using MATLAB to simulate both the network and the prisoner's dilemma game, results have been obtained that support these requirements. In addition, a snapshot of the California Institute of Technology Facebook social network (as of 2005) is employed as a representation of a real life network.

(d) Byron Roland and Caleb Shimberg, *Analysis of influenza-like illness outbreaks at ETSU*. During the course of seven months, data was collected from the student health

clinic located on the East Tennessee State University campus. The clinic reported the number of patients with influenza-like illnesses seen by each nurse in the facility. A model for the spread of this influenza-like illness was proposed using a basic single-outbreak SIR model. The differential equations defining the SIR model were solved numerically using a built-in MATLAB function called `ode45` (based off an explicit Runge–Kutta(4,5) integration method). In this system of equations a fourth was created to report the incidence rate of the influenza-like illness. This incidence rate is what we are going to fit to our data in order to determine transmission rates, reproductive rates, and recovery rates. In this project there are two models, one with constant parameters and another with a time-dependent transmission rate. In the second model, we will use another MATLAB function called `Pchip` (piecewise cubic Hermite interpolating polynomial) to interpolate the values of transmission rate over the time of the data. This interpolation allows us to vary the number of interpolating values of transmission and to explore subintervals for major shifts.

From October 21–22, 2011, six of these students attended the Undergraduate Research Conference at the Interface of Biology and Mathematics, organized by the National Institute for Mathematical and Biological Synthesis. Four of them gave oral presentations, while two students presented posters.

Because of the interest sparked by the CBMS conference and MATH 4010, some students from this group joined a continued discussion on infectious disease modeling during the spring 2012 term. In this term, Cintrón-A and Godbole led a seminar titled *Theory of Networks & Epidemics*, with a diverse attendance including undergraduate and graduate students (from mathematics and sociology) as well as faculty members (from biology and mathematics). In this seminar attendees took turns in leading discussions centered around network analysis and disease transmission. Additionally, this seminar had three external speakers: J. Rivera, *Spreading speed, traveling waves and linear determinacy for STD Models*; E. Shim, *A game dynamic model for vaccine behavior*; J. Medlock, *Optimizing influenza vaccine allocation*.

Due to the momentum generated by the CBMS conference, the undergraduate research experience, and the follow-up seminar, there were two MATH 4010 students from the 2011 class who decided to apply to external REUs. They successfully landed several offers. Mrs. Jessica Lunsford decided to attend the Mathematical and Theoretical Biology Institute (MTBI) of Arizona State University (June 12–August 1, 2012). Mr. Jordan Angel participated in the Interdisciplinary Program in High Performance Computing, hosted by the University of Maryland, Baltimore County (June 12–August 10, 2012).

When interviewed about the role that MATH 4010 played in their external REU participation, these students gave their impressions.

Mrs. Jessica Lunsford: "The summer coursework for MATH 4010 was by far the hardest class I have ever taken. I spent most of the class dazed, confused, and generally lost. However, when it came to the project, I was able to discover some of the material on my own. This made me proud of my work. Something that generally doesn't come from rote computation, as my prior experiences have asked of me.

To me, my participation in MTBI only sealed the deal. I wanted to go so that I could learn as much as humanly possible from a person who has made their career by blazing new trails in this field, Dr. Carlos Castillo-Chavez. What I got was exponentially more than I expected. We worked in groups and learned enough mathematics to make our projects viable. Upon completion of our classroom portion, we were able to work in small, independent groups on a project of our choosing. My group tossed around project ideas for a little while and settled on studying a genetic disorder called Friedreich's ataxia. From that we learned about cell biology and the importance of different proteins involved in iron regulation. From that knowledge, we were able to build and improve upon an existing model such that our research culminated in a publishable, viable, and robust model of cellular iron homeostasis as it pertains to protein levels influenced by Friedreich's ataxia."

Mr. Jordan Angel: "The [REU] program is structured so that the first three weeks are spent completing a 3 credit course on parallel computing. During this time, many potential project mentors visit and pitch projects to student teams. My team and I chose to work with Richard Murphy of Sandia National Labs and David Mountain of NSA (National Security Agency). The project they pitched was to implement a memory access benchmark on UMBC's computing cluster and explain our results based on the machine architecture. We presented our results at UMBC's Summer Undergraduate Research Fest (SURF), an undergraduate research conference that hosts talks and posters for students completing research over the summer at UMBC.

The structure was similar to my MATH 4010 experience. Both started with an intense introduction in a lecture setting, then unique projects were taken on by teams. This is how the REU site advertised itself and was one reason I chose to apply. Both experiences have helped me to understand more clearly what mathematics I am interested in pursuing in graduate school."

Based on his supervising experience during the Summer and Fall 2011, Cintrón-A is currently putting together proposals for external funding, with a slightly different focus of undergraduate research while maintaining some the key tipping points of training and mentoring MATH 4010 students. He is submitting proposals to the Center for Undergraduate Research in Mathematics and to the Tennessee Board of Regents under Access and Diversity Initiative Grants.

9. Closing remarks

The overachievers tend to use MATH 4010 to jump into a Research Experience for Undergraduates outside of ETSU, or to solidify ideas for a project that crossed their mind while they were participating at an external REU. Eventually the combination of MATH 4010 and an external REU fuels and facilitates plans of graduate studies.

For the average students, this tends to be their only research experience during their undergraduate studies. Sometimes these average students struggle in certain areas of mathematics, and they are not very proficient. However, despite some nonlinearities in mathematical background this course serves them well from the standpoint of technical writing and public speaking.

For example, for many of our majors with a mathematics education track (who may very well be overachievers but tend to join the workforce immediately upon graduation and do not pursue graduate studies), writing a 15-page paper on mathematics and giving oral presentations falls within the day-to-day demands of their future job (writing lesson plans and giving lectures, another form of public speaking).

Our department continues to be challenged in accommodating students who enroll in MATH 4010, and we are currently revising the prerequisites (several core courses at the sophomore level). Another challenge for our department is the evaluation metric, that is, how to give grades, especially when there are multiple professors mentoring students with projects in distinct areas of mathematics.

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