# Faculty Learning Community

## College of Natural Sciences & Mathematics

## Final Report: 2018-19 Cohort

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# Executive Summary

The 2018-19 CNSM Faculty Learning Community (FLC) included six instructors from five departments and was co-led by Josh Chesler and Jason Schwans.

In Fall of 2018, participants engaged in five structured online discussions (using Slack™) based on readings and videos. These topics of discussion were:

1. *Engagement (part 1).* Participants read about some general strategies for engaging students and they discussed their own strategies.
2. *Engagement (part 2).* Guided by the previous discussion, participants each tried something new in a course that s/he was teaching.
3. *Assessment.* Participants discussed both something they've figured out about assessment and something they are trying to figure out. This was framed by relevant readings.
4. *Humans.* The FLC learned about and discussed some affective considerations of teaching (e.g., stereotype threat, impostor syndrome). Learning was enhanced by participation (by most FLC members) in the *CNSM Symposium on Inclusive Pedagogy and Growth Mindset*.
5. *Proposals*. Participants shared (and received feedback on) their ideas for interventions to implement and study in Spring 2020.

Each participant also observed the classrooms of two other instructors, at least one of whom was a 2018-19 FLC participant. These visits were framed by some guiding questions related to both instructor choices and students' classroom experiences. This was followed by a debrief.

The goals of Fall 2018 were to frame the work for the Spring semester by engaging in the above discussions and to put the C in the FLC – to focus on building community. The latter goal was accomplished, in part, by avoiding the conference room and conducting meetings at the Nugget or the Coffee Bean. Though there are typically no FLC meetings in the Spring, participants *voluntarily* met multiple times throughout the semester, a sign of the esprit de corps built in the Fall.

In the Spring semester, Dr. Schwan organized a Munch N' Learn colloquium by Dean Bennett titled *Discovering What Your Students Are Thinking.* The abstract was:

> *Curtis Bennett, Ph.D. in Mathematics, will lead a discussion to further our understanding on what students are thinking in the classroom and throughout their college experience. Dean Bennett will facilitate an interactive discussion allowing ample time to brainstorm, share practices, and potentially discover new approaches you would like to pursue in your teaching.*

Though, the primary focus of Spring 2019 was the implementation and study of the participants' interventions. This document includes the participants' reports on these projects, each of which sought to increase student success in a novel and well-reasoned way. Each report is briefly summarized below, with commentary on broader implications for the CNSM.

- Elaine Bernal (Chemistry) used an attitudinal survey to measure students' perceptions of CHEM 100 and its integration of virtual laboratories.
    - *CNSM Takeaway:* There are existing tools (e.g., virtual labs) that can benefit our students. We can make use of existing frameworks, like the Colorado Learning Attitudes about Science Survey (CLASS), to help instructors make sense of their students' experiences.

- Jayne Bormann (Geology) created structured writing groups for Geology students finishing their masters theses. Students reported an increased sense of community and positive impacts across multiple affective dimensions. She offers constructive advice for how such a program could be implemented and improved.
    - *CNSM Takeaway:* Any student working on a masters thesis or undergraduate honors thesis could benefit from a program like this. It could be organized either at departmental or college levels. Participation could be written into 698 thesis unit contracts as a requirement.
- Andrea Johnson (Mathematics & Statistics) addressed student engagement and attendance in a large lecture course by creating accountability for in-class group work that emphasized consensus building. Students from the previous semester served as a control group. Absences were cut in half, student-to-student interactions dramatically increased, and students reported being more engaged & confident.
    - *CNSM Takeaway:* This intervention seems to hit the sweet spot: it's not labor intensive, yet it yields large dividends. Plus, it probably makes the class more fun to teach. This is worthy of consideration for any large lecture.
- Sandy Kawano (Biology) had students create concept maps to help them organize their knowledge. This was supported by giving quizzes prior to class so that students would do the reading that would support creation of concept maps in class. Though Dr. Kawano did the intervention, she did not submit a final report because she is no longer at CSULB.
    - *CNSM Takeaway:* Using class time to support the creation of concept maps has many potential benefits for students, regardless of the class. It can help students see the "big picture" and build a strong conceptual base.
- Thomas Klaehn (Physics) implemented several course features that encouraged students to read and comprehend their textbook. In support of this, he flipped his course on strategically-selected days. Students reported enjoyment of the reading and made productive use of what they read. Dr. Klaehn attended to portable skills that could help students in any course.
    - *CNSM Takeaway:* All instructors want their students to engage productively with assigned readings. Dr. Klaehn built this into his course in multiple ways that are general enough to be used in any course.
- Jeffery Pair (Mathematics & Statistics) asked his students to attempt to prove open conjectures in mathematics. The goal was to engage students in authentic mathematical activity and frame discussions about the nature of mathematics.
    - *CNSM Takeaways:* Students in all departments need to explicitly engage in discussions and experiences related to the nature of the discipline. Dr. Pair's approach may need some adaptations to work outside of mathematics, but it provides evidence that this is an important and feasible pursuit.

The work of the FLC participants was creative and impactful. It is encouraging that small, yet thoughtful, changes may help our students succeed in their coursework and develop productive skills & attitudes.

SYLLABUS

# CNSM Faculty Learning Community 2018-19

Leaders: Josh Chesler (5-1554), Jason Schwans (5-7778)

## OVERVIEW

The Faculty Learning Community (FLC) is a small reading and discussion group of CNSM faculty focused on sharing, learning about, and implementing effective and engaging teaching techniques. The "leaders" of this group do not claim any special expertise in this area; we serve primarily to organize the community and to encourage participants to keep the discussion going.

The FLC includes two semesters of activities. The first includes six discussion topics, each covered over one or two weeks in a hybrid format (we will meet as a group a few times during the semester, and the remaining discussion will take place online). Topics are shown below in the schedule. We will provide links to brief readings about each topic at the beginning of the semester; all readings will be available at all times during the semester. Because watching others teach is a great way to get ideas about how to modify your own teaching, after the initial discussions there will be several weeks of scheduled peer classroom observations. By the end of the Fall semester, you will propose <u>one</u> change to be implemented in one of your courses in the Spring semester and a plan to tell whether the change "works" or not.

During the Spring semester you will implement the proposed change and evaluate its effect on student learning. Within a few weeks of the end of the spring semester you will turn in a short report describing the change and its measured results. Reports from past FLC participants are posted if you'd like to get a sense of what people have done previously. You will also be asked to attend a Munch n' Learn which will likely take place in the Spring semester.

A tentative schedule for the course is below. We would like the whole FLC to meet in person on four occasions during the semester; I have tentatively chosen Fridays of the relevant weeks (in red) for those meetings, but we will query you before semester start to see if those days work, and if so, to find a time we can meet on those days. All other activities can happen on your own schedule, in the date range provided.

## SCHEDULE

### In-Person Meetings (Fridays)

- September 14: Intros, goals, debrief on Symposium on Inclusive Pedagogy and Growth Mindset
- October 5: Goals of observations, discussions (assessment, stereotype threat, impostor syndrome, etc.)
- November 9: observations debrief, discuss proposals
- December 7: ideas for modifications of FLC
- Spring 2019, TBD: debrief on projects, etc.

### Online Discussions

9/7-9/21: Online Discussion 1, Student Engagement

9/24-10/5: Online discussion 2, Assessment

10/8-10/19: Online Discussion 3, Stereotype threat & impostor syndrome

10/22-11/2: Online Discussion 4, Revisit growth mindset & inclusive pedagogy

## Mandatory Events

- September 7: Symposium on Inclusive Pedagogy and Growth Mindset
- TBD (likely Spring): Munch n' Learn

## Deliverables

- November 16: Proposals due
- May 3, 2019: Final Report

## 2018-19 FLC PARTICIPANTS (12)

| Role | Name | Title | Dept |
|---|---|---|---|
| Participant | Elaine Bernal | Lecturer | Chemistry |
| Participant | Jayne Bormann | Assistant Prof | Geology |
| Co-Leader | Josh Chesler | Associate Prof | Math & Stat |
| Participant | Andrea Johnson | Lecturer | Math & Stat |
| Participant | Sandy Kawano | Assistant Prof | Biology |
| Participant | Thomas Klähn | Assistant Prof | Physics |
| Participant | Jeff Pair | Assistant Prof | Math & Stat |
| Co-Leader | Jason Schwans | Associate Prof | Chemistry |

**2018-2019 College of Natural Sciences and Mathematics Faculty Learning Community (FLC) Report**

**Elaine Villanueva Bernal, Ed.D.**
**Lecturer, Department of Chemistry and Biochemistry**

## Background and Introduction

CHEM 100, Chemistry in Today's World, is a course for non-science majors and provides a chemical context for sustainability initiatives and issues at the local, national, and global community. CHEM 100 includes basic principles of chemistry and a consideration of the benefits and problems arising from applications of chemistry. The course also encompasses discussions of foods and food additives, drugs, plastics, and other materials of everyday life, fuel sources, the atmosphere, and freshwater.

Since 2014 I have been developing CHEM 100 to be more practical, engaging, and relevant to current sustainability and environment issues. I have been teaching in the Active Learning Classroom for four semesters, have incorporated group work for most lectures, and have been able to adapt my course to use mobile and web apps to teach concepts that can be a challenge to visualize. For example, reduction and oxidation, or "redox" reactions are often difficult to make sense of. Typical questions include how to determine where and how electrons flow, particularly when it comes to voltaic cells and the various materials used for batteries. I use a virtual voltaic cell lab in which students can change the anode and cathode using zinc, copper, or silver, and the web application shows where the gain and loss of electrons are taking place within the cell. Further, I use the CHEM101 app to support visualization of Lewis structures and molecular shapes in a mobile friendly format. Another example of how I use technology in the classroom is the Physics Education Technology (PhET) Interactive Simulations from University of Colorado Boulder, in which students work with interactive web applications such as acid-base chemistry simulation that my students do as part of group work.

## Methodology

Anecdotally, students share that these educational technology resources help them make sense of content. However, I have not formally assessed how educational technology integration strategies support student learning. I chose the Colorado Learning Attitudes about Science Survey (CLASS) for chemistry, which is part of the PhET and the Physics Education Research

Group at Colorado (PER@C). Over one third of my class activities use the PhET platform. The CLASS-Chem survey takes a look at how student beliefs and perceptions about chemistry are shaped through classroom experience. The survey has fifty questions and is based on a Likert scale, and was administered at the beginning and the end of the Spring 2019 semester. The total enrollment for CHEM 100 was 178 students. The pre-survey response rate was 97% and the post-survey response rate was 48%. A paired t-test was used to determine significant changes among survey items.

## Results and Discussion

The results show significant changes ($p < 0.05$) among the following items:

| Survey Item | Post-Pre Mean | p value |
|---|---|---|
| "A significant problem in learning chemistry is being able to memorize all the information I need to know." | -0.858 | 0.00 |
| "I think about the chemistry I experience in everyday life." | 0.931 | 0.00 |
| "I think about how the atoms are arranged in a molecule to help my understanding of its behavior in chemical reactions." | 0.637 | 0.02 |
| "I cannot learn chemistry if the teacher does not explain things well in class." | -0.55 | 0.00 |
| "I can usually make sense of how two chemicals react with one another." | 0.414 | 0.03 |
| "To understand chemistry I discuss it with friends and other students." | 0.574 | 0.01 |
| "I do not spend more than five minutes stuck on a chemistry problem before giving up or seeking help from someone else." | 0.384 | 0.04 |
| "In doing a chemistry problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem." | 0.576 | 0.00 |
| "In chemistry, it is important for me to make sense out of formulas before I can use them correctly." | -0.460 | 0.00 |
| "When I see a chemical formula, I try to picture how the atoms are arranged and connected." | 0.400 | 0.02 |
| "The arrangement of the atoms in a molecule determines its behavior in chemical reactions." | 0.342 | 0.05 |
| "I can usually figure out a way to solve chemistry problems." | 0.413 | 0.03 |
| "When I'm solving chemistry problems, I often don't really understand what I am doing." | -0.715 | 0.01 |

The results suggest that students are able to problem solve, visualize, and work with others regarding course content. The significant increase in, “I can usually figure out a way to solve chemistry problems,” and the significant decreases in the items, “A significant problem in learning chemistry is being able to memorize all the information I need to know” and “When I'm solving chemistry problems, I often don't really understand what I am doing” suggest that students are able to make sense of what they are learning without relying on memorization and are confident about their understanding of chemistry. Further, students feel comfortable working with other students and discussing chemistry problems as demonstrated by significant increases in the items, “To understand chemistry I discuss it with friends and other students, ” and, “I do not spend more than five minutes stuck on a chemistry problem before giving up or seeking help from someone else.” Students were able to connect atomic and molecular behavior to chemical reactivity as shown by significant increases in items, “I think about how the atoms are arranged in a molecule to help my understanding of its behavior in chemical reactions,” “I can usually make sense of how two chemicals react with one another,” “When I see a chemical formula, I try to picture how the atoms are arranged and connected,” and “The arrangement of the atoms in a molecule determines its behavior in chemical reactions.” Results that need further clarity would be the significant increase for, “In doing a chemistry problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem,” and the significant decrease for, “In chemistry, it is important for me to make sense out of formulas before I can use them correctly.” Regarding calculations, CHEM 100 students focus on basic algebra, which includes balancing oxidation numbers (or ionic charges) to write appropriate chemical formulas, and stoichiometry. My current thinking is that students perhaps feel confident in being able to accurately calculate with support or feedback from peers, which may reduce the need for self-checking. Further, I would like to explore items that perhaps, had positive correlation with other items, but did not. For example, the item, “To understand a chemical reaction, I think about the interactions between atoms and molecules,” increased in the mean scores but the change was not significant. In context of the items, “I think about how the atoms are arranged in a molecule to help my understanding of its behavior in chemical reactions,” “I can usually make sense of how two chemicals react with one another,” “When I see a chemical formula, I try to picture how the atoms are arranged and connected," and "The arrangement of the atoms in a molecule determines its behavior in chemical reactions," this suggests that students think of atoms and molecules as static rather than dynamic. This is an opportunity to explore strategies on how I can effectively demonstrate that atomic and molecular dynamics. I currently teach students that the asymmetrical stretches of carbon dioxide absorb infrared, which is connected to carbon dioxide and other molecules such is hydrofluorocarbons being classified as greenhouse gasses. This course content is only two lectures, however I can strategize how I can discuss molecular dynamics and practical applications.

## Conclusion

What I was most excited about in the results was the significant increase for the item, "I think about the chemistry I experience in everyday life," which is one of the primary objectives of CHEM 100. I can strategize about further incorporating interdisciplinary content in the coursework and assessing its effectiveness. In Fall 2018, my students were able to work with real time, census level, air quality data and propose strategies on how to support and advocate for communities in Long Beach that are most impacted by unhealthy air quality. My class did not do such a project in Spring 2019, but I think I can implement this project again in Fall 2019 then assess how this helps students see chemistry not only in their daily lives but in others'. Further, the results imply that the educational technology resources and group work were conducive to student engagement and learning. For future research, I would like to explore which classroom strategies and/or educational technology tools worked best for students, especially when it comes to making sense of atoms, molecules, and chemical reactivity.

2018-2019 CNSM Faculty Learning Community Project Report
Jayne Bormann

**Project Name:**
GeoTAG (Geology Thesis writing Accountability Group)

## Context and Motivation

Although meant to be the culmination of a graduate degree, writing a thesis is a large and all-encompassing task that often overwhelms graduate students, sometimes to the point of inaction and in detriment to their mental and physical health. In recognition of the difficulty of the task, many professors encourage their students to start writing early, to write often, or to take advantage of programs like writing programs offered through the Graduate Studies Resource Center. Despite these warnings and encouragement from faculty, and evidence that writing groups increase student happiness and success at thesis writing (Maher et al. 2008), few students take advantage of thesis writing support programs.

The goal of GeoTAG (Geology Thesis writing Accountability Group) was to test if removing the barriers of joining an unknown writing group in an unfamiliar place by providing time, space, and support for writing within the CSULB Geology Graduate Program, would help Geology graduate students be happier, more productive, and more successful writers.

## Intervention

I ran GeoTAG as a 9-week thesis writing accountability group that led up to the library thesis submission deadline. The goals of the group were two-fold: 1) to promote writing success and student happiness by providing community support and a convenient, comfortable, and place for thesis writing; and 2) to help students develop self-regulated and reflective writing practices through weekly reflections and goal-setting activities.

Research on graduate writing group success shows that participant buy-in to group structure and facilitation are key factors in student participation and satisfaction (McMurray, 2017). During the first meeting, interested students collectively designed the writing group format and ground-rules for participation using the writing group typology developed by Haas (2014). Following the first meeting, each participant completed a self-evaluation of their practices and attitudes toward writing and set a long-term goal for the writing group duration. I then held eight weekly writing sessions where participants shared reflections on the previous week's progress/challenges, set immediate goals for the group writing session, and at the end of the meeting, set goals for the upcoming week that build toward their long-term goal. Although the timing of the group coordinated with the library thesis submission deadline, the group was open to all graduate students actively writing theses or thesis proposals without the expectation of completing a thesis this term.

## Evaluation

Changes in student attitudes towards writing, writing habits, and thesis progress were evaluated in pre and post writing group surveys. The surveys consisted of a combination of open-ended free response and multiple-choice questions. Evaluation of the program is qualitative due to the of the small number of program participants
.

Possible outcomes that I hypothesized could be indicative of project success included:

- successful progress towards completion of graduate student thesis,

- an increased sense of community between students in the writing phase of their graduate programs,
- a decrease in negative feelings such as loneliness, isolation, self-doubt, and anxiety that are common during the thesis writing process (Ferguson, 2009),
- the development of self-regulated goal-setting practices to accomplish research/writing tasks, and
- the desire to continue to the group beyond the original 8-week program.

## Results

Participation in the GeoTAG was entirely voluntary. In total, 10 of the 14 active geology graduate students participated in the writing group at some level. Seven students attended more than 50% of the writing sessions, and five students attended at least 75% of the sessions. During the GeoTAG organizational meeting, the students set the writing session ground rules with expectations that members would be on time, participate in the full 2-hour session, and minimize interruptions from cell phones. The strictness of these rules may have contributed to some of the early attrition from the group.

Of the seven regular participants, two students were actively trying to finish their theses during Spring 2019, three students were trying to make progress on initial sections of their theses such as the background and methods, and two students were trying to complete their thesis proposals.

### *Pre-GeoTAG self-assessment*

After the GeoTAG organizational meeting, I distributed a paper self-assessment to measure student motivations for joining the group and their goals for the program. Five students completed the self-assessment. The most commonly cited reasons for joining GeoTAG included: increased accountability (3), faster writing progress (3), learning new writing strategies (2), and community (2). Skills the GeoTAG participants hoped to build fall into two broad categories: more efficient writing practices (4) and regular writing habits (2).

### *Post-GeoTAG evaluation*

For the post-GeoTAG evaluation, I designed a Qualtrics survey that consisted of free-response and multiple-choice questions. All seven active participants completed the post-GeoTAG assessment.

Six of the students found the group to be very helpful, and one student found the group to be moderately helpful. Free response answers indicate that participants found the most valuable parts of the GeoTAG to be the routine of having a designated time and place for writing each week (5), the accountability of setting daily and weekly writing goals (3), and the increased sense of community. Four of the seven students completed their writing goals, and three students made progress toward their goals. Perhaps unsurprisingly, the students who completed their goals were most satisfied with their participation in GeoTAG, whereas students who made progress towards their goals were only moderately satisfied.

All students overwhelmingly agreed that participating in GeoTAG increased their sense of community with other graduate students, and six students indicated that participating in GeoTAG decreased negative feelings that many students face when working on individual graduate writing projects. All students reported that they would be likely or very likely to participate in an on-going weekly writing group, and five of the seven students indicated that they would actively encourage other graduate students to join the group.

## Discussion and Recommendations

My original question about if removing the perceived barriers of joining an unfamiliar writing group by providing time, space, and support for writing within the CSULB Geology Graduate Program would contribute to happier, more productive, and more successful writers can be rephrased in the proverbial misquote from the movie *Field of Dreams*, “If you build it, will they come?” In the case of GeoTAG, the answer is yes – if you make the group personal and approachable, they will come. Furthermore, students reported that participating in the group contributed towards increased productivity, a greater sense of community, and a decrease in negative feelings such as isolation, anxiety, and self-doubt that many students feel during their graduate programs – highlighting many of the hypothesized indicators of program success.

Despite students’ satisfaction with the program and the perceived benefits of participating in scheduled regular writing, the students did not take the initiative to continue a weekly writing group after the 8-week session. This may be because many of the more active GeoTAG students completed their writing projects and no longer needed a writing group. However, the lack of a student-led continuation indicates that prolonged faculty direction would most likely be necessary for a sustained writing group. If you build it, they will come; however, you will need to keep building it to keep them coming.

Overall leading GeoTAG was a relatively low effort but time-intensive process that resulted in positive changes to student perceptions of the graduate writing process. From a programmatic standpoint, the students offered many ideas to make the program more helpful. Suggestions for modifications included longer writing sessions, more than one writing session per week, incorporating peer-review, and separating writing sessions from workshop-type community building, goal setting, and troubleshooting sessions. Participants’ feelings towards the goal-setting and troubleshooting discussions were the most divergent, with many students saying those were the helpful parts of the program and many other students saying they would prefer not to participate. Notably, students who set concrete goals that involved completing a project were more successful in meeting their goals and experienced higher levels of program satisfaction than students who set goals of “making progress” on their thesis. In light of this feedback, I would encourage students in future iterations of GeoTAG to set clearly-defined and discrete process or product goals and to identify self-assessment metrics, so participants can readily gauge their progress throughout the program.

## References:

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Maher, Damian, Seaton, L., McMullen, C., Fitzgerald, T., Otsuji, E., and Lee, A., 2008, Becoming and Being Writers’: The Experiences of Doctoral Students in Writing Groups: Studies in Continuing Education, v. 30, n.3, p. 263-275, doi:10.1080/01580370802439870

# Show We Agree Team (SWAT)

Teams of students to increase engagement in a large lecture course

Andrea Johnson, Department of Mathematics & Statistics

## MOTIVATION

My objective for creating SWAT teams was to increase participation in class, increase engagement, receive feedback from students to better gauge their understanding during a lesson, hold students accountable for their attendance, and to provide students with opportunities to make connections with their classmates. The results of a survey of my Math 112A large lecture students in a previous semester indicated there could be improvement in all these areas.

## INTERVENTION

Show We Agree Teams (SWAT) are teams of 3-4 students who share a slip of paper to respond to questions in class. The SWAT questions were written to assess students' understanding of a concept presented in the same lesson to get "real time" formative feedback and to allow students to self-assess their understanding of the lesson presented that day.

There was at least one opportunity during each large lecture session for students to collaborate, come to a consensus, and respond to a question in class. I assisted and interacted with groups of students to answer questions as they work, but they primarily relied on each other to answer the SWAT questions together.

## EVALUATION

Students were surveyed at the end of the Spring 2019 semester and responses were compared to a sample that I surveyed in Fall 2018 before the intervention was implemented. Survey questions centered around students' level of engagement, number of times they interacted with a classmate during class, number of times they interacted with an instructor during class, and an estimate of the number of times they were absent from class.

## RESULTS

The surveys indicated that:

- A typical student missed half as many classes compared to the previous semester
- Students interacted with classmates much more often (from an average of 3 times over the whole semester in the previous semester, to 1-2 times each class in the semester with the SWAT intervention)
- Students reported that they felt more engaged and confident with their understanding of the content

The SWAT program proved to be an effective way to create a student-centered environment in a large lecture setting. From the instructor's perspective, the course was much more enjoyable to teach because of the opportunity for interacting more personally with students during class.

Responses to the SWAT questions served as formative assessment feedback to determine whether to have a whole group discussion to resolve misconceptions or to summarize and move on to the next concept so the course was taught more effectively based on the needs of the students. Most importantly, the overall morale and motivation of the class was greatly improved by having students work together.

Thomas Klaehn
Department: Physics and Astronomy
Class: Phys 310, Analytic Mechanics
Students: 13 enrolled, 12 completed

I|READ - Integrated Reading Exercises by Assignment Design

This has been my first time teaching this undergraduate course. Although the first in a long row of courses to follow I consider analytic mechanics as one of the most impactful courses for physics students. Most of the fundamental physics principles and mathematical techniques physics students will encounter in more detail during their further studies are introduced and trained for the first time at a sophisticated level in this course. As first impressions often matter this introductory course has to serve two purposes: Ideally, the student should finish this course with a fair grasp of analytic mechanics and at least maintain, better grow the initial interest in physics. While this expectation is certainly shared by student and lecturer, they ideas how to achieve this goal may differ. One of the ingredients for successful learning is an active reading habit and the development of advanced reading skills, as

- comprehending a text book and navigating it as a learning tool rather than a novel.
- extracting relevant information from 'text-heavy' problems.
- extracting strategies to solve new (kinds of) problems.

Mastering any of these skills is crucial for student success in advanced physics (and other) courses; a sooner transition to active reading habits will help to enrich a student's study and contributes to a successful career.

My goal for this semester has been to for my students to learn the direct relation between regular reading and academic success; viz. help them to realize that reading is not an unwelcome chore but a constructive process which is an essential part of home and class work.

In order to achieve this goal I took several steps. I explained the relevance of reading and the positive impact it has on learning and problem solving at several occasions throughout the semester. I scheduled reading assignments, specific and close to the covered topics which have been complemented by short bridge questions to open each class and which lead to problem solving sessions or a more detailed coverage of the topic. Instead of introducing a new topic during class from scratch I chose a class format where I often flipped the class room, viz. reading assignments laid the ground for problems that have been solved in class. I further posed more complex problems during class which required additional reading but have been left ungraded. This last choice I made to create an environment where mistakes can be understood as part of the learning experience. Last, I have been prepared to assign additional reading time during class in case students seemed to be in general unprepared. However, this did not happen.

Results:

I have been very happy with my class as I found them to be eager readers, as I can illustrate with results from a survey my students filled at the end of the semester voluntarily and directly after their final exam. 10 out of 12 students participated, one student took the final test out of class and therefore could not participate anonymously (and therefore not contribute data). Although the sample number is too small for solid conclusions, I try to interpret the results. The left panel of Fig.1 indicates that reading for school is not perceived as enjoyable  as recreational reading. Still, the majority of my students has a positive attitude towards textbook studies which compares well to their recreational reading habits. Considering, that most students reported that they perceive reading in general as enjoyable, the numbers of days the actually do read is wider spread. Although I cannot offer a certain answer why that is so (the reasons can be manifold and range from economic necessities to private preferences and other constraints) it is encouraging to see that students who barely read would read more often for school.

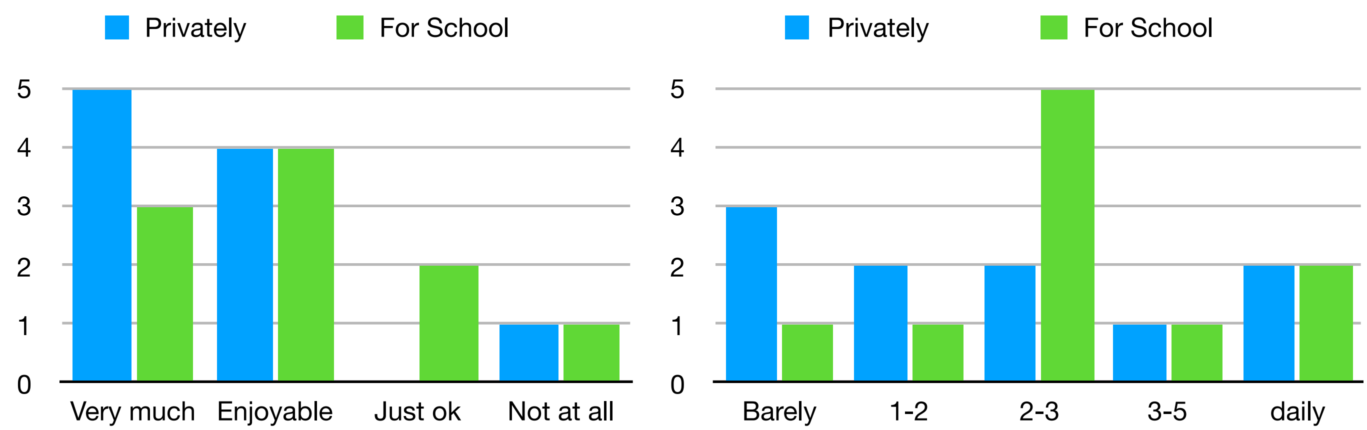


Fig.1: How much do you enjoy reading? (left) How many times per week do you read? (right)

The same trend is visible when asking how much time my students read when they read. It is notable that the numbers of heavy readers (>2hrs) are identical when it comes to recreational and study related reading. This correlation is not random. Each student who answered to read more than two hours answered so for both, private and study related reading. All other students read less, in general, but with a few exceptions assign a significant amounts of time to school related reading.

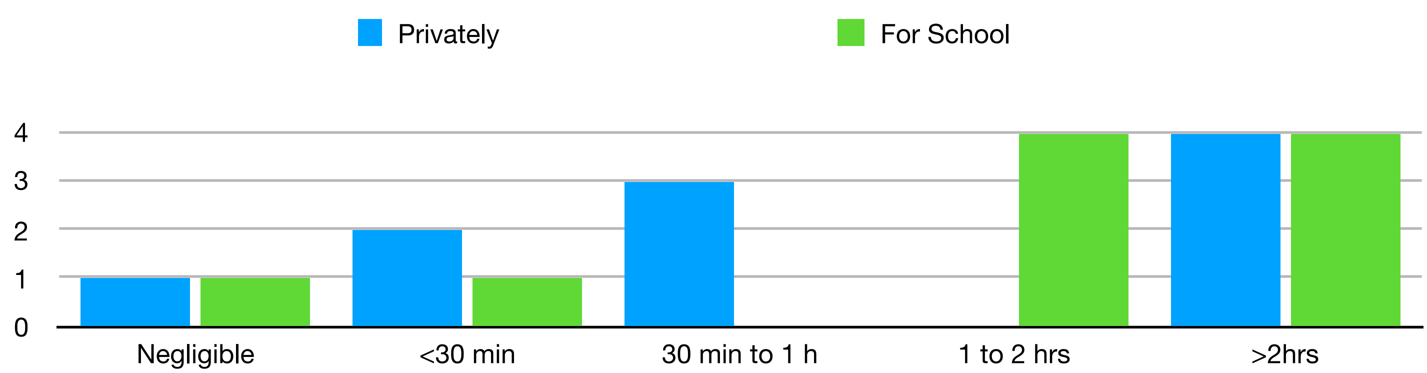


Fig.2: How much time do you spend reading?

Fig.3 illustrates the preference of students regarding their reading medium. I expected a stronger preference for (cheaper) e-books, but this does not seem to be the case. Not surprisingly, websites and internet resources are often used by students. Nevertheless, books and e-books are still choice number one, privately and for school.

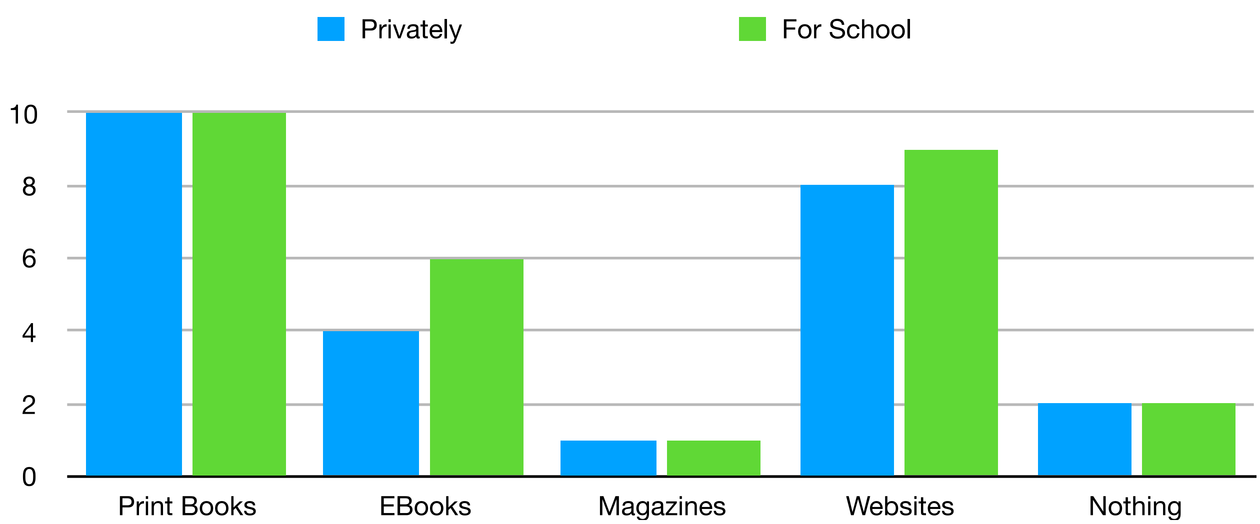


Fig.3: What do you prefer to read? (multiple choices)

This high appreciation of books is reflected by the students assessment of the usefulness of textbooks for learning and problem solving. Although it indicates that students realize the usefulness of textbooks in both regards one can interpret this graph such, that the majority experiences (at least occasional) struggles when extracting information from a book.

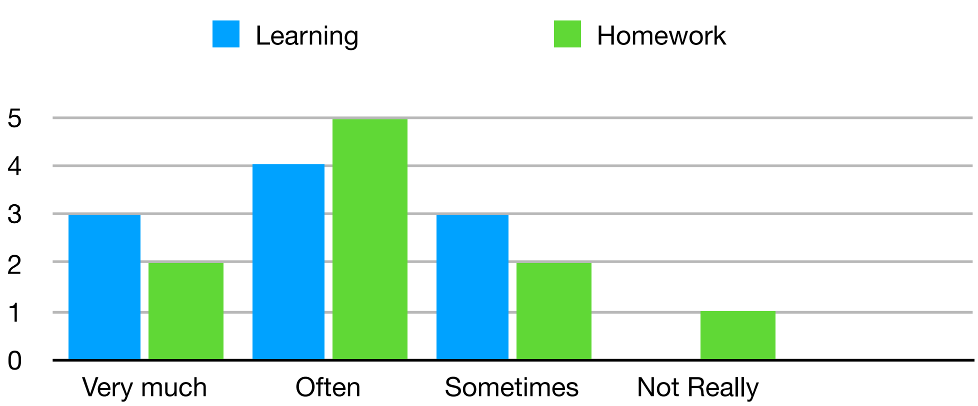


Fig.4: Do textbooks help positively with your … ? (multiple choices)

However, the next graph illustrates, that this might not have to be the case but could just reflect that students are versatile in their choice of sources. I have been surprised by this nearly even distribution.

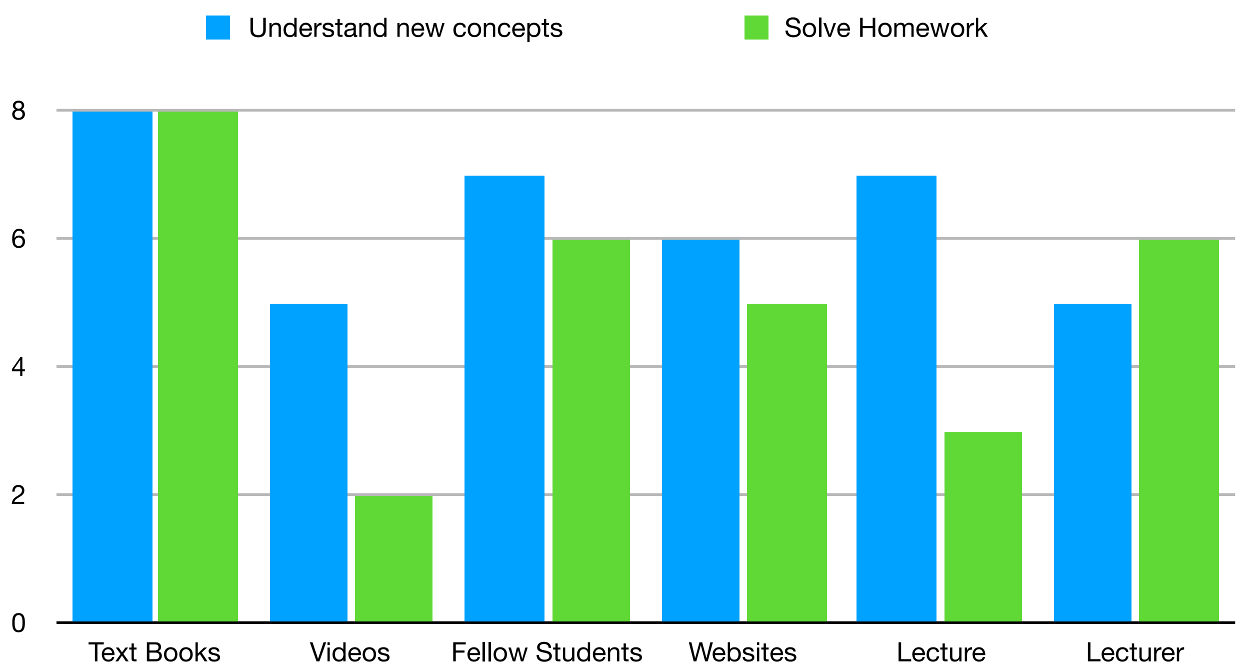


Fig.5: Which resources are helpful to …? (multiple choices)

Although I want to stress again, that my very limited sample does not permit firm conclusions, I want to attempt a conclusion nevertheless: I ran a semester course which has been partially designed to encourage active reading patterns. Although I do not have enough samples to draw conclusions whether my approach actually helped to raise my students willingness to read[1] I can conclude from data as well as class room observations that the majority of students in this particular course enjoyed reading and uses textbooks to solve problems and to understand new concepts. This seems very healthy and productive to me. Although it takes time and patience to hone these reading skills further I am optimistic that students have a very positive attitude towards reading and all other means of acquiring knowledge. The main conclusion from this semesters project is that demanding from students to read for a purpose (solving a problem, understanding a concept) is a valid and working way to train specialized reading skills. However, the majority of students value learning from books as they value learning from surrounding people and other sources. This semester helped me to explore a more holistic approach to teaching in which I find my purpose in feeding and funneling natural curiosity and excitement of my students.

[1] I distributed the same survey in the beginning of the semester but less forcefully as the end of the semester survey (as part of a test). Consequently, I had less feedback. Considering the very small sample number already for the presented data I refrained from comparing to an even smaller earlier sample as any conclusions drawn should be subject to a more careful analysis than I could provide.

**Advanced Mathematics Pathway Through Unsolved Problems (AMP UP)**

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## Context

In the Department of Mathematics and Statistics at CSULB, Fundamental Concepts of Advanced Mathematics (Math233) is a required course for students majoring in either pure mathematics or secondary mathematics education. This course is a dividing point in the curriculum as students transition from the computation-focused courses (Pre-Calculus, Calculus) to the advanced proof-focused courses (Abstract Algebra, Number Theory, Analysis). This transition is challenging for many students who struggle with proof and do not quite understand its role in mathematics.

## Intervention

The purpose of this intervention was to provide students in Math233 the opportunity to reflect on the nature of mathematics and the purpose of proof through exploration of unsolved mathematical conjectures. As Courant and Robbins (1941) claimed in the introduction to their book *What is Mathematics?:* "it is not philosophy but active experience in mathematics itself that can alone answer the question: What is mathematics? (p. xix)" I believe that if students are to understand the nature of mathematics, they must have experiences similar to those of practicing mathematicians. In the case of pure mathematics, that means working on unsolved problems.

As an added component to the normal course activities, students were required to work in research teams on either the Twin Primes Conjecture (There are an infinite number of twin primes.) or the Collatz Conjecture (Given any natural number n, if it is odd multiply by 3 and add 1; if it is even, divide by 2. Then repeat the process on the result. Keep repeating. Eventually the sequence will reach 1.). As these are famous unsolved conjectures, students were not expected to find a complete solution to these problems. Rather they were expected to explore, try to come up with a proof, and document their efforts. The students documented their work in a mathematician's notebook. In this notebook, the students were also responsible for writing several reflections about their exploration. They sometimes read about the different conjectures online or watched videos pertaining to the conjectures and described what they learned. Their work in the notebooks accounted for 5% of their course grades.

In the first notebook assignment, students were tasked with exploring both the Twin Prime conjecture and the Collatz conjecture. They then chose a conjecture they would like to work on for the duration of the semester. They were also assigned to work in groups based on their preferences. About half of the students worked on the Collatz Conjecture and half on the Twin Primes conjecture, with some students exploring both. Midway through the semester we took the majority of a class period for students to share their findings with other members of the class. The students learned about new ways of attacking the problems and tried similar methods on their own. The students turned in their notebooks three times during the semester (once at the end), and two of those times I gave individual students and/or groups of students pointed feedback and direction to guide them in their exploration.

## Evaluation

Students had several reflective prompts they were required to address in their notebooks. For instance, during the first week of the semester, students responded to the prompts *What is mathematics all about?* and *What is a mathematical proof, and how is it used by mathematicians?* The students responded to these prompts again at the end of the semester, when they also responded to two additional prompts: (1) *How has your thinking regarding mathematics and mathematical proof developed and changed during this semester? Which changes were the result of engagement in the standard course activities (e.g. homework, tests, lectures) and which changes were the result of your experience conducting mathematical research (working on the unsolved conjectures)?* and (2) *What were the challenges and success of your experience with mathematical research this semester?*

My goals with this project were for students to engage in meaningful mathematical exploration, and to enrich their conceptions of the nature of mathematics and proof. In order to judge the effectiveness of the intervention, I reviewed each student's notebook, looking for evidence of productive mathematical engagement and changes in students' conceptions of mathematics. I especially focused on students' beginning of the semester and end of the semester responses to the reflective prompts. I especially sought to identify changes in the students' descriptions of mathematics and/or proof. As I reviewed the notebooks, I transcribed interesting and relevant student quotes and placed them into the following categories: 1) Enrichment regarding students' understandings of the nature of mathematics and proof; 2) Changes in students' descriptions; 3) Success; 4) Challenges; and 5) Fun discoveries. I then analyzed these quotes, looking for themes and takeaways. Analysis continued as I went back to students' notebooks, looking for evidence to support the different findings I was uncovering.

## Results

### Students' Productive Engagement in Mathematical Exploration

*Interesting Explorations of the Twin Prime Conjecture*

I now present a few of the interesting discoveries that students made. In the notebook assignments, I sometimes attempted to scaffold students by asking them to prove specific things, (e.g. any twin prime pair can be represented as $(6n-1, 6n+1)$ for some natural number $n$). One female student wrote, "The most time consuming and gratifying challenge was proving the twin primes are of the form $(6n-1, 6n+1)$. It was rewarding to have proved it, but it was quite difficult. That proof shows my best work."

In addition to being prompted to explore the conjectures in structured ways, students were also encouraged direct their own investigations, look for patterns, and document their results. One student, a pure mathematics major, found that the distance between twin prime pairs is always equal to $3x+1$ for some natural number $x$. During office hours he excitedly explained his conjecture to me, and he later explained his finding to the whole class. In Figure 1 you will find the summary of his argument that a female classmate, one of the student's group members, had written in her notebook.

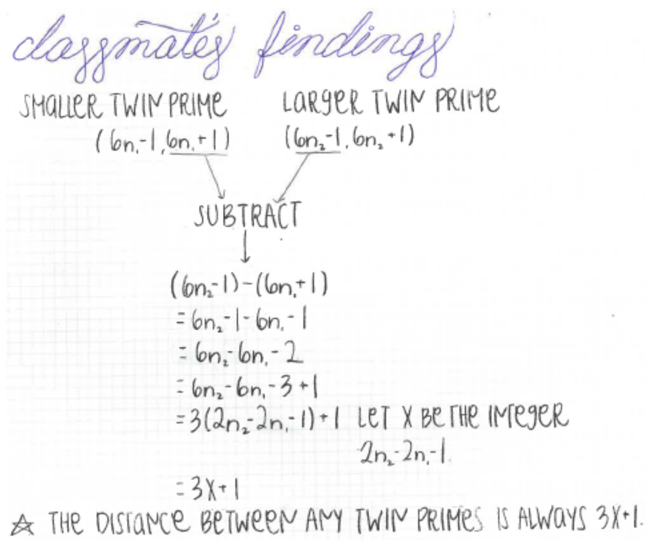



*Figure 1.* The distance between twin prime pairs

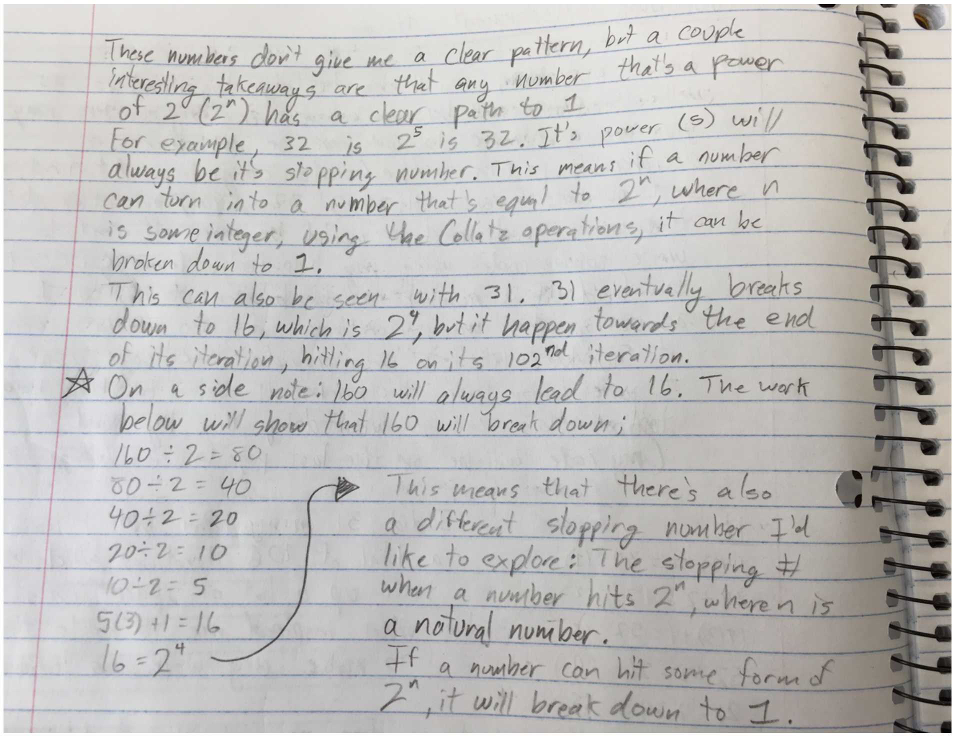
This classmate noticed that the $x$ in $3x + 1$ must always be odd. The student who originally discovered the result later wrote in his notebook,

> This notebook assignment has been one of my favorite math experiences yet. The idea of unsolved math problems fascinates and excites me […] I've been telling my friends that I'm in a math class where creativity is required, and they don't get it! I really like that the creative part of my mind is being used with the logical/analytical part for these problems. Looking forward to learning more!

The student's finding also sparked an interesting discussion in class, as coincidentally the distance between primes happened to be $3n + 1$; and half the class was working on the $3n + 1$ problem! Inspired by this possible coincidence, several students subsequently explored the connection between the Collatz Conjecture and twin primes.

*Interesting Student Explorations of the Collatz Conjecture*

As part of their directed investigations, students explored the *stopping number* pertaining to the Collatz Conjecture. If $n$ is a natural number, then the stopping number of $n$ is the number of iterations it takes before the Collatz sequence reaches 1. I asked students to find the stopping numbers for several natural numbers and look for patterns. Most students noticed that the stopping number of a natural number of the form $2^n$ is simply $n$. A particular student took this a step further, creating the concept of a $2^n$ stopping number: the number of Collatz iterations required before a number's sequence reached a power of 2. Figure 2 is an excerpt from his notebook in which he documented his discovery. This student later created a computer code that he used to find the $2^n$ stopping numbers of the first 100 natural numbers.



These numbers don't give me a clear pattern, but a couple interesting takeaways are that any number that's a power of 2 ($2^n$) has a clear path to 1
For example, 32 is $2^5$ is 32. It's power (5) will always be it's stopping number. This means if a number can turn into a number that's equal to $2^n$, where n is some integer, using the Collatz operations, it can be broken down to 1.
This can also be seen with 31. 31 eventually breaks down to 16, which is $2^4$, but it happen towards the end of its iteration, hitting 16 on its 102nd iteration.
☆ On a side note: 160 will always lead to 16. The work below will show that 160 will break down;
$160 \div 2 = 80$
$80 \div 2 = 40$
$40 \div 2 = 20$
$20 \div 2 = 10$
$10 \div 2 = 5$
$5(3)+1 = 16$
$16 = 2^4$

This means that there's also a different stopping number I'd like to explore: The stopping # when a number hits $2^n$, where n is a natural number.
If a number can hit some form of $2^n$, it will break down to 1.

*Figure 2.* A students' invention of the $2^n$ stopping number.

Other students creatively decided to work backwards, and several made trees such as the one in Figure 3, in which a female student mapped several natural numbers' paths to 1 along their respective and overlapping Collatz sequences. The students each explored the conjectures in their own way, making many unique observations and discoveries.

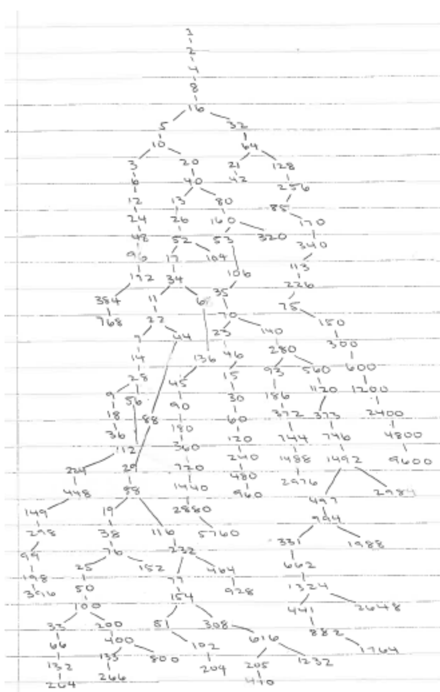


*Figure 3.* Collatz Tree

**Enrichment Regarding Students' Understanding of the Nature of Mathematics and Proof**

*Moving Beyond a Computational View of Mathematics*

Many of our mathematics majors, especially mathematics education majors, tend to enjoy mathematics because of its computational nature. Math233 is a struggle for many students who are asked to understand mathematics on a deep level, and write proofs, for the first time. Through this project, I hoped that such students' views would be challenged, and that they would develop more informed views of the nature of mathematics.

Indeed, I observed that several students' descriptions of mathematics changed from the beginning to the end of the semester. Here is a striking example. When responding to the prompt *What is mathematics all about?* early in the semester, one student wrote "Mathematics is about using formulas and equations to solve problems." And then at the end of the semester when responding to the same prompt the student wrote, "Mathematics is all about solving the world's greatest mysteries. Just from taking this class I have learned that mathematicians discover new problems and then spend their life trying to prove/understand it."

Other students had similar experiences, and they reflected how they were learning for the first time how proofs are used by mathematicians in the discipline. One student wrote, "Mathematics is more than just knowing formulas and how to use them but knowing how to use them and knowing why they work." As a last example of the contrast from students' beginning of the semester thinking to their end of the semester thinking consider the these responses to the *What is mathematics all about?* prompt:

> *First day:* "Mathematics is all about logic, theory, and computation. Mathematics is one of few subject matters that will give you an exact answer every time. The realm of theory and computation give mathematics multiple perspectives to get the same answer."
> *Last day:* "Mathematics is all about problem solving and trying to utilize different methods to solve a problem. Part of what makes mathematics so intriguing is the challenge itself and the struggle to get a potential solution. The work itself is what is of value when solving any sort of mathematics. Math is a true art of its own and it can be difficult at times to appreciate the complexity its gone through for us to understand it."

*Creativity and Mathematical Proof*

In the previous quote we find a student reflecting that math is a "true art." Earlier I described how one student enjoyed working on the unsolved conjecture because it provided him the opportunity to be creative. Creativity was a theme in many of the students' reflections. At the end of the semester a student reflected that "Math seems to be about persistence and wonder. […] Constantly pushing the axioms to form theorems means that we could potentially never stop discovering new mathematical ideas." While the creativity of mathematics was exciting for some students, it was a challenge for many. One student wrote,

> The main challenge I experienced during this research was using my creativity. It was very difficult for me to decide how and where to start. As Maynard had said in the video, he had to be passionate about primes and creative when he came up with his idea to do his proof.

Many students described the challenge of not knowing where to begin when working on the conjecture, or not knowing what to do when one could not find a pattern. An important aspect of being a creative mathematician is trying new strategies when one does not work. Several students wrote about how they learned that there are many ways to approach a proof. One student wrote, “I always thought that there was only one way to solve every proof. Now I know that it is not true. Every proof has similar outlines but the steps to get to the conclusion can vary.” Similarly, another reflected, “I learned we can look at an idea from many different angles, what matters is not giving up if one way doesn’t work.” Some students wrote about how they were required to think outside the box: “It forced me to think outside the box and use critical thinking skills I thought I’d never use in math.”

*A fuller understanding the discipline of mathematics*

In my past experience teaching introduction-to-proofs courses such as Math233, I have found that many students are not aware that modern mathematicians work to prove unsolved conjectures. Such students have never learned about the famous conjectures, the proofs of which have eluded mathematicians for hundreds of years. A student reflected, “If you have a conjecture, the only way that you can safely be sure that it is true, is by presenting a valid mathematical proof. A proof has to be well thought out and tested before being accepted.” I believe that the teaching intervention was valuable because students were able to learn about conjectures and the inner workings of mathematics. One student wrote that the experience working on an unsolved conjecture “showed me what goes into looking into a theorem or proof deeply.” Another wrote “Taking this class again and having done the notebook this time has been a great experience to understand what lies beneath mathematics.” Students learned about what Hersh (1991) referred to as the “back” of mathematics, the messy human work that goes into producing polished theorems and proofs. A student reflected that “it was definitely interesting getting a glimpse of what professional mathematicians struggle with when trying to prove something for its first time.”

Several students described how proof is used to build mathematical knowledge, and how the discoveries of one mathematician are used by future mathematicians. After watching a video interview of the mathematician James Maynard, a student wrote, “Mathematicians use these proofs to help prove other conjectures. As Maynard’s proof has influenced by Zhang’s proof. Eventually, Maynard’s proof will be used to help prove other conjectures.” I am encouraged that students learned about this building up of mathematics. There is evidence that some students even saw themselves as inheritors of the mathematical knowledge that has been developed by mathematicians: “Also by trying to prove the conjecture I am much more appreciative of mathematicians before proving and thinking up all of these theorems, formulas, and conjectures.”

*The importance of communication*

The last theme that I observed regarding benefits of this project for students pertains to the importance of communication in mathematics. When describing their successes in working on the unsolved conjectures, students described the benefits of collaborating with others. One student wrote, “With this conjecture work, it has helped me be more interactive with my group in regular class discussion, because we all know where we stand in terms of solving a conjecture.” Others discussed how impressed they were with their classmates’ findings related to the conjecture, remembering the day they had the opportunity to share their findings during class. At least one student reflected on the importance of collaboration for succeeding in mathematics:

> "I think working on this [Collatz] conjecture <u>alone</u> made me feel more like a mathematician. The stuff I realized and shared with the class was cool because they learned from me and vice versa. I wish we could have had more time to do so in class. It made me realize that the research/work of a mathematician can: 1: be done as a normal person, without the stress of working 24/7 on math with no breaks. And 2: heavily rely on others. Doing this work alone may not get anywhere any time soon, but working with a group of others will guarantee some progress.

**Challenging Experiences**

One of the most commonly noted challenges, as I described above, was the struggle with finding where to begin proving the conjectures. Some of the students seemed overwhelmed at the prospect of exploring an unsolved conjecture that many mathematicians have tried and failed to solve. Some even expressed misconceptions, believing that they were being asked to prove something "impossible." Others were confused how they were supposed to go about proving something "unprovable." One student wrote, "I think the main challenge is just the fact that it's a conjecture. I could not find a way to write any proof because I did not understand or recognize the pattern behind it. I'm not sure if I'm doing the assignment correctly." Other students had a defeatist attitude, not believing that they would have anything positive to contribute: "Working on the conjecture was more irritating than exciting because I can't prove it. It took away all the satisfaction because it is a famously unproven conjecture and I couldn't solve it." Another student wrote, "Although it was intriguing, I gave up preemptively because I knew that I would not do anything that would help come to any conclusion." These students described struggles, most were able to engage with the conjectures in some ways. In the future when implementing this project, I will need to find better ways to scaffold and support students as they work on this very challenging task.

## Concluding Thoughts and Takeaways

I believe there is evidence that many students learned a lot about the nature of mathematics through their work on unsolved conjectures. Several students had very productive mathematical experiences. But I also recognized that some students struggled and there are many things I can improve upon next time I teach this course and implement this project.

I found that students were very motivated to work on the conjectures initially, but it was not sustained throughout the entire semester. That is, they eventually become frustrated after they could not find a pattern or hit a dead end in their approaches. In the future, I would like to dedicate more time in class for students to present and share their findings. I think that this would encourage students who were stuck, as other students in the class may have insights into ways they might move forward.

Beyond having the experience of working on an unsolved conjecture, I think that the notebook assignments also helped the students reflect on what they were learning throughout the course. That is, they could step back and assess what they were learning about mathematical proof through the notebook reflection prompts. For instance, one student reflected,

> I think writing proofs slowed down my thought. I meant it in a positive way because I always make assumptions throughout the steps. I needed to understand that every step has to be true and supported by some logical statements. I had to take a step back and rethink if the statement I wrote holds true. Writing proof is not about finishing them fast, but it's all about the detail of each step.

In summary, I believe that this project was a success. Many students' conceptions of mathematics were enriched through the notebook assignments. Students learned about the behind the scenes work of the mathematician, the creativity involved in mathematics, and their own potential for mathematical exploration.

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