Note: Due to the fact that Math’s assessment activities take place throughout the 2017 spring semester, the draft submitted on 21 April 2017 was incomplete. The final assessment report for 2016-2017 is to be submitted by 3 June 2017.

Closing the Loop template
** Please see resources at the Academic Planning website

Department _____Mathematics______________________________

Department Contact _____David Bao ______________________

College ___of Science & Engineering ______________________

Please list your program learning goals.

Prose written on 18 May 2016 for the 2015-2016 Assessment Report:

There are many program learning goals listed in our assessment report. Here we would like to focus on Student Learning Objective 2a in our most recent (2011-2013) assessment report.

“Students will have learned how to guide their exploratory thinking when formulating and analyzing conjectures. They will have learned the rudimentary tools that are needed for constructing rigorous proofs; these tools include elementary logic and set theory, mathematical induction, relations, and functions. Students will also have learned how to articulate their arguments in sound mathematical English. “

Material added shortly before 21 April 2017 for the 2016-2017 Assessment Report:

We are maintaining our focus on students formulating and analyzing conjectures and constructing arguments.

Material added shortly before 3 June 2017 for the 2016-2017 Assessment Report:

No new material added
What assessment finding(s) is the department addressing?

Prose written on 18 May 2016 for the 2015-2016 Assessment Report:

MATH 301 (Exploration and Proof) is a required course of math majors, and is a curricular host of the SLO 2a outlined above. Within MATH 301, there are six Measurable Student Learning Outcomes (MSLO [1] through [6]); these metrics for assessment are more refined than the course grade. The most recent assessment (2011-2013) concluded that more effort needs to be invested in MSLO [6] “cardinality concepts”, because its risk index (failure rate of students who performed poorly on MSLO [6] versus the failure rate for all students in the course) has gone up slightly when compared to an earlier assessment.

Material added shortly before 21 April 2017 for the 2016-2017 Assessment Report:

On October 26, 2016, the faculty teaching Math 301 in Fall 2016 and Spring 2017 (Matt Beck, Federico Ardila, and Kim Seashore) along with associate department chair, Serkan Hosten, formed a working group to create an action plan for formative assessment in Math 301. We discussed common assessments, shared analysis of assessments and instructional responses to perceived students learning needs. As outlined in the CTL planning document, we agreed to focus specifically on MSLO [2] “Students will understand the role of definitions–axioms–theorems in building mathematical systems and constructing mathematical proofs” and MSLO [3] “Students will learn to construct, revise and critique correct mathematical proofs.” These two MSLO’s are fundamental to students’ continued success in upper division mathematics classes.

We agreed to gather new data about our students’ progress toward these MSLOs in the Math 301 classes in 2016-17. This data collection occurred in two ways: Direct observation and analysis of written student work.

Direct observation: The members of the faculty working group observed each of the four sections of Math 301 taught in 2016-17 (2 sections in Fall 2016 taught by Ardila and Beck, and 2 section in Spring 2017 taught by Beck and Seashore.) After each of these observations they debriefed what they had learned about student thinking, shared questions and strategies for addressing student difficulties that were arising in the class. Summaries of these observations will be shared with the deferred to the first Math department faculty meeting of Fall 2017, to include the results from the second Survey, administered in May 2017.)

Student work: In Spring 2017, students in both sections were given an assessment, survey 1, of their use of definitions and propositions, their ability to translate from English into mathematical notation, and their ability to structure a proof for a new
proposition. The working group met to analyze the results of these surveys and identified both productive and erroneous student conceptions.

Both the observation and the student work show that many students continue to struggle in Math 301 to identify what is known and what needs to be proven. Students demonstrated knowledge of several fundamental forms of proofs: direct proof, use of cases to prove a statement with “or” in the conclusion, proof by induction and proof by contradiction. However, students also showed confusion about which of these forms of proof applies to the specific proposition or how to productively apply the proof to the case.

Material added shortly before 3 June 2017 for the 2016-2017 Assessment Report:

**Survey 2:** In the final week of the semester (May 2017), we administered a follow up survey to students in the two sections of Math 301, Exploration and Proof. Survey 2 used the same definitions and propositions as survey 1. Similar to the first survey, this survey assessed students’ understanding of the role of definitions and propositions in an axiomatic system and their understanding of the structure of a logical argument. However, whereas survey 1 assessed students’ ability to interpret the meaning of mathematical language and outline a proof, including selecting an appropriate proof technique, survey 2 provided the outline for a particular proof of the proposition and required students to fill in the details. This allowed survey 2 to focus more specifically on students’ construction of particular parts of an argument and thus provided more insight into the specific challenges students were continuing to exhibit in writing proofs.

The five sections if the proof outline were structured to show the following aspects of proof:
a. A direct proof of an algebraic identity relying on axioms for the natural numbers.
b. Proving a bi-conditional statement and using a given definition (of “even”).
c. Identifying and using a given proposition in one case of a proof.
d. Recognizing when one case in a proof simply satisfies the conclusion and thus does not require further justification.
e. Concluding a proof with a summarizing statement.

In administering survey 2, students were given an unscored version of their work on survey 1 to use as a reference. Both surveys are included at the end of this report.

**Findings from student work on survey 2:**
Thirty students completed survey 2. The Math 301 instructors, Matt Beck and Kim Seashore, along with math department chair, David Bao, met to analyze the results. Student papers were given a holistic score of 1, 2, 3, or 4 representing overall accuracy and level of mastery conveyed by the work. The breakdown of the scores was as follows:
The majority of student surveys, 21 of 30, scored 1 or 2. This result is concerning, as it indicates that even at the end of the proofs course, many of the students are uncertain about how to employ these basic proof techniques or to follow an outline for a proof that may differ from their own.

We then completed additional analysis of each of the components of the survey. Just over half of the surveys (17/30) successfully completed part a, the direct proof of an algebraic property. Only 5/30 of the surveys completed part b correctly, but another 11/30 completed part b with a partially correct response. However, of these 16 responses, 5 chose to break this argument into separate cases rather than recognizing a single argument that would work for all values of m and n. 9/30 of the student surveys completed a correct argument for part c, although only 5 of these made use of the given proposition. Finally, 4 students completed parts d and e accurately and successfully concluded the proof.

The survey responses included many instances of students assuming the conclusion that were being asked to prove, using statements that were not justified with an axiom or proof, or assertion of propositions that had neither been given on the survey nor proven in class. In a few cases (4), students used numerical examples as a proof without generalizing from these examples. In three different instances, the students ignored the given structure and attempted to write their own proof. One of these attempts was mostly correct (making an argument using exhaustive cases) while the other two were not.

From these findings, we concluded that we need to focus additional work on students’ understanding of these particular proof structures as well as students’ ability to analyze their own work for some of the most common mistakes.

What was the process through which faculty considered a response to those findings? A department meeting? A special meeting about assessment? An end of the semester or academic year retreat? A department assessment or curriculum committee?

Prose written on 18 May 2016 for the 2015-2016 Assessment Report:

The said finding was discussed briefly during a departmental meeting, and then in more depth among some of the instructors of MATH 301.
Material added shortly before 21 April 2017 for the 2016-2017 Assessment Report:

The working group met together to develop responses to the findings from these two assessments. They developed both short term responses and a longer term response described below. These results and responses will be shared with the department at the meeting in May 2017. (This was deferred until the first departmental meeting of 2017 – see below).

Material added shortly before 3 June 2017 for the 2016-2017 Assessment Report:

These additional findings will be briefly shared in the opening departmental meeting in Fall 2017. In addition, we will be sharing these findings with the instructors for Modern Algebra (335) and Real Analysis I (Math 370) for Fall 2017. These are the classes that build most directly on Math 301. We are also planning on tracking continued progress with aspects of proof writing in these courses (see additional assessment activities below).

What changes have you made or are you seeking to make in order to address the findings?

Prose written on 18 May 2016 for the 2015-2016 Assessment Report:

During the discussions, it came to light that MSLO [6] “cardinality concepts” was taught near the end of the semester, when there was less time for the instructor to reinforce that learning and for the students to master that knowledge. Thus it was not a deliberate lack of effort that resulted in the risk index going up, but a matter of priorities. We also realized that any effort to improve the course would be better spent on MSLO [2] “definition-axiom-theorem” and MSLO [3] “writing correct proofs” instead, because these two MSLOs are key indicators of how well prepared our math majors are for their subsequent core courses.

Material added shortly before 21 April 2017 for the 2016-2017 Assessment Report:

Short term responses for Math 301:
The working group is developing a class activity for students to review a sample of the responses from the assessments in groups and to identify productive and erroneous aspects of these responses. This activity will include a class discussion of each of these categories of responses, such as reasons why induction does not apply to a particular proposition. Members of the working group will observe this discussion in one of the sections of Math 301. Following this activity, the instructors will be administering an additional assessment task based on the same proposition in early May 2016. Students will be asked to complete a proof given several possible productive templates. This second assessment will determine if students in these
two sections are making progress toward the goal of articulating their mathematical arguments clearly.

**Longer term responses:**
The working group will be sharing the finding and examples of student responses with the other math faculty and support similar discussions throughout the upper division, proofs-based mathematics courses. In addition, the working group continues to meet and coordinate with future instructors in Math 301 and other upper division, proofs-based mathematics courses, to identify resources for student to practice structuring and explaining mathematics and for making use of definitions, axioms and propositions.

**Material added shortly before 3 June 2017 for the 2016-2017 Assessment Report:**

We are continuing with the plans outlined above, particularly in the areas of Longer term responses. In addition, we are developing additional resources and exercises for students to target their identifying common errors in proof writing that can be added to the material for Math 301. We will continue to use a modified version of these surveys to see if these changes are improving student outcomes for future students in Math 301.

Suggestions regarding the students from the current Math 301 course. Mastering proof techniques is a challenging part of learning to engage the in the practice of formal mathematics. The work shown by students earning a 2 on this assessment, while concerning, also demonstrates emerging understanding. These students’ ability to write proofs is developing and we believe that the additional supports during the proofs class outlined above, along with building continued support for proofs into the subsequent math classes, will provide them the the necessary tools to be successful. The students with survey scores of 1 are a different concern. While some of these students may have performed better on more familiar tasks, their work on survey 2 shows they are having substantial difficulty with constructing fundamental elements of a mathematical argument. We will reach out to these students as well to offer additional support, particularly since some of them may be re-taking the proofs course next year.

**What assessment activities do you plan to undertake next academic year? Is there a particular program learning goal that you would like to assess? Are there other assessment findings that you’d like to address? In light of your assessment work, changes in the field, or other influences, do you want to take the opportunity to revise the program goals next year? Will you move on to assess a different learning goal?**
For the next academic year (2016-2017), we would like to invest more effort in MSLOs [2] & [3], as follows.

(a) We would like to make more specific our expectations in MSLO [2] “definition-axiom-theorem” and MSLO [3] “writing correct proofs”.
(b) We would like to share resources and activities (such as lesson plans and homework assignments) among instructors, with the hope that this mutual benefit will enhance the students’ performances on MSLOs [2] & [3].
(c) We would like to cultivate in the students an appreciation for the difference between the skeletal logical structure of a proof versus the equally important communicative aspects (key insight, viable idea, main ingredients, flow of the story line, impact of the conclusion, role in the Big Picture) of the same proof.
(d) We shall attempt to develop a common assessment mechanism for those two MSLOs, with the hope of constructively accounting for the difference in student performance that is possibly a reflection of different instructors’ teaching styles.

We believe that we are making progress on this very challenging learning goal. We know that this is a critical area for our students and that presents substantial challenge. The assessment tasks that we have developed this year we will continue to refine and use across sections of Math 301 in future courses to inform the instruction in those sections relative to these two MSLOs.

In 2017-18, we would like to survey students’ use of proof techniques in the fundamental courses that build on Math 301: Math 310, Math 335 and Math 370. We would like to use the assessment of students work in these courses to further inform modifications to teaching in Math 301, as well as in these courses.

No additional recommendation beyond those outlined in April, 2017.