Assessment of the Undergraduate Major without Faculty Buy-in

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Abstract. In response to accreditation requirements, UNR administration mandated that we assess our major. No consensus on how to proceed could be reached. In order to avoid losing operating money, the chair had to assess anyway. What worked well was to look for prominent problems. The department chair devised a simple spreadsheet tracking system and formalized a pre-existing exit interview scheme. The main problem that emerged was a high failure rate in our key analysis sequence. Our investigations showed that this was the result of inconsistent instruction and some misconceptions about the course. By promoting discussion it was possible to simultaneously engage the faculty and satisfy the administration. Important lessons to help others in handling similar situations are summarized at the end.

Background

In addition to numerous temporary instructors the department has 24 regular faculty. We offer bachelor of science and master of science degrees with options in mathematics, applied mathematics and statistics. In response to an accreditation visit, administrators decided that every department on campus must assess its majors. Unlike other useful assessments that math departments could do, such as for example an analysis of their lower division core liberal arts offerings or their service courses for engineers, looking at our majors required getting all faculty on board. Since departmental governance is highly democratic, all major policy decisions require a vote of the regular faculty. For assessment of the major, none of the standard approaches such as portfolios (which were seen as too much work) or exit exams (which were seen as bad for recruitment of majors) could garner a majority of support and thus reaching a consensus on how to proceed became impossible.

Details of the assessment

With no other choice but to assess alone, the chair settled on a very simple spreadsheet-based tracking system. This showed the courses and the grades received for each student. This did reveal some useful patterns. In particular, performance in Analysis I and II were observed as key predictors of overall success. In addition, failure rates were high and variable from year to year.

Departmental Mission Statement

The undergraduate mathematics and statistics major seeks to develop students who have knowledge in a broad set of content areas. These will vary in depth and precise content with program option but will include a significant number of the following:

- Calculus (Required)
- Linear Algebra (Required)
- Differential Equations (both PDE and ODE)
- Analysis (proofs-oriented advanced calculus) (Required)
- Probability and Statistics
- Numerical Methods
- Discrete Mathematics (graph theory, combinatorics, game theory)
- Topology
- Abstract Algebra
- Complex Variables
- Mathematical Modeling (although largely interdisciplinary with many of the other topics listed above, we also teach the difference in philosophy and approach required for many applied problems.)

In the process of obtaining this knowledge, the student will also achieve a significant number of learning outcomes described in Appendix A.

Long before the assessment mandate, the previous chair used a program of exit interviews with graduating seniors. Although this has been entirely the chair's responsibility, and thus a significant burden, it is a very useful activity. By providing a unique global perspective of department faculty, such a scheme is important both for assessment and annual merit evaluations. Because of the mandate, we decided to formalize this process. (See Appendix B for our questions).

In exit interviews it can be hard to get honest answers to questions like "Who was your least effective instructor?" or "Do you have complaints about our program?" Despite this, some very useful ideas for improvement were obtained but it wasn't always clear how to use these insights. For example, some professors were identified as inadequate in fundamental ways. How seriously should teaching assignments be reconsidered based on this?

As with any exit interview system, accuracy in measuring learning outcomes is severely limited. For example, questions that ask about the mastery of specific academic topics cannot be fully trusted. Most students simply do not possess the maturity to properly judge their level of expertise or the precise role of various subjects within their future needs. In many cases, however, the interview can be a good learning experience for students (especially when conducted in groups) and a recruiting tool for the department's graduate programs.

Findings

In addition to the variable passing rates and success which was highly dependent on performance in our analysis sequence, grade tracking also revealed a large increase in enrollment in Analysis I. Class sizes, which just a few years earlier had been in the low teens and below, were now regularly above 30. We were puzzled that there was no corresponding rise in graduation rates.

Exit interview data partially confirmed these observations. In all, 16 of 22 interviewed students reported that Analysis I & II was a massive culture shock that many students simply could not recover from. This is the transition between computational mathematics and the deeper theoretical aspects of the subject. Many seniors reported that other students changed their major as a result of Analysis.

These findings suggested that a more detailed examination of the courses was needed. Consequently, the chair focused closely on the tracking of all students (not just majors) who had taken Analysis I in the years from 1998-2001. He chose those years since virtually all the students involved would have completed or dropped out by now. Furthermore, the instructor was different in each of those 4 years. A study of student evaluations for these professors and courses was also revealing. To illustrate this, consider the following student comments. Each comment is from a different year. The indicated percentage shows those who went on to complete a mathematics degree.

- "Dr….. taught well and always helped outside of class. However, his grading was not as helpful. He often did not explain his marks on the homework." *46.6% success rate*
- "'Don't you get this?' and 'Isn't this obvious?' and other similar questions do a good job of building walls between you and students. These also take away bits of confidence from us each time. Not only do you easily follow rabbit trails, but you often create your own out of a misunderstood question from a student." *50% success rate.*
- *"*The instructor demonstrated a thorough understanding of the material and methods. However, he did not effectively relate this knowledge to the class in a way that was conducive to student progress. I had a very hard time learning from him. The class seemed to be a lot of magic and hand waiving [sic]." *52.2% success rate.*
- *"*I think the group concept worked very well. It turned out to be far more effective than if he had lectured to us. We discovered things on our own, and when we had questions, he was always extremely helpful." *68.7% success rate.*

While some level of failure is inevitable for students who simply do not have the passion and ability for proofs, remarkable improvements may be possible with the right teaching style. Encouraging students to work collaboratively and allowing them to redo and continuously improve on their work is critical to the success of this course and our programs.

Assessment via exit interviews was useful not only for what it revealed about our Analysis sequence. The following points show how assessment can be both rewarding and a refutation of commonly held misconceptions.

- Roughly 90% of graduating students reported that their professors were in general very helpful.
- Approximately 95% of students don't feel advising is an issue for them. The program is self-explanatory and the only times they had complaints were when extremely technical advising questions could not be answered quickly and definitively. This would be very hard to remedy in any systematic way. This is in contrast to administration's claims that the campus is doing a poor job with advising.
- Student tastes are very mixed. In addition to being the most difficult course, Analysis occurred over 75% of the

time as either one of the most relevant or one of the least relevant courses taken.
- Teamwork is very valuable for learning and the formation of study groups is very common. However, in some courses where work is graded this way there is a sentiment that not all team members share the workload. Consequently instructors may wish to promote group study habits without grading in groups.
- No one was able to say that the department teaches the use of technology in any systematic way.
- In contrast to the big push in mathematics for new forms of pedagogy, successful students overwhelmingly prefer the standard lecture format over other more interactive classroom formats.
- Students would like more information about career opportunities and internships as they proceed through the program. Mathematics students (as opposed to those in statistics) are often very uninformed about possible career paths. In the short term, the possibility of some graduate courses and the opportunity for part-time teaching is often extremely appealing.

Use of findings

From our key finding about Analysis I & II, it became clear that the department must carefully try to understand what is working in these courses and what needs to be improved. To this end the following conclusions were drawn:
- Analysis cannot be taught like other courses in the sense of lecture, homework, lecture, homework, exam. Instead, students must be given practice in writing proofs with constant feedback and many opportunities to redo and discuss their work. Only those instructors regarded as excellent one-on-one mentors who have lots of time outside of class should teach these courses. Group studying should be encouraged.
- Students who are not prepared for Analysis should be encouraged to a more gentle introduction to proofs course like the three semester secondary education preservice sequence. Recent discussions have proposed the creation a new transition to proofs course specifically for mathematics and statistics majors.
- Students must have more frequent access to Analysis. At the beginning of this assessment round Analysis I was offered every fall and Analysis II every spring. Once a year is just not enough for students who need to repeat these courses. The department has now gone to a system of offering each class every semester. This means that when an instructor is a poor fit with a class or a student is simply a slow learner, he or she can get right back in the game the next semester with a different professor. Conversely, when a student likes his or her professor in Analysis I they can follow them to Analysis II.

Truth in Advertising. Large enrollment increases in Analysis without a corresponding rise in graduation rates told us that we had a retention problem. On reflection, we realized that some students were attracted to mathematics because of their love for computations. Naturally, such students would be disillusioned when they encounter the shock of Analysis and it may not be appropriate to continue. We should not just give up on them but we also cannot expect to win every battle. This led us to rethink the course descriptions for these courses. We illustrate this with Analysis I :

> *Before Assessment:* (Analysis I) A re-examination of the calculus of functions of one-variable: real numbers, convergence, continuity, differentiation and integration. Prerequisite: Calculus III.

To the unaware this could have been interpreted as a kind of calculus IV taught in the usual way. Our new description will hopefully remind these weaker students of those scary passages in their calculus book which they always tried to avoid.

> *After Assessment*: (Analysis I) An examination of the theory of calculus of functions of one-variable with emphasis on rigorously proving theorems about real numbers, convergence, continuity, differentiation and integration. Prerequisite: Calculus III.

Reflections, lessons and next steps

In hopes that other departments can effectively benefit from our experiences, we present some lessons learned the hard way. Key points are highlighted.

Mathematics departments have a diversity of service missions unparalleled in other disciplines. This unique role can have a critical impact on departments when they are faced with assessment mandates. Dealing with assessment in a meaningful way that is not intrusive on the important professional practices of a large faculty, is an important consideration. *Mathematics departments should monitor the interpretation and formulation of assessment mandates on their campuses very carefully.* Some universities will be happy with any assessment while others will demand a specific kind or even mandate that departments assess everything in their service role. In contrast, most accreditors will not be too particular about what assessment departments do and this will mean that there are many opportunities to appeal to the expertise of specific faculty without engaging the entire department. For example, in our case experts in

mathematics education have NSF funding to consider the assessment and placement of students in lower division precalculus courses. Had we been proactive with the administration and their consultations with the accrediting agencies, we could have made this the centerpiece of our assessment efforts. The administration's lack of support of these placement efforts could be disastrous in the long run.

The beginning of the assessment procedure is deceptively simple and inviting. A mission statement and broad description of learning objectives are easy to agree on. However, *faculty involved in assessment should take care in distinguishing between a broad mission statement and extensive learning outcomes that shape what is expected of students and what faculty strive for and those aspects of a curriculum that can be reasonably evaluated.* The former is great to advertise your program, but for the latter it is essential to keep things manageable. For example, in our case the learning outcomes which require an appreciation for the interconnections of various areas of mathematics or the interplay between pure and applied mathematics are certainly important. However, they are impossibly broad to assess in a meaningful way.

Grade tracking is a useful alternative to a full blown portfolio system. There are, however, many ways this can be done, but care must be taken to factor in the grading standards different instructors have. In hindsight, for example, we could see that an expanded system where sequencing and instructor information is also used could have been very helpful.

We have learned that *there are several important techniques to making effective use of exit interviews.* At UNR we give students the exit interview questions in advance and they are asked to spend some time thinking about their responses before the interview. In addition, to get them to further reflect it is often helpful to have the interviews conducted in groups. This allows them to ponder each other's responses and further elaborate or provide counterpoint to the discussions. However, *exit interview questions and techniques should be continuously refined to be aligned with department goals.* For example, in the future we might well try to align our questions more directly with out learning outcomes (e.g., "Did your experience provide you with an appreciation of the interconnections of various mathematical disciplines?")

As we have explained, Analysis represented a serious problem for our majors. *When learning to prove things, hands-on activities with group studying and the opportunity to try again and again are essential.*

In retrospect, assessment has not been hard because our deficiencies and the key nature of Analysis sequence were obvious. However, by appealing to the faculty's desire to improve rather than to an attempt to motivate them to assess, we have simultaneously harnessed faculty energy for change and kept our administration satisfied.

We now need to document that these improvements are effective. Given the long range approach which we used to analyze the problem it will take some time (e.g., 4-5 years) to see the full effect of these modifications. In the meantime, we should begin anew with some other problematic aspect of our curriculum. We close with some brief musings on this.

- UNR has an office of institutional analysis that can access data for UNR and K–12. For instance, the ability to track student performance in our major programs in relation to various high school indicators (such as GPA or the highest math taken or whether math was taken during the senior year), could be exceedingly revealing. We should use this office to give us ideas for future assessment.
- We now have an additional mandate to assess all of our graduate degree programs. We will rely heavily on exit interviews and follow up alumni surveys. The additional perspective gained several years after graduation should be useful and the lessons learned in our exit interviews of undergrads will be valuable.
- While the department's major is not highly populated, we do service a very large number of mathematics minors. Could they be evaluated? What would be the objectives in this case? How can we know if we are helping students achieve these goals or if their own major programs deserve the credit? Since all the courses taken by our minors are also taken by our majors, such an investigation would also provide valuable insight to our major programs from a different perspective.

The secondary information gained through our exit interviews is also a great source of ideas for future assessment. In this regard the department could consider several approaches:

- Development of a survey for those who drop out of our major programs and courses.
- Alumni interviews might help shed light on the following: Should programs in applied mathematics and statistics be de-emphasizing the role of proofs in favor of other preparations? How much technology should we be teaching?

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Appendix A. Learning Outcomes

In the process of obtaining the broad base of content and skill based knowledge described in the department's mission statement, the student will also achieve a significant number of the following skills (whose precise emphasis will again vary by program option)

1. *Problem Solving Skills:* The ability to make precise sense of complicated situations in a variety of subject areas. This can include situations where there is too much or too little information and solutions will involve a variety of techniques from a range of different subjects.
2. *The appropriate use of technology*: This involves a range of activities from making routine calculations to modeling real world phenomena to experimentation with mathematical systems for the purpose of formulating conjectures and producing counterexamples.
3. *Modeling:* translating the real world into mathematical models that can be explored with technology and theoretical considerations. The results of such investigations must then be communicated to the lay mathematician or lay professional in a concise and effective manner.
4. *Methods of Proof:* Learning how to make rigorous mathematical arguments including how to both prove and disprove conjectures. This will also include reading mathematics and checking the proofs of others for completeness and correctness.
5. *Statistical Analysis:* This includes a firm understanding of a broad range of issues from the design of experiments to hypothesis testing and prediction to an understanding of when circumstances require consultation with more experienced statisticians.
6. *Working with axiomatic systems:* Proving basic facts from the axioms and determining if given examples satisfy the axioms. (Examples include but are not limited to the axioms for a vector space, groups & rings, a topological space, or those of Euclidean and non-Euclidean geometries.)
7. *Equivalence Relations and Equivalence Classes:* Understanding when operations are well defined on these classes and how functions either are or are not well defined with other structures.
8. *Appreciation for the interconnections of various mathematical disciplines:* This will include but is by no means limited to exposure to problems whose solutions involve a variety of disciplines as well as seeing techniques and modes of thought common to many subjects.
9. *Appreciation for the connections between applied and pure mathematics:* Understanding why distinctions between the two areas are not precise and how applied questions often generate large amounts of theoretical research.
10. *Appreciation for the career and educational opportunities for mathematics and statistics majors:* The realization that many professions value the problem solving skills of mathematicians and their ability to quickly learn and adapt to new situations. Likewise, statisticians possess a unique ability to interpret and gather highly useful and intricate quantitative descriptions of a vast set of circumstances. Both of these could certainly include internship experiences and a discussion of possibilities for advanced degrees.

Appendix B. Undergraduate Exit Interview Questions

Dear graduating senior,

Congratulations on your imminent graduation. Your hard work is about to pay off!

In order to improve our programs and curricula, we would like you to consider the following questions. When you meet with the chair soon he would like to discuss your feelings about each of these points. Your thoughtful and honest responses will be most appreciated. If possible, we may try to conduct these interviews along with other students. We have found that their responses often trigger deeper consideration and explanation of your sentiments as well.

Thanks you so much for your time and perspective on this very important matter.

1. What is your program option?
2. Are you getting a second degree?
3. What is your minor and how do you think these courses helped or hurt you?
4. What are your future career or educational plans?
5. What course(s) did you find most useful for your education?
6. What course(s) did you find least relevant to your education?
7. What course(s) did you find the most challenging?
8. Did you have instructors that you found to be most effective? Least Effective? Why?
9. What teaching styles did you think were most effective? Least effective? Why?
   - Traditional Lecture.
   - Computer Demonstrations.
   - Lab experiences/assignments.
   - Group Work.
   - Use of email.
   - Use of the internet.
   - Other.
10. How important was learning to write and read correct mathematical proofs?
11. Did you learn to use technology effectively and how important was this to your education?
12. How effective was the advising you received?
13. How important was the core curriculum to your education?
14. Do you have any general complaints or compliments about your experiences?