My Course Portfolio: A window on student learning and an entrance into further study

Case study of a mathematics capstone class (work in progress)

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During the fall semester of the 2000-2001 academic year I taught a capstone class in mathematics for prospective secondary mathematics teachers at Michigan State University. This paper is the story of my investigation of this course and what it has led to. I was originally interested in determining whether semester long student research projects in the course were effective in getting students to be more mathematical in their thinking. As the course progressed, however, I felt that better question was to examine and describe what was going on in the course, and how the projects might be affecting the progress of the course. For this investigation, I decided to create a course portfolio as an "occasion to investigating student learning" (Hutchings, 1998). As any good investigation should, this has led to further questions, in particular, what do conversations during office hours look like? And what happened in the case of one particular student to cause an apparent change in his attitude and understanding? The purpose of this article is to discuss the portfolio, describe how it led to other questions, and to discuss the current work I am doing to investigate these other questions.

Background and Description of Portfolio:

The capstone course (MATH 496 at Michigan State University) is meant to be a final mathematics course for students that brings together the disparate topics in the mathematics major. The students in my course consisted of seniors in mathematics that planned to become high school teachers. The idea of giving students a capstone experience in mathematics has come into vogue the last ten years or so, and MSU chose to have a course in some advanced mathematics topic that brought everything together. One of the problems with such courses is: How to engage students. That is, students with no intention to study advanced mathematics may have little interest in the course. As unengaged students do not learn to make connections, as they see little value in it, this can be a major problem. When first teaching such a capstone course at Bowling Green State University (BGSU), I noticed a second version of this problem. Namely, even though the students in the course were above average, few of them understood what mathematics was as they had no experience doing it, and thus they never became fully engaged in the course. The result of this was that the students treated work in the course as a set of hoops they needed to jump through.

The second time I taught the course at BGSU, in an attempt to engage the students in authentic mathematics, I instituted semester-long open-ended mathematical research projects as a component of the class. In groups of two or three students, the students answered complicated mathematical questions that forced them to confront issues their coursework never led them to before. For example, they needed to create definitions, to refine mathematical problems, and to become owners and creators of mathematics.[1] I began the work on my Carnegie project and my portfolio to investigate whether the projects were having the desired effect. As is common in research, however, my investigation of the question led me to understand that the question needed to be refined and changed. As a teacher, I knew that the projects were valuable for the class, and in my desire to *prove* this, I wanted to show that the projects were *working*. What became clear to me, however, was that the question should not be were they valuable, but rather the right question was why did I find them valuable? Consequently, the portfolio changed from an evaluation of student learning to an investigation of the class and student learning.

For the portfolio itself (Bennett (2001)), I collected pre- and post-surveys of the students, made copies of almost all of the graded homework assignments and exams, taped office hour conversations with the project groups, kept a journal, and conducted interviews after the grades were turned in. After sifting through this data, I then decided upon four introductory pieces setting the stage of the portfolio, ten artifacts centering on pieces of the class that I wanted to use to investigate student learning and how the class functioned, and four reflections on the course. Once these pieces were completed, I finished with an Executive Summary giving five different paths through the portfolio.[2] Of the five paths, two are concerned with investigating student learning: one on the projects, the other on the overall change in the students in the course. Two other paths deal with how I teach and grade the course: one devoted entirely to student work, the other focusing on my teaching. Finally the fifth path is for people that are teaching a similar course to read, and it focuses on the nuts and bolts of the course, the assignments, the outcomes, etc.

The artifacts in the portfolio correspond to ten segments of the course that give an overall impression of the course. The guiding thread for these artifacts and hence the portfolio is how I taught the class to attempt to get the students to have a deeper understanding of

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[1] Yakel and Cobb (1996) discuss how in mathematics classes at the K-12 level students rarely, if ever, see the creation of definitions, creating algorithms, etc. as part of mathematics that they are supposed to do. Rather they see this work as something the teacher does.

[2] I am indebted to Jack Bookman, a Carnegie Fellow, for the idea of giving multiple paths through the portfolio.

what mathematics is. Much like Roberto Corrada (see Corrada, 1996) needed to change his labor law course so that students could go through the process of forming a union, this course requires giving the students scaffolds for mathematical investigations. Thus the first artifact concerns the early homework sets where the students are asked to do small-scale investigations, while the second artifact discusses the research project requirement itself. After these two artifacts, other artifacts are presented to develop an understanding of student growth throughout the course. Of these others, the most important artifact as far as this paper is concerned, is the seventh, which focuses on one student's journey to mathematics.

Finally, there are four reflection pieces in the portfolio: "changes in the course wrought by the projects," "a surprising development on student conversations," "reflections on the course and running it again," and "concluding remarks." The reflections piece functions as an aid to memory so that the next time I taught the course I would remember insights I had from making the portfolio that I might otherwise forget. This falls into Hutchings (1998) characterization of a portfolio as an aid to memory. The concluding remarks piece is the assessment of whether the students (as a whole) met the objectives of the course. The first two reflection pieces, however, are of a different nature than the last two. These were the reflections on the surprises, and in particular, what I learned from process of collecting the data and reflecting on it to create the portfolio.

What I learned from the portfolio:

Dan Bernstein argues, "that the major benefit of the course portfolio lies in uncovering how effectively the course goals for student learning are being met." (Bernstein, 1998, p.77) Certainly, this is one of the things I was able to glean from the portfolio. To write the last of the reflection pieces, I was forced to go through the outcomes one-by-one and evaluate what assessments were relevant, and occasionally to only be able to make sense of whether the students achieved the outcome by turning to interviews and other non-graded assessments. Indeed, as Bernstein further argues, one "benefit of the course portfolio is not that it transforms one into an education specialist, but that it makes visible the need for and power of information about student learning." Based on my experience, I would alter this statement slightly. For as I will argue later in the paper, the portfolio itself led me to approach new questions about student learning. Thus the portfolio did more than make visible the need for information about student learning, it dictated the type of information to gather[3]. I was able to conclude from the portfolio that these students were achieving the objectives of the class for the most part, although for many of the process objectives, it was necessary to use non-graded assessments.

While assessment of a course is a reason that one might want to present a course portfolio, in truth, it was of lesser importance to me. This relates to my belief that I can

[3] I differ from Bernstein, however, in that for me it was not the assessment portion of the portfolio that led me to believe in a need for greater information about student learning, but rather it was an analysis of the teaching and why I felt the projects were beneficial that led to this need.

assess fairly well whether a course has been successful in achieving its objectives without the work required of creating a portfolio. Indeed, I contend that if the only purpose of the scholarship of teaching and learning is in assessing our courses, then the field[4] is in trouble, as it will cease to be a tool for scholarly investigation and turn into a tool for "proving" that we are doing our jobs. Indeed, it was only after I decided not to assess the semester long research projects in this scholarship that I decided to make a portfolio[5].

The true value of my portfolio for me was, in the words of Deborah Langsam (1998), "as an organizational framework for my thoughts about teaching and learning" in this course. By modeling the portfolio on an artist's portfolio, I selected ten items that I thought were most explanatory of my work in teaching the course. Like such a portfolio, however, I wanted to make each artifact one that you could spend between one minute and one day on.[6] Consequently, while each page is meant to be short, there are many possible links so that one can get lost in it. The value of this for me is in the reading and rereading to garner insights. The portfolio has provided a window through which I can explore and understand my teaching and the students learning. On the small scale, I recognized that in order to make the student project work successful, I was providing the students with more scaffolding than I imagined. In fact, the first artifact was an outgrowth of this, as I realized that the first homework set could be viewed as a first entrance for students into conducting their own research.[7] Other discoveries were that the students saw the central point of the class differently and yet more clearly than I did myself. Alan[8] remarked that the class was really about "how you do mathematics." Until he put this into words, I did not see this framing of the class; one I now find valuable for framing the discussions of the class.

In the creating the portfolio, I found myself spending days on each artifact, sifting through data, organizing ideas, and presenting work. The downside of this is that the rigor level of the portfolio is not as strong as one would want for investigating specifics of student learning. Thus, the portfolio provided me with a framework that produced insights and questions from which I could move forward to investigate other issues in teaching and learning. Among these issues are the two that I am beginning a new evaluation of: the evolution of the learning of a single mathematics student, and an analysis of student-professor interactions in office hours.

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[4] Indeed, in a discussion of what is the field of the Scholarship of Teaching and Learning at the Carnegie Reunion conference, Lee Shulman (2002a) argued that what mattered in this field is if we met the standards of (1) Commodity – is it worth something? (2) Firmness –will it stand up? And (3) Delight – is it fun? If assessment is the only purpose of such scholarship, then I think it will satisfy firmness, but will fall far short in the areas of commodity and delight.

[5] A similar sentiment is heard from Donna Martsolf when she suggests that "constructing a course portfolio made sense only when I had a compelling reason to do so" (p.28).

[6] In the words of Carnegie scholar Peter Alexander, the portfolio is "easy to skim, but hard to read."

[7] In fact, the next term when I taught a different set of students, one of them remarked after not doing the first set that based on classroom discussion it seemed that the point of the set was more to encourage investigation than to have the students give specific answers.

[8] The names in this paper are pseudonyms for the actual students.

Investigating the learning of a single student:

The seventh artifact of the portfolio is “a student’s journey to mathematics.” This artifact analyzes the growth of a single student, Neal, throughout the term. In the portfolio, I provide a snapshot of Neal’s learning by presenting four of his homework sets, his midterm, his final exam, and the project that his group submitted. Neal interested me as a case study of a common type of prospective mathematics teacher. He reported that he was good at mathematics in high school, and yet when he reached higher-level collegiate mathematics, he discovered that he was no good at this “proof stuff.” Indeed, as related in the portfolio, early on he came to my office to tell me that he needed a “B” in the class to be allowed to do his student teaching.

The portfolio artifact argues that Neal transformed throughout the semester and became much more mathematical in his thoughts and approaches to the class and to teaching. The argument unfolds through the analysis of his work. Quoting from the portfolio (Artifact 7, Analysis):

> In his initial survey Neal said, “...my success in mathematics has not been spectacular in the past two years....” He described himself as someone that had not been competent at mathematics and had gained little understanding of the role of proofs in mathematics, and his role in creating proofs. Moreover, Neal was not alone. During the first week of class, I noted in my journal, “I am suddenly aware how much the students fear doing any math on their own.” Many of the students had been unhappy when I asked them to attempt to write a calculator program that performs long division. They found the work frustrating, but also very different from what they had done in the past.

This perspective was further shown in the homework that Neal was doing early in the term. Again with early homework problems, he has difficulty working with mathematical language and recognizing key steps in problem solving. Again, the portfolio frames these questions.

> These two traits together are worrisome in a prospective teacher. To begin with, teachers that are only procedurally competent at mathematics do not have the deep understanding that is necessary to approach topics in multiple ways. Moreover, they are unlikely to be able to develop ideas on how to help students in specific cases. The second shortcoming is even more damaging. Teachers that do not engage in investigation of mathematical topics are unlikely to acquire what Li Ping Ma refers to as “Profound Understanding of Fundamental Mathematics (PUFM)” (Ma, 1999). In her work, she interviews Chinese and American elementary mathematics teachers. She notes that the teachers that truly exhibit PUFM are those that tackle new problems as investigations and engage in the

> investigation. An attitude towards mathematics that includes a belief that, "I could not afford to be creative" will make teachers unlikely to perform investigations of topics that require this sort of thinking. If one hopes to see American teachers starting classes off with problems as the Japanese teachers do in the TIMSS tapes (Stigler and Hiebert, 1999), they need to be able to engage in the problem with confidence. Moreover, as Shulman (1985) points out teachers that lack confidence in their abilities in the content of the discipline are less likely to teach in engaging ways.

The portfolio analysis led to similar ideas surrounding Neal. In his interview, when asked, "would you be more likely to deal with a student's question that you don't know the answer to? Now versus before?" his response was

> *Yeah, because, whereas before it seemed like oh, shove it under the rug somehow, and yeah.*

By the end of the semester, however, Neal is different. On his final exam, Neal shows competence at presenting mathematical proofs. Moreover, he recognized his inability to answer some questions. For example on the first problem of the final exam he wrote:

> *As for the third derivation... I am empty-handed. However I see something that may be of use...*

Recognizing his inability to answer and engaging in a discussion of what can be done. Neal also showed an attitudinal difference in the course. At the end of the term, he felt that mathematics must be sparked by an "inner motivation inside the individual." Moreover, his ideas of how to teach and present changed by the end of the class.

> *So one thing I definitely want to apply as a teacher is to try to instill the idea with kids, with students, encourage them to bounce ideas off of each other. So in creating lessons, in creating discussions, group work when bringing up challenging ideas, see what kind of questions they have. Trying to spark an interest with the students themselves, but letting them do the exploration so they can create a sense of ownership - perhaps.*

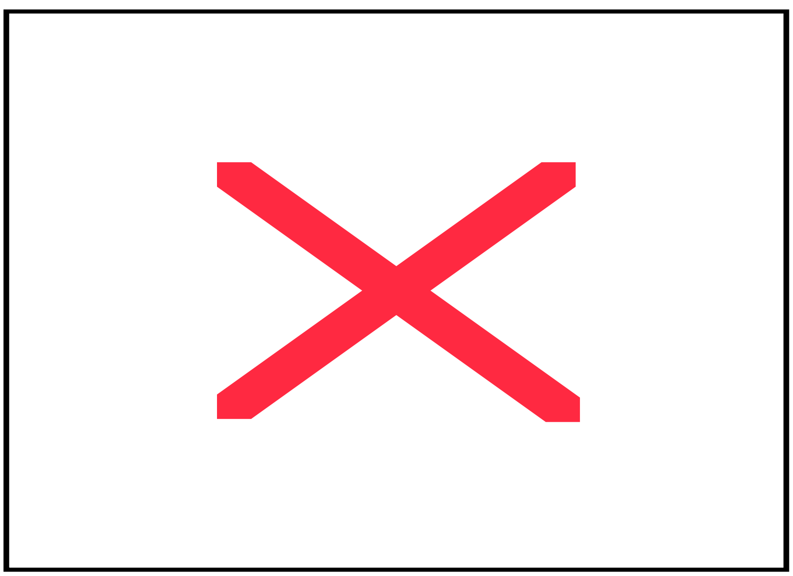
Finally, his confidence changed. He realized that he was no longer afraid to attack mathematics problems, when he said,

> *Not being afraid to say, well, OK why are we why are we looking at this, where does it come from, and I think there is a motivation factor in there. Once you know why, you can go ahead and maybe develop some confidence in attacking things.*

Thus the portfolio argues that Neal had undergone a transformation. This, however led to important questions: Will a more rigorous analysis of the data lead to a similar conclusion? And if so, what factors led to this change?

Currently, I am wrestling with these two questions together with David Meel, a colleague at Bowling Green State University. This analysis is taking coursework gathered for the portfolio together with a copy of Neal's course notes in the term, and his interview transcripts and attempting to provide a richer understanding of Neal's transformation. In particular, we are approaching the evidence with more rigorous research standards, and we are viewing it through a framework of mathematical understanding and problem solving work (see Schoenfeld, 1985 among others).

The analysis of Neal's notes has proved incredibly interesting so far. His notes contain many marginal notes, diagrams, and comments. The content of the marginalia changes throughout the term, and our early analysis of this shows three clear trends. Perhaps most interestingly, the notes that reflect applying the learning taking place in the course to teaching occur at greater frequency as the term progresses. Indeed, in the first ten days worth of notes, there are no marginal comments about teaching, while in the last twelve days, Neal averages one marginal note concerning teaching every day. Cross matching this data with the taped office hours on the project discussion, we see that somewhere around the 20th day of note taking, the project conversation turned heavily to what can be taken to the high school classroom. This conjunction seems particularly compelling to the idea that Neal's thinking was transforming. As we are completing this research, a next step is to transcribe this specific conversation and analyze it.



A second interesting occurrence in the marginal comments is that factoid comments, those of small mathematical significance, drop off as the term progresses. Again, one conjectures that Neal saw less relevance of factoids to his learning. A third trait is that noting down heuristics also seems to decrease as the term goes on. On all three marginal notes, other possible explanations do come to mind, however. In particular, one possibility is that how I taught the class changed through the term changing what he paid attention to. In truth, I think there may be some truth to this in the case of studying heuristics. Early on in the course, I provide scaffolding for my students for their research projects by raising various mathematical heuristics to help them do their own investigations. Another explanation is that as the students became familiar with my grading of the class, they felt factoids and heuristics were less important to remember, while teaching was more important.

To finish the work on Neal's understanding, we still have much to do. A stronger analysis of the data needs to be performed, and Neal's work on the homework should be cross-referenced with his project discussions and notes to get a fuller picture of how he went through the transformation. Let me present one interpretation which we will test against the evidence using Shulman's taxonomy of learning (Shulman 2002b)[9]. Shulman's taxonomy consists of the following six steps: engagement, understanding, performance, reflection, design & judgment, and commitment. Neal began the semester unengaged with higher-level mathematics (as seen in his comment about not being able to do the "proof stuff," but still feeling competent to teach mathematics in the high school). Indeed, his vision of mathematics as he would teach it was one of "practice the procedures"[10]. The project and coursework *engaged* him with mathematics by situating the mathematics in context and making him part of the construction process. In acting (or *performing*) mathematically to attack the problem, he began to *understand* the true nature of mathematics as a creative discipline. In particular, he was forced to make *judgments*, create definitions, and use mathematical heuristics. This is supported by office hour tapes. To write the project paper and to answer homework questions relating work in the class to the high school curriculum and our understanding of numbers, Neal was pushed to *reflect* on his mathematical understanding. Quoting from the portfolio, Neal "starts making the comparison **for himself** between the pairing of algebraic and transcendental numbers." Indeed, when he said, "I like to think of algebraic plus transcendental numbers as parallel to the integers plus the rationals, plus the irrationals plus the complex numbers…" he showed a greater ability to reflect and build understanding. This reflection then built a greater willingness to *judge and design* mathematics. His project group created conjectures about what might happen on questions related to the ones they were studying, something they appeared unwilling to do at the beginning of their investigation. Moreover, Neal began to recognize when he didn't know things. That is, he exercised his own judgment in reflecting on his work. In the post-class interview, Neal showed a *commitment* to mathematics that was missing early on. In particular, at the beginning of class, he was satisfied with getting a B in the class and being able to go on to the high school classroom and present procedures. At the interview, however, he said:

> *So in creating lessons, in creating discussions, group work when bringing up challenging ideas, see what kind of questions they have. Trying to spark an interest with the students themselves, but letting them do the exploration so they can create a sense of ownership - perhaps.*

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[9] A key point of Shulman's taxonomy is that progress through it need not be unidirectional or even necessarily linear in fact, Shulman explicitly said that "directionality is situated in context" (2002b).

[10] Stigler and Hiebert (1999) describe U.S. mathematics teaching (at the middle school level) as one of "learning terms and practicing procedures." They contrast this with teaching in Germany and Japan (via the TIMSS study) as "developing advanced procedures" and "structured problem solving" respectively.

He has become committed to bringing his students a sense of mathematics as it is really practiced.

Of course, this pathway to becoming a mathematical thinker needs to be fleshed out further – and more evidence needs to be found. That is the work we are undertaking now.

Analysis of Office Hour Conversations:

The other exploration we are undertaking as a result of the portfolio arose out of noticing that classroom conversations in this class seemed different from other classes. Students asked about mathematics research several times in the class, something that rarely happens. During the term, there were four specific cases that I noticed. One day they asked me about my research areas, one day they stopped class to ask me to explain how we know  is transcendental, one day they asked me detailed questions about cardinality issues and non-standard analysis, and one day they asked me to explain Gödel's incompleteness theorem. One explanation for this difference in conversations and questions from the students is that the students of the class were special. However, the students themselves admitted that they do not usually ask so many questions. Some attributed the questions to the instructor and my methods of teaching, but other reasons were suggested. In analyzing conversations during office hours over the projects, I felt that these were somehow different than typical office hour conversations I have. Thus, these ideas together brought up the question of understanding conversations in office hours more deeply, and in particular trying to understand if the differences I sensed were imagined or not, and how they might apply to the classroom discussions.

Typical office hour conversations with students are like a formal dance. Students come in to ask me about a specific problem in the book. They believe that their job is to ask questions until suddenly they happen upon the right question that causes me to give them the key to solving the problem. On the other hand, I see my job as to ask them questions to create a greater understanding so that they can work their way through the problem. In the dance we work together with different goals, and when the dance is over, if it goes well, both of us think we have succeeded. I believe one thing that makes the dance hard to stop is the time component. Students ask about problems that are due soon. They don't want to leave until they have answered the question. For my part, I am concerned that the students finish the assignment and don't become discouraged. Consequently, I am happy to keep working with them until they have the answer, thus forcing the dance to come to a close when we meet.

Office hour conversations around the projects, however, appeared to have a different tenor. Neither the students nor I are worried (during the early stages) about the students leaving my office without an answer. Rather, they want direction, and I am happy to give them some direction. Interestingly, because of the open-ended nature of the projects, early on it seems what they really need is encouragement. Consequently I appear to spend a great deal of time early in the term saying things like "that's a good idea" and then let the group wrestle with its problem in the way a mathematician does. I theorize that the projects create a more authentic environment for doing mathematics, and this carries over to the office.

Upon analyzing these conversations, however, it became clear that I don't have evidence to support my view of traditional office hours. Moreover, it is also apparent that there are many different types of interactions. Thus, another current project is to characterize office hour conversations. To this end we have collected data from two courses taught in the fall term. Nearly every office hour conversation was taped. Thus we have over 100 conversations in our database to categorize and study. The goal, however, has again changed from evaluative to descriptive. Rather than judge whether the projects create better office interactions, rather we want to see what interactions occur, and try and see if we can suggest reasons for them occurring. The nuts and bolts of this investigation have not really started, however, and reporting on this must wait till another time.

Conclusion:

A distinction should be made between portfolios meant for assessment and portfolios meant for analyzing student learning. A portfolio whose aim is assessment needs to be short and directed, while a portfolio that describes student learning (and the course) will be longer and open to multiple readings. A main contention of this paper is that a course portfolio of the latter type provides a springboard for other projects in the scholarship of teaching and learning, even if this was not the original intent. Moreover, these two purposes, describing student learning and raising questions for study, are symbiotic. In writing the portfolio, questions arise that the portfolio begins to answer. Meanwhile, the questions help determine what is examined and described by the portfolio. For me, a descriptive portfolio has value for the scholar of teaching and learning, because, as with any good research, the results usually lead to more questions.

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