



Primarily Statistics: Developing an Introductory Statistics Course for Pre-service Elementary Teachers

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Abstract

We developed an introductory statistics course for pre-service elementary teachers. In this paper, we describe the goals and structure of the course, as well as the assessments we implemented. Additionally, we use example course work to demonstrate pre-service teachers' progress both in learning statistics and as novice teachers. Overall, the course aims to help pre-service teachers recognize the importance of statistics in the elementary curriculum, as well as the integral role they, as teachers, can play in a student's entire statistical education. Our course serves as a model/resource for others interested in pre-service teacher development.

1. Introduction

Introductory statistics pedagogy is evolving to help create a statistically literate society ([Kettenring, Lindsay and Siegmund 2004](#)). The Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report recommends introductory statistics courses emphasize statistical literacy, foster active learning and develop effective communication of statistical concepts ([Garfield et al. 2005](#)). However, sound statistical reasoning skills are not obtained in one general education statistics course, but instead need to be nurtured and developed over the course of one's entire K-16 educational experience ([Franklin and Kader 2010](#)).

The GAISE Pre-K-12 Report outlines the different levels of inferential understanding K-12 students should acquire, but teachers need to be adequately prepared to help students meet such standards ([Franklin et al. 2007](#)). According to the Mathematical Education of Teachers (MET) II Report ([Conference Board of the Mathematical Sciences \(CBMS\) 2012](#)),

Many teachers... will need to study content that they have not previously taught, particularly in the areas of statistics and probability (p. 68).

While this applies to teachers at middle and high school levels, elementary teachers are also ill-prepared to construct meaningful learning experiences that foster statistical literacy:

Statistics is the science of data, and the daily display of data by the media notwithstanding, most elementary teachers have little or no experience in this vitally important field ([CBMS 2001, p. 87](#)).

While introductory statistics courses typically meet the need to create statistically literate citizens, they do not necessarily provide the opportunity to develop pedagogical content knowledge that goes beyond a basic understanding of the content teachers will be teaching. To define statistical knowledge for teaching, [Groth \(2007\)](#) builds upon the [Hill, Schilling and Ball \(2004\)](#) description of common versus specialized knowledge. He argues that statistical knowledge for teaching requires a different level of understanding and skills than mere subject matter knowledge. For example, both statistical practitioners and teachers need to possess the subject matter knowledge of how to make and interpret boxplots and dotplots. However, teachers also need additional knowledge “of how students decode such data displays” ([Groth 2007, p. 430](#)), so they can anticipate common student difficulties and structure pedagogy accordingly. Therefore, pre-service teachers need a course that integrates not only content, but also pedagogy and assessment issues ([Franklin and Kader 2010](#)).

We created a course designed to develop and equip pre-service elementary teachers with the statistical knowledge they need for teaching. [Metz \(2010\)](#) describes a similar introductory statistics course for pre-service elementary and middle-level education teachers, and how it was revised using the GAISE framework ([Franklin et al. 2007](#)) and the National Council of Teachers of Mathematics (NCTM) Standards for Data Analysis and Probability ([2000](#)). The units described in the revised course outline focus mainly on descriptive statistics and probability, with emphasis placed on understanding and appreciating variability in data; statistical inference is left as an optional topic. While the goals of our course are similar to those described by [Metz \(2010\)](#), we want to elicit inferential thinking in our pre-service teachers throughout the majority of the course.

As we were developing our new course, a group of researchers at the University of Minnesota was creating introductory statistics materials to immerse students in statistical thinking. Their work was part of the National Science Foundation-funded CATALST project ([Garfield, delMas and Zieffler 2008-2012](#)). The CATALST activities use simulation and randomization-based methods similar to those described by [Cobb \(2007\)](#), [Rossman and Chance \(2008\)](#) and [Tintle, VanderStoep, Holmes, Quisenberry and Swanson \(2011\)](#) to reinforce the concept of natural variability and, in turn, inferential thinking. These methods are used to build empirical sampling

distributions for statistics (e.g., \hat{p} , \bar{x}) commonly covered in introductory courses. Because elementary teachers are encouraged to use simulation with manipulatives in the classroom (e.g., [Franklin et al. 2007](#)), the simulation/randomization approach seemed like a natural fit with our course goals. In addition, the MET I and MET II reports ([CBMS 2001](#), [2012](#)) emphasize the importance of developing the habits of a mathematical/statistical thinker, which coincides with the goals of the CATALST project. The CATALST materials are aimed toward a general audience, so we collaborated with the CATALST group to adapt some of their activities for use with pre-service teachers.

In this paper, we describe the course we developed and taught so that it can serve as a model/resource for others interested in developing and/or revising a similar course. We provide details on the goals and structure of the course, as well as the assessments we implemented. Additionally, we use example course work to illustrate what the pre-service teachers have learned as students of statistics and as novice teachers.

2. Course Goals and Logistics

The newly developed course is a 3-credit hour, non-calculus based introductory statistics course. Most undergraduate introductory statistics courses at the University of Nebraska-Lincoln (UNL) are taught by graduate student instructors. In contrast, two statistics faculty members (the authors) were assigned in fall, 2011 to develop and co-teach this new course for pre-service elementary educators. We both had previous experience developing and teaching courses for in-service middle-level and high school teachers, and we were both in the classroom during all class meetings.

The goals of our course align with those presented in the GAISE College Report ([Garfield et al. 2005](#)). The course emphasizes statistical thinking and focuses on the need for data, the importance of context, and the omnipresence of variation and its role in inference. We also incorporate a purposeful balance of content, pedagogy and assessment. That is, in addition to covering statistical concepts, we directly discuss and/or indirectly model how to teach and assess student understanding of these concepts. Overall, we hope to help pre-service elementary teachers gain a deeper understanding of statistical concepts and a vision for providing elementary students with meaningful, enriching opportunities to develop sound statistical reasoning skills. In addition, we want pre-service teachers to develop an appreciation for statistics as a discipline separate from mathematics and an awareness of its connections to multiple subjects, such as science and social studies.

Because our vision for the course encompasses both statistical content and pedagogy, we structure the course to model effective classroom practice and to prepare the future teachers for their upcoming professional responsibilities. We purposefully encourage a student-centered learning environment, in which we replace lecture with student-driven activities and discussion. During most class periods, pre-service teachers complete statistical activities chosen to emphasize key ideas for teaching and learning statistics. Most of these activities, including those adapted from CATALST, involve the use of simulation implemented in the TinkerPlotsTM software ([Konold and Miller 2011](#)). Our classroom provides one computer for every two students, so lab activities are generally carried out by pairs of pre-service teachers. The course

offered in fall, 2011 met twice per week, and the 75-minute class periods allowed us to complete most activities, including a wrap-up class discussion, during a single session.

While our course does not have a practicum component in which the pre-service teachers have the opportunity to interact with elementary students, we still want to expose the pre-service teachers to common student conceptions in elementary-level statistics. The course uses, but does not rely heavily on, the textbook *Mathematics for Elementary Teachers with Activity Manual*, 3rd edition (Beckmann 2010). Two chapters of the book cover statistics, data and probability, and the activity manual includes exercises focused on pedagogy and diagnosing student errors. While we acknowledge that other textbooks may be more comprehensive, we chose this book because it is used by the required mathematics classes at UNL for the elementary education major. The textbook and activity manual are predominantly used during the data summary section of the course. The CATALST curriculum (<http://www.tc.umn.edu/~catalst/>) did not require the use of an additional textbook, and we adapted some of its materials for use during the inference sections of the course.

In order to become endorsed, or certified, to teach at the elementary level in our state, teachers must complete a minimum of six credit hours in mathematics, which includes statistics; our newly created course fulfills three of these credit hours. During this initial semester, one section of the course was offered, and enrollment was limited to 30 students who had declared an elementary education major. At our university, students who major in elementary education apply to a Teacher Education Program once they meet the course and competency criteria required for advanced phases of teacher education.

Twenty-six pre-service teachers were enrolled in the course during the fall, 2011 semester. Of the 26, 23 were female and 3 were male. The majority of the pre-service teachers were underclassmen (freshmen and sophomores), and, in fact, 65% (17/26) were first-semester freshmen. Consequently, most of the pre-service teachers had not yet been admitted to a Teacher Education Program and had little experience with elementary students beyond their own memories of primary school. In addition, due to the large number of first-semester freshmen, the pre-service teachers were still adjusting to college and its elevated expectations. We expect pre-service teachers in future iterations of the course to have similar characteristics.

3. Course Outline

The course has three main units: 1) Chance Models and Simulation, 2) Data Summary and 3) Models for Comparing Groups. These three class modules are based on the first two units from the CATALST project. Because of the emphasis on data summary in the elementary curriculum, more time is devoted to data summary in our course than in the CATALST materials. We devoted approximately the same amount of time to each of these three units.

The first unit, Chance Models and Simulation, focuses on helping pre-service teachers understand concepts of randomness, including variability. These are key statistical ideas the CBMS (2012) states prospective and practicing teachers need to know. The materials used help pre-service teachers recognize that variation is expected and that the behavior of random processes can be modeled through simulation. With the use of interactive software, such as

Tinkerplots™ ([Konold and Miller 2011](#)), pre-service teachers transition from modeling random occurrences literally (e.g., the number of heads observed in 15 coin flips) to modeling real-life situations abstractly (e.g., the frequency of incorrect true/false test responses as represented by the number of heads observed in 15 coin flips). In each activity, pre-service teachers must identify the underlying random process used to simulate the null model. Dotplots of the simulated results illustrate that variability is natural and provide pre-service teachers with a means by which they can gauge the “unusualness” of observed sample data. In addition, because of the nature of the simulations, pre-service teachers investigate differences between theoretical and empirical probabilities, a recurring standard in the elementary curriculum. Discussions focus not only on how the pre-service teachers can use the simulated models to answer research questions and quantify the estimated likelihood of certain outcomes, but also on how they can use a similar approach in their own classrooms to help their students develop statistical thinking skills and understand the differences between theoretical and empirical probabilities.

After modeling random processes, pre-service teachers then shift their focus to how to describe the characteristics of distributions. While only one CATALST activity specifically addresses this learning objective, our course devotes an entire unit to data summary. The elementary curriculum provides rich opportunities for teachers to use data summary as a vehicle to extend and enhance their students’ statistical thinking and reasoning skills. Interactive in-class activities and discussions, such as those described below in Sections [4.1.1](#) and [4.1.2](#), are used to help pre-service teachers understand and interpret various graphical and numerical measures, as well as to help them translate that knowledge into classroom practice. These materials were created to ensure the unit maintains a careful balance between content and pedagogy. The materials were designed to push pre-service teachers beyond calculating numbers without context. Instead, we want them to tell stories with data. Additionally, pre-service teachers have the opportunity to envision how they will explore these same concepts with their own students in various grade levels and subjects. For example, after the pre-service teachers complete an in-class activity about variability, they identify the key learning objectives and describe how the activity can be translated in an age-appropriate manner to an elementary classroom to address similar learning objectives.

Finally, the course transitions to the third unit, Models for Comparing Groups. The activities in this unit extend the inferential reasoning skills pre-service teachers develop in the first unit to more complex scenarios involving multiple groups. For example, randomization-based tests are used to compare the means of two groups. Discussions revolve around how inference procedures are not explicitly taught in elementary classrooms, but inferential thinking can nonetheless be instilled in students, even at a very young age. For example, [Russell \(2006\)](#) describes a conversation in which kindergarteners were asked to interpret a chart displaying their favorite mitten colors. In this example, the students were not able to focus on the actual meaning of the data until they were asked to compare their favorite colors to those of a first grade class. By asking the kindergarteners to compare the two charts, the teacher created a rich learning experience that elicited inferential thinking from her students.

Even though Russell demonstrates that such statistical thinking skills can be developed at a young age, they must be fostered throughout a student’s entire education ([Franklin et al. 2007](#)). Other class discussions in this unit focus on how a deeper conceptual understanding of statistics

helps teachers create grade-appropriate learning opportunities for their students and recognize the various levels of statistical knowledge their students will obtain as they progress through school ([CBMS 2012](#)). In addition, we directly discuss how statistical concepts from each of the three units can be taught in conjunction with concepts from another subject, such as science or social studies. For example, we talk about how answering a research question by collecting, summarizing and interpreting data naturally links to the scientific process taught in science classes and how interdisciplinary activities can be created and/or adapted in age-appropriate ways to reinforce students' understanding of the material and to build rich connections between multiple content areas.

4. Course Assessment, with Examples and Commentary

Because our vision for the course encompasses both statistical content and pedagogy, we include course requirements that model effective classroom practice and prepare the future teachers for their upcoming professional responsibilities. These requirements include both informal and formal assessment exercises.

4.1 Informal Assessment

We use informal assessment tools to encourage pre-service teachers to come to class prepared to engage with their peers and to foster active participation during class time. These informal assessments account for 35% of the final grade and include in-class activities, classroom discussions and journals.

4.1.1 In-Class Activities

The statistical activities we use emphasize key ideas for teaching and learning statistics. The activities used in units 1 and 3 are either from the CATALST curriculum or adapted CATALST materials and make use of simulation via TinkerPlotsTM ([Konold and Miller 2011](#)) to answer a pre-specified research question. During unit 2 (Data Summary), we use activities designed to model effective classroom practice because this unit focuses entirely on material that is in the elementary curriculum. For example, during class time we explore the concept of the arithmetic mean as a balance point. Similar to activities described in the literature (e.g., [Franklin et al. 2007](#)), pre-service teachers are given sticky notes and poster board with a displayed number line. The pre-service teachers are told to arrange the sticky notes on the number line such that the mean of the values is 6, but subject to a constraint such as “no observation at 6” or “no observation less than 4.” Completed activities are collected every class period and graded solely for completion. We use these completed activities to verify attendance and to monitor in-class engagement.

4.1.2 Class Discussion

To prepare for classroom discussions, pre-service teachers read and reflect on a journal article pertinent to the current classroom unit. For example, during the unit on Data Summary, pre-service teachers read “More than ‘Meanmedianmode’ and a Bar Graph: What’s Needed to Have a Statistical Conversation” ([Friel, O’Connor and Mamer 2006](#)). The readings were selected from

articles in *Thinking and Reasoning with Data and Chance* ([NCTM 2006](#)), and the pre-service teachers reflect on how the author's findings can translate to their future classroom practice. Specifically, we give the students the following instructions:

Please read the assigned article and be able to discuss it in class. As you read the article, please note any comments, doubts, questions and/or ideas that come to mind. Please also reflect on the following questions:

- * *What is your reaction to the article? What did you take away from the article?*
- * *What are the conclusions/findings in the article?*
- * *How can the results translate to classroom practice?*

Completion of the readings is monitored through class discussion. At the beginning of the semester, we model how to lead a discussion before students are expected to lead one themselves. For each reading thereafter, a pair of pre-service teachers is randomly selected to lead the discussion. In order to encourage all of the pre-service teachers to come to class prepared, the selection does not occur until the beginning of the class discussion. The discussion leaders are encouraged to ask probing questions and to call on their classmates if they think individual prompting is necessary. Because discussion times vary in length depending on the article assigned, we typically begin class with the discussion to ensure there is enough time available for a thorough conversation. This also deters the pre-service teachers from completing the reading assignment during class when other course material is being covered.

4.1.3 Journals

Over the course of the semester, each pre-service teacher keeps a journal to record his or her reflections. Each class period, a journal prompt is supplied and the pre-service teachers respond to the prompt outside of class. If a reading is assigned, the journal prompt focuses on the reading. If not, a prompt germane to the classroom unit is assigned. These prompts encourage pre-service teachers to reflect on their own understanding of the statistical concepts. For example, early in the semester pre-service teachers respond to the following prompt: "What is your definition of random and why? How would you define random to a 2nd grader? to a 6th grader?" Other examples are provided in [Appendix A](#), within Table A.1. Journals are collected every few weeks and checked for completion. Because we want to encourage the pre-service teachers to think of the journals as a "safe place" to record their misunderstandings and frustrations, we do not write any comments on the journal entries. Instead, we record recurring themes and discuss them broadly with the class. Common conceptions and misunderstandings (e.g., the idea of randomness as synonymous with haphazard, as observed in the responses to the example prompt above) also help shape subsequent class discussions and inform us about what content needs to be revisited.

Following is one specific example of a journal prompt:

How has your opinion about the relationship between mathematics and statistics changed over the course of the semester? How can you communicate their differences in the classroom? How could their differences be used to complement one another?

At the end of the semester, we give this prompt and examine pre-service teachers' responses to summarize emerging themes. We are particularly interested in their responses to this specific prompt, because the prompt addresses one of the main goals of the course: developing an appreciation for statistics as a discipline separate from mathematics and sharing that appreciation with their own students.

With this group of pre-service teachers, we found nearly all of them reacted only to the question "How has your opinion about the relationship between mathematics and statistics changed over the course of the semester?" In doing so, they tended to contrast the two subjects, as opposed to reflecting on how their opinion changed (or did not change). The pre-service teachers also neglected to discuss similarities between the disciplines, such as the importance both place on problem solving and critical thinking skills. Instead, the comparisons centered around two underlying themes: (1) Math provides an exact answer, while statistics does not and (2) Statistics requires context or a real-life situation, whereas mathematics is abstract. The majority of responses conveyed that math gives an exact answer. The more reflective responses referenced the intellectual conflict this could elicit in their future students. Some believed it would be frustrating:

The main difference between stats and math that I noticed was math has only one answer and deals with numbers and statistics isn't black or white. It has a ton of material and there is not one set answer and can be very discouraging and hard to understand and that can make it hard to teach a class because they can get even maybe more discouraged.

Others believed the intellectual conflict would give students confidence:

Statistics requires more reasoning and supporting your answer. This I like, because in mathematics, there is only one right answer. In statistics, each person could have your own answer and with their supporting argument [sic], it could be right. This . . . may ease the stress and frustration and allow them to just try and not worry about getting the answer right but rather understanding it.

Almost no one discussed how they could use the differences to complement one another. The pre-service teachers who tried to respond to all questions in the journal prompt gave a superficial answer to the third question (e.g., "I think their differences complement each other because mathematical properties are used in statistics and vice versa."). We were also disappointed in the level of effort and lack of reflection demonstrated in some journals. Some pre-service teachers seemed to be very conscious of the instructors as the audience, and composed entries that seemed like the "right" answers to them:

I saw how closely related they are to each other. I also saw how much everyday life is incorporated in math and statistics. ... This will help show the connection between the two and their differences at the same time.

I now see that statistics is a very important part of mathematics and something that elementary students are very capable of understanding when taught by an effective teacher.

Even though we read several superficial journal responses throughout the semester, follow-up whole class discussions helped us elicit richer reflections and conversations amongst the pre-service teachers. However, the varying degree of effort we witnessed does lead us to re-think how journal entries should be assessed. In the future, we will use a grading rubric that encourages reflective journal responses but does not penalize pre-service teachers for inaccurate statements.

4.2 Formal Assessment

Our course has two types of formal assessment: exams and lesson plans. There are two exams during the semester, and together they account for 25% of the final grade. Lesson plans account for 40% of the final grade, with the final project weighted more heavily than the other two submitted mid-semester.

4.2.1 Exams

The pre-service teachers take two exams, one after each of the first two course units. We only use open-ended exam questions to assess key learning objectives from the respective unit(s), and the CATALST researchers provided us with some of these questions. We wrote others to address the unique learning objectives of our course, specifically to assess the pre-service teachers' statistical knowledge for teaching. In addition to answering typical, calculation-based problems (i.e., "Find the mean of the following set of values"), the pre-service teachers are asked to diagnose errors commonly made by elementary students. For example, on the second exam, our pre-service teachers were presented with a data set and the resulting graphs constructed by four elementary school children. The test question asked them to identify which of the elementary kids (if any) understand how to appropriately graph the data, and what evidence they were using to make this determination.

Some questions we wrote to assess the pre-service teachers' understanding of statistical concepts also gave us insight into their progression as teachers. For example, one question we wrote (see Figure 1) for the first exam in fall, 2011 assessed the pre-service teachers' understanding of variability and randomness and best captured the range of responses we typically observed. The pre-service teachers were asked to compare two sequences of 50 coin flips and identify which was the outcome of a real experiment. Most of the pre-service teachers focused their explanations on one of two features: the total number of times an outcome (heads or tails) occurred in a sequence or the maximum number of times an outcome occurred in sequential flips. For example, one pre-service teacher wrote:

I think sequence 2 might be the actual one. Sequence 1 has no more than 3 in a row of heads or tails where as sequence 2 has stretch[e]s where there are way more than 3 of heads or tails in a row. I think the first one is almost too

perfect like if he was afraid to have too many of the same one in a row (I would have been.)

Figure 1. Exam question.

Fifth-grade students were told that they were each going to flip a penny 50 times and record the result of each flip. Before actually flipping a penny, each student had to write down the sequence of heads and tails s/he predicted to flip. At the end of the activity, each student compared his or her prediction to his or her actual flip results. One student accidentally mixed up his predictions with his actual results and asked you for help deciding which is which. The student had the following two sequences:

| | |
|--------------------|---|
| Sequence 1: | H T H H H T H T H T T T H T H H T H T T H T H H T (Flips 1-25) |
| | H T T T H T H T H H T H T H T T T H T H T H T H H (Flips 26-50) |

| | |
|--------------------|---|
| Sequence 2: | T H T H H T T T T T H T T H H H T T H H T T T H (Flips 1-25) |
| | T H T H H H H H T T H T H T H T T T H T T T H T H (Flips 26-50) |

Which sequence (1 or 2) represents the actual results of 50 flips of a penny? Explain.

Yet, another pre-service teacher wrote:

Sequence 2, because even though there is a 50-50 chance of rolling a head or tails it is unlikely that you will get half heads and half tails in your result. Most students would put half heads and half tails when predicting because they know there is a 50-50 chance of getting both. So they assume that each one will pop up an equal amount of times.

In both of these responses, the pre-service teachers provided sound reasoning for their choices. However, these pre-service teachers also explained why they think the fifth-grade student created the first sequence for his prediction. These responses indicate the pre-service teachers not only understand the content assessed, but also common student misconceptions. In contrast, most pre-service teachers who answered the question incorrectly focused only on the statistical content, irrespective of which feature they focused on in their explanations. For instance, two different pre-service teachers wrote:

Sequence one represents the actual results because there were 25 heads and 25 tails. When you flip a coin, there is a 50/50 chance that it will land on heads and a 50/50 chance it will land on tails. With that said, the results should be half heads and half tails, like sequence 1.

I would say that sequence 1 represents the actual results of 50 flips. Sequence one seems to be more random because the highest sequence is 3 and in sequence two there are a lot higher sequences like 5 or 6. Sequence two seems unlikely because of this.

In both of these responses, the pre-service teachers did not convey an understanding of the concepts assessed. These pre-service teachers also did not explain why the student created the second sequence as his prediction. While we did not specifically ask for this type of explanation, the pre-service teachers who attempted to describe the fifth-grade student's thought process often demonstrated a deeper understanding of the concepts than those who did not. The latter groups' answers focused solely on the statistical content rather than the fifth-grade student's understanding of the material.

Open-ended exam questions give us the opportunity to assess the pre-service teachers' statistical content knowledge, as well as their statistical thinking and reasoning skills. Some questions directly assess the pre-service teachers' statistical content knowledge for teaching. However, other questions, such as the previous example, often elicit voluntary explanations about elementary students' statistical knowledge. We appreciate both the solicited and unsolicited responses, because they give us a better picture of what a pre-service teacher understands not only as a statistics student, but also as a future teacher.

4.2.2 Lesson Plans

Over the course of each unit, pre-service teachers work in pairs to construct a lesson plan for an elementary school classroom. For the first two units, pairs of pre-service teachers are randomly assigned to a grade level (K-6) and are required to select a content standard pertinent to the unit being covered in class. Standards may be selected from the [Nebraska Mathematics Standards \(2009\)](#), the [NCTM Standards \(2000\)](#) or the [Common Core State Standards for Mathematics \(2010\)](#). Then the pre-service teachers write a grade-appropriate lesson plan to address the selected standard. For example, during the first module, Chance Models and Simulation, the pre-service teachers select at least one standard that addresses probability. While pre-service teachers use mathematics standards, they are free to address their chosen standard(s) in a different subject, such as science. The teachers are provided a template detailing the required components of a lesson plan, as well as examples of model lesson plans to reference during the semester.

The lesson plans are peer reviewed during class time using a set of instructor-provided questions (see [Appendix B](#)). Each pair of students partners with another pair assigned to the same grade level. They exchange lesson plans and answer each of the questions we provide. After each pair answers the questions, comments are exchanged and elaborated on verbally. The peer review process takes approximately 45 minutes, and we observed some groups are uncomfortable giving oral feedback. After this process is complete, the pre-service teachers have an opportunity to revise their lesson based on the feedback they receive from their classmates. The revised lesson plans are then critiqued by the instructors using a rubric (see [Appendix C](#)) on which the peer review questions are based. The instructor comments are returned, and then the pre-service teachers have a second chance to revise their lessons before they are formally graded. The final

versions of the lesson plans are scored using the same rubric utilized during the instructor critique.

Due to the overwhelming number of underclass pre-service teachers in the course, the class as a whole had little experience with creating lesson plans. The iterative revision process was implemented to ensure the pre-service teachers received ample constructive feedback. Not only did it allow the pre-service teachers to improve their lesson plans, the process also guided them in their transition from students to novice teachers.

For the third unit, the pre-service teachers self-select their working groups of size two to three and choose any grade level and standard of interest to them. The final project asks pre-service teachers to identify a topic in statistics that is often misunderstood by students in elementary school. They write a report detailing the misconception, describing ways in which teachers may inadvertently reinforce the misconception, and suggesting ways teachers can correct the misconception. The report must reference at least two scholarly sources. The lesson plan accompanying the report needs to address the chosen misconception, including what should be done during the lesson to check for and correct the misconception if it arises. Each group presents a summary of their final project to the rest of the class.

While grading the lesson plans, we observed that several of them were not grade-level appropriate. For example, one lesson plan for kindergartners had the students writing probability definitions in their math notebook. Conversely, a lesson aimed at 3rd grade students had them conclude a lesson on bar graphs by drawing pictures of their favorite weather. In general, upperclass pre-service teachers, who had observed classrooms, were more successful at matching their lesson plan to the grade level.

When developing the class, we did not anticipate having so many first-semester freshmen. As a result, we included additional supports, such as sample lesson plans and detailed instructor feedback prior to final grading. We plan to offer similar guided direction in the future so that lesson plans can remain an important part of the course. Our end-of-the-semester feedback from the students indicates that the lesson plans are the most valuable aspect of the course.

5. Conclusions

In the course we developed, pre-service elementary teachers are exposed to inferential and statistical reasoning skills they can instill in their own students, even if only at a very basic level. By carefully integrating content, pedagogy and assessment, the course helps guide pre-service teachers in their transition from students to novice teachers and emphasizes the importance of understanding both a vertical and a horizontal alignment of statistical concepts, i.e., understanding “the content appropriate for students at their grade level,...[as well as] the relationship of this content to associated concepts at other developmental levels” ([Franklin and Kader 2010, p. 2](#)).

We encountered a few speed bumps in the first iteration of this course, specifically the high proportion of first-semester freshman. However, with appropriate modifications and additional supports, such as peer and instructor review of lesson plans, the pre-service teachers were still

able to benefit from the variety of materials, activities, discussions and strategies we used to help them gain a deeper understanding of and an appreciation for statistics. While the value of these additional supports cannot be overstated, it is very time consuming to provide timely and regular feedback, and instructors should prepare accordingly.

We also faced other challenges that are not easily addressed. For example, we struggle with how to align assessments with the course goals and make them authentic measures of statistical knowledge for teaching, not just measures of statistical content knowledge. In future iterations of the course, we will provide more explicit course goals and learning objectives to better help pre-service teachers identify key concepts and become self-sufficient learners. We will also explore alternative ways to assess pre-service teachers' understanding of the concepts that better align with the way they learn and will teach the material.

In pre-service teachers' final reflections, they shared the benefits they received not only as students, but also as future teachers. For example, one pre-service teacher wrote:

The most beneficial thing to me this semester was being part of an engaging classroom and learning things hands on. It is much easier to design a lesson plan when I have experienced the same things that I will be teaching.

This pre-service teacher highlighted how the student-centered learning environment deepened his/her own understanding of statistics and helped him/her translate this knowledge into classroom practice. In addition, another pre-service teacher reflected:

...[one] thing I found important about this class was when we talked about not just being able to teach your subject area and grade level, but also being able to teach multiple grade levels. This is important so that you can tie information together for your students . . . if we just teach to our grade level we are limiting what the students can achieve....we need to reinforce old and new material so that they can get the most out of their education.

As evidenced by these comments, we helped these pre-service teachers recognize the integral role they play in a student's entire statistical education. Through the dissemination and delivery of this new course, we hope to inform efforts to improve the quality of teacher education programs and, ultimately, to develop teachers who foster a conceptual rather than a procedural understanding of statistics in their K-12 students.

APPENDIX A SELECTED JOURNAL PROMPTS

Table A.1 Examples of Journal Prompts and Corresponding Week When Assigned

| Week | Journal prompt |
|------|---|
| 1 | How did this activity [iPod MEA] affect your view of the kinds of problems addressed in statistics? |
| 2 | What is your definition of random and why? How would you define random to a 2nd grader? to a 6th grader? |
| 3 | What aspects of the peer review process were most helpful or useful? What suggestions do you have to make peer reviewing more helpful? What questions do you still have about your lesson plan that you don't think were addressed and/or answered? |
| 4 | Compare and contrast these two definitions of random: Random is a selection without a pre-determined order. Random is a selection with no specific order. Why are these two definitions different? Why does the first definition accurately describe random, but the second definition doesn't? |
| 5 | How good does evidence have to be to reject a model? |
| 5 | Write an interpretation of one of the p-values you got in the <i>iPod-Shuffle-Revisited</i> activity. What conclusions does this p-value lead you to make about the original hypothesis? How would you explain what this p-value means to a 2 nd grader? to a 6 th grader? |
| 9 | How could you extend the class activity to an elementary classroom, using a different type of candy? What questions and data summaries would you have the kids explore? |
| 10 | Compare and contrast the peer review process to what happened last time. What aspects of the peer review process were most helpful or useful? What suggestions do you have to make peer reviewing more helpful? What questions do you still have about your lesson plan that you don't think were addressed and/or answered? |
| 10 | In class, we've talked about shape, center and spread of distributions. What unique information does each summary provide about a data distribution? That is, Assuming the shapes and spreads of two different distributions are the same, what information does differing centers provide? Give a specific example. Assuming the shapes and centers of two different distributions are the same, what information does differing spreads provide? Give a specific example. Assuming the centers and spreads of two different distributions are the same, what information does differing shapes provide? Give a specific example. |
| 11 | Skim the standards for statistics. Are there topics you are particularly nervous about teaching? If so, please explain what you are nervous about. |
| 11 | How would you connect the reading to the "Reading Graphs at Different Levels" section of the textbook (pp. 643-644)? How do the three levels of graph comprehension lend themselves to statistical conversations? |
| 12 | Describe in detail how you would collect and summarize data to answer the |

| | |
|----|--|
| | following question: "Do first grade students spend less time on homework than fifth grade students?" A complete response will include how you will collect the data, what type of data you will collect, how you will summarize the data and how you will use that information to answer the question. |
| 12 | In comparison to the first exam, how do you plan on preparing for the second exam? What strategies seemed to be most successful the first time around? |
| 15 | Often, teachers comment on how they only need to know the content for the grade level they teach. For example, some say, "I won't need to know that, because I am teaching [Kindergarten, 8th grade, High School, etc.]." Comment on the limitations of this narrow mindset. How could it affect students' education? What <i>should</i> effective teachers (at any grade level) know? |
| 16 | How has your opinion about the relationship between mathematics and statistics changed over the course of the semester? How can you communicate their differences in the classroom? How could their differences be used to complement one another? |

APPENDIX B

LESSON PLAN PEER REVIEW QUESTIONS

Directions: Use these questions to guide your peer review of the lesson plan. You will be reviewing the lesson plan of the other group with your grade level.

1. Lesson Plan Authors:

2. Lesson Plan Reviewers:

3. What standard is the lesson plan addressing?

4. What did you like best about the lesson plan? Why?

5. Do you think the lesson plan addresses the identified standard? Why or why not? If not, what suggestions would you give to the authors to improve it?

6. Do you think this lesson plan is appropriate for the grade level? Why or why not?

7. Does the lesson plan provide enough detail that you could use it in a class without any additional information? If not, what additional details would you need/like?

8. Do you think the assessment plan identified will assess student understanding of the concept? Why or why not? If not, what suggestions do you have for improvement?

9. Did you find the Teacher Notes helpful? What else, if anything, do you think should be included?

10. Were all adapted materials adequately referenced?

11. What other constructive feedback do you have for the authors?

APPENDIX C LESSON PLAN RUBRIC

| Grading Criteria: | Excellent | Adequate | Fair | Missing/ Minimal |
|---|-----------|----------|------|---------------------|
| 1. Appropriate standard | | | | |
| 2. Learning objectives | | | | |
| 3. Lesson plan description: | | | | |
| Introduction | | | | |
| Activity | | | | |
| Conclusion/Summary | | | | |
| 4. Lesson plan addresses standard | | | | |
| 5. Lesson plan is appropriate for the grade level | | | | |
| 6. Appropriate and specific assessment plan | | | | |
| 7. Teacher notes | | | | |
| 8. Detail is sufficient | | | | |
| 9. Lesson plan demonstrates an understanding of the concept(s) taught | | | | |
| 10. Overall quality of work | | | | |

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