Student-Centered Instruction In A Theoretical Statistics Course

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Abstract

This paper provides an example of how student-centered instruction can be used in a theoretical statistics class. The author taught a two-semester undergraduate probability and mathematical statistics sequence using primarily teacher-centered instruction in the first semester and primarily student-centered instruction in the second semester. A subset of the students in the teacher-centered course also took the student-centered course. Student feedback suggests that the student-centered approach, while more difficult for both student and instructor, is beneficial when compared to the teacher-centered approach. The specific method of implementation will need to vary with class size and level of student preparation but the author's example presents a starting point for those interested in moving away from a traditional teaching approach in theoretical statistics classes.

1. Introduction

Probability and mathematical statistics classes are often described by the students enrolled as being dry and irrelevant. Potential reasons are that the material is often presented in a teacher-centered, theorem-proof lecture format. Further, little perceived connection may be made between the theory presented and more applied content that students may see in other classes. One reason for this is the varied background of students taking these classes, particularly when it is the first theoretical statistics class in the curriculum. While some students who have declared a statistics minor or major may have already taken applied classes, others may take the theoretical statistics class as a sole statistics requirement for a mathematics major. These latter students have little hands-on applied statistics work to motivate the theoretical content. One hoped for result of any such class is to foster an appreciation for the importance and role of theoretical statistics.

The primary focus of this paper is advanced (second or third semester) courses in statistical theory, however the discussion is relevant for introductory courses also. Learning objectives of theoretical courses will differ depending on the level of the course. The following may be similar to those in an advanced theoretical statistics class a student encounters:

1. learn some of the building blocks of classical statistics including likelihood ratio tests, tests of hypothesis,

theory of regression and analysis of variance,
2. prove, in a valid style, some of the main theorems and results behind classical statistical methods,
3. correctly apply the building blocks and their results to general classes of problems.

The first objective addresses the need for graduates to have knowledge of certain theoretical results. The second objective requires the use of precise notation and the ability to determine any relevant theoretical results and use these to prove some new result of interest. The last objective targets a student's ability to determine the theoretical results that are relevant in a particular context and correctly apply them.

I considered student-centered instruction in order to have students play an active role in their instruction. The hope was that active learning would reduce some of the perceived dryness of the course content, give the students hands-on practice at writing valid proofs and at applying the results, and help to build an appreciation for the content. Active learning in the classroom could also allow real-time input from peers on style and content of a proof as well as quicker input from the instructor on appropriate notation for proofs. Weimer (2002) is a good introduction to the practice of and motivation for student-centered instruction. Weimer also addressed the issues that may arise during implementation and gave examples of how student-centered instruction is used in various disciplines such as english, communications and chemistry.

Various authors have written of their use of student-centered instruction methods and those that influenced my approach will be discussed next. The methods discussed differed in the proportion of class time in which student-centered rather than teacher-centered approaches are used. New users of student-centered approaches may wish to introduce the approach slowly due to the preparation time required, or one may believe that students need a certain amount of lecture in order to learn the basics of the content before exploring the remaining content in a student-centered way.

Guided inquiry learning has been used successfully in chemistry instruction in high schools and universities. Lewis and Lewis (2005) describe a peer led guided inquiry approach in which one of three weekly classes was student-centered. Hanson (2006) describes process oriented guided inquiry learning (POGIL) from the instructor's perspective. POGIL may be used exclusively for an entirely student-centered learning classroom or in conjunction with lectures. Experienced users of POGIL and those in disciplines with POGIL activities readily available use it exclusively. The Moore method (as described in Parker (1992) and Parker (2005)) is used effectively in the teaching of mathematics and in its purest form uses no lecturing. In a Moore classroom students generate all the content within the context built by a problem set provided by the instructor. Avoiding the use of lecture relies on the students already having a certain core of knowledge to build on or the instructor being able to design sets of problems that will lead students to the content. In introductory classes one may have to use lecture at the beginning of the semester in order to introduce students to the basics.

Parker (2007) provides a draft outline of a one or possibly two semester inquiry learning based elementary statistics class. Mini-lectures or some other direct delivery of content are required in at least one topic in these non-calculus based course(s). Rossman and Chance (2005, 2008) have done considerable work in advancing the use of active learning in elementary statistics courses and one-semester calculus based theoretical statistics courses.

Gonzalez (2006) and Black (1993) used student-centered instruction methods in conjunction with lecture in computer science and organic chemistry courses respectively. Gonzalez structured class so that a 20-30 minute lecture that presented new material took place in between cooperative learning activities. Black randomly assigned students to work on particular problems or be audience members when they entered the classroom. The students chosen to work on problems wrote the solutions on the chalkboard and audience members then reviewed the solutions. Black's role was to guide the audience members to determine if the solutions were correct or perhaps to see the ramifications of the solution. This exercise took 5-10 minutes and the remaining class time consisted of lecture.

It was the work of Black (1993) and Weimer (2002) that had the most influence on the student-centered approach I developed for my theoretical statistics course. Weimer's discussion allowed me to anticipate issues that could arise in a student-centered classroom, such as student discomfort with the approach or the potential negative effect on course evaluations, and plan my approach accordingly. The appeal of Black's approach was its involvement of all students in the problem-solving process; one concern I had previously was that the limited amount of chalkboard space in any classroom prohibits direct involvement of all students in solving problems. However, if students not presenting are given the task of determining if the solution is correct or the solution's role in the curriculum then all students are involved. Further, the random assignment of students to either presenter or reviewer roles means that all students would at some point be given the task of critiquing the work of their peers. This provided an opportunity for the student to learn how to critically examine a solution and to provide constructive and polite criticism.

In adapting Black's approach for my theoretical statistics course I considered how his presenter/audience problem-solving approach could (1) be used in a smaller class, (2) be used for the entire class period rather than the first 5-10 minutes, and (3) have the problem solving used in the assessment of students in some way.

I now briefly describe the student-centered approach developed for my two-semester theoretical statistics course. I also describe the theoretical statistics course taught and how I assessed the students in the new context. A teacher-centered approach was used in the first semester of the sequence and a student-centered approach in the second semester with a common set of students so I also provide the students' comparisons of the two approaches.

2. Implementation

I teach a two semester 400-level probability and mathematical statistics sequence in the Department of Mathematics and Statistics at James Madison University. The sequence presents the theory underlying classical probability and statistics. The textbooks used for the sequence vary with instructor; I used Wackerly, Mendenhall and Scheaffer (2002). The first class in the sequence is required of all majors in statistics; the second course is required for those students in the mathematical statistics track. The department has several double majors in mathematics and statistics in a given year; these students typically enroll in the mathematical statistics track. Other quantitative majors may opt to take one or both courses in the sequence. Prerequisite courses include a 300-level probability and mathematical statistics course as well as calculus I and II. Students typically enroll in their junior or senior years.

I taught the first course in the sequence during fall 2007 using an almost entirely teacher-centered approach. Occasional (perhaps once per week) departures from pure lecture format consisted of students working alone through the second of two examples of a concept; I had completed the first example on the chalkboard. Of the eight students enrolled in this course, four also took the second-semester course in spring 2008.

The second semester class met Tuesday and Thursday for 75 minutes each day. Tuesday was teacher-centered with lecture notes written on the chalkboard. I covered all the assigned sections for the week in this one class. This meant that I made sure to give clear explanations of the concepts and how they should be used but had less time for worked examples. At the end of Tuesday's class, I randomly assigned one problem to each of the students to present in class on Thursday. I made sure that at least one of the chosen in-class problems addressed each of the concepts presented Tuesday and that the in-class problems were standard rather than unusual applications of a concept.

In-class problems were chosen so that a reasonable expectation of the students was that they could successfully complete all in-class problems in class on Thursday. This included consideration of whether they could reasonably prepare a solution between lecture Tuesday and class Thursday as well as whether there was time for solutions to be written and discussed on Thursday. These concerns may necessitate changing the number of problems assigned in a particular week. In choosing problems you should also make sure that the students have the necessary skills and knowledge or that they could reasonably find it in their text or notes. If you choose problems that are difficult (have large skill or knowledge leaps) consider giving them written or verbal hints with the problem that bridge the gap. It is important, especially early in the semester, that they learn to trust that you are giving them problems that are reasonable. Once this trust is established and you better understand their abilities you can increase the difficulty of the problems.

I also gave a take-home problem set with four questions that was due the subsequent Tuesday. These take-home problems may have included non-standard or unusual applications of the concepts. I was also careful to point out how the take-home problems related to the in-class problems and class notes. An example of a typical week in terms of the content covered and the assigned in-class and take-home problems is given in Figure 1.

Tuesday's lecture material: 8.5, 8.6, 8.8 from Wackerly, Mendenhall and Scheaffer (2002)
In-class problems for Thursday:

1. Exercise 8.40(b,c). For (b): start by finding the CDF of $\frac{Y}{\theta}$. Then show that this and $\frac{Y}{\theta}$ satisfy the properties required of a pivotal quantity. *Illustrates pivotal quantities and the 3-step approach to finding CI based on these.*
2. Derive using the 3 steps from section 8.5 the large-sample CI for *p*. Do we have to estimate the standard error? If so, what effect does this have (if any)? *Illustrates the pivotal quantity and CI applicable for a proportion when sample sizes are large.*
3. Derive using the 3 steps from section 8.5 the large-sample CI for $\mu_1 - \mu_2$. Do the variances have to be known in this case? Explain. *Illustrates the pivotal quantity and CI applicable for a difference in means when sample sizes are large or both populations are known to be normal.*
4. Exercise 8.76(a). Derivation of the pivotal quantity and an example are in the text beginning page 401. *Illustrates the pivotal quantity and CI applicable for a difference in means when sample sizes are small.*

Take-home problems for Tuesday:

1. Exercise 8.42. *Application of the large sample CI for p.*
2. Exercise 8.54. *Application of the large sample CI for* $\mu_1 - \mu_2$.
3. Exercise 8.78. *Application of the small sample CI for* $\mu_1 - \mu_2$.
4. Exercise 8.35. *Illustrates pivotal quantities and CI based on these.*

Figure 1: Structure of the class material for a typical week. Similar content was posted on the class web-site each Tuesday. Exercises were selected from Wackerly, Mendenhall and Scheaffer (2002). The italicized text was used to show how the in-class and take-home problems related to each other and to the lecture material.

Class on Thursday began with an at most 10-minute quiz to emphasize the main concept(s) from Tuesday's lecture. This was definition/concept based rather than problem based. My motivation for having these quizzes was a concern that students would review only the concept relevant to their assigned in-class problem. These quizzes were worth 10% of the final grade. After the quiz I then stood back and watched the class solve their assigned in-class problems at the board. The class as a whole debated and developed the solutions. My role on Thursday was to indicate where there were errors, to record their solutions, and to try not to intervene. Once the students had indicated that they had completed their problem I placed a ✓ next to correct portions of the solution and indicated omissions or errors by a question mark or by circling the error.

I did use mini-lectures (about two minutes each) on two or three occasions when it was clear that the majority of the class had not understood a concept or could not remember a previously discussed concept. In these cases I made sure to clarify the the concept rather than tell the students how to solve the problem, but only after it was clear they had referred to the available resources such as notes or text. At the beginning of the semester I encouraged the class to work together, encouraged the class to critique each other, and sometimes let the class know to listen to a correct idea whispered by a shy student.

After Thursday’s class I scanned and posted their solutions to the in-class problems on the class web-site. If an assigned problem was solved correctly I made notes with a different color pen to show exactly what it took to make their solution complete (rather than just correct). These edits most often addressed their use of imprecise notation. I did not annotate the unsolved problems beyond the ✓ marks, question marks or circling of errors given in class. Examples of the types of edits used in a successfully completed consistency problem and an incomplete sufficiency problem are given in Figures 2 and 3 respectively. Students then used the annotated solutions as guides to complete the take-home problems. The reason I used their in-class solutions rather than my own "model" solutions is that the students did not always start a problem the way that I did. They reported getting more value out of seeing how to get their approach to be complete than in seeing a completely different approach. The class commented that the color-coded approach to solutions was useful.

Each student had one free pass for the semester that allowed them to not complete their assigned in-class problem. They had to announce their intent to use it before the problems were assigned on Tuesday. If a free pass was used the problem assigned to that student would pass to the take-home problem set. No free passes were used by my students.

Midway through the semester it became apparent that the class was preparing only their assigned problem prior to Thursday’s class and that they were not looking in depth at the other in-class problems during the Thursday problem session. This often meant that they did not get the hands-on practice at one or more concepts. To address this I decided (with the students’ permission) to assign each student one of two problems on Tuesday and to tell them after the quiz on Thursday which of these two problems they would actually present. For instance: student A knew to prep problems 1 and 3, student B knew to prep 3 and 4, student C had problems 1 and 2, and D had problems 2 and 4. Immediately after the quiz on Thursday students A, B, C and D were then told to present problems 1, 3, 2 and 4 respectively.

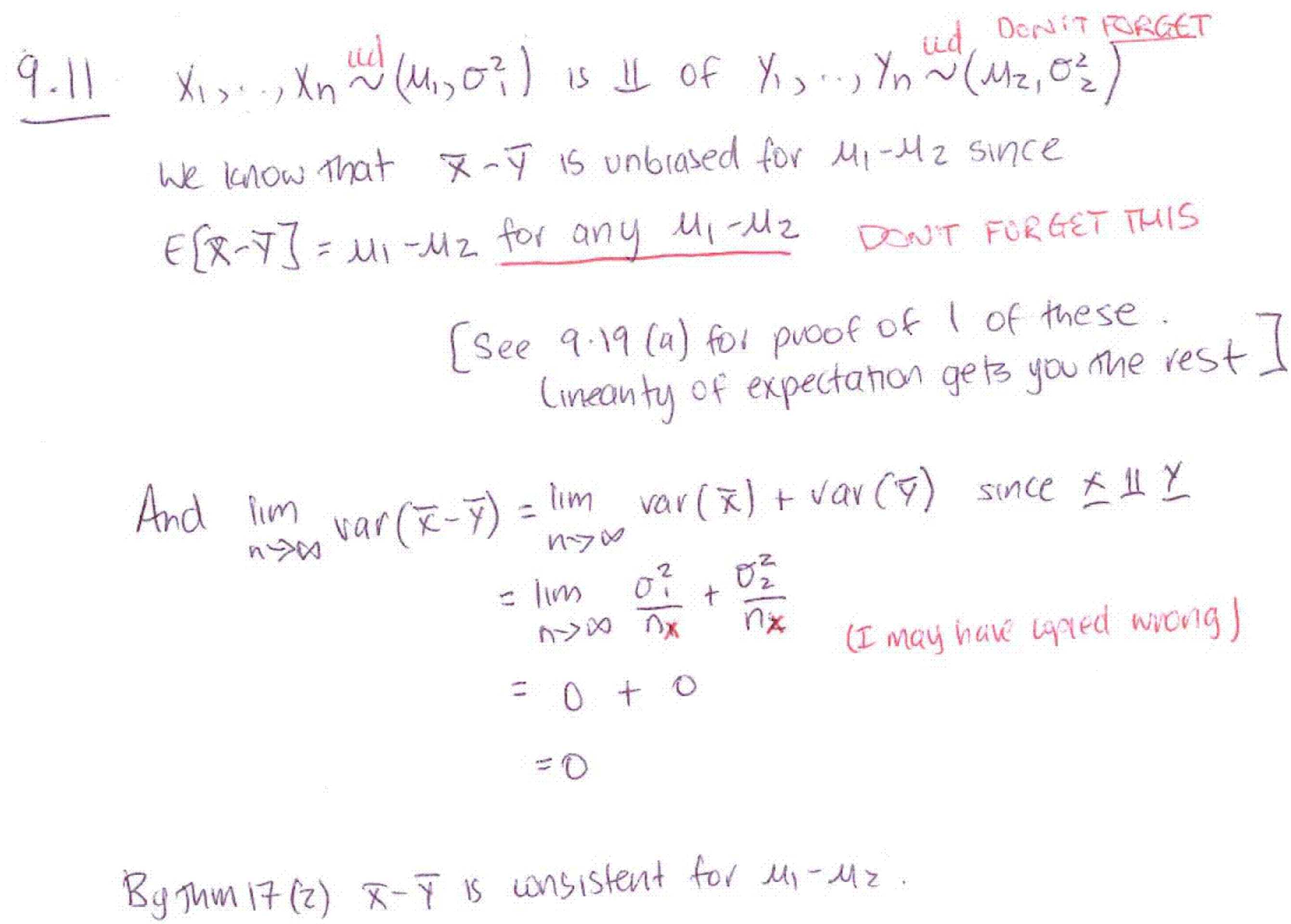

Figure 2: Example of edits made to an in-class homework problem for which students received credit. All text in black ink is exactly as written by the students in class. Text in red ink was added by the author to illustrate how to make the solution complete.

Assigning multiple problems to each student presents options for the free pass policy. I did not have to determine the best approach as no free passes were used. One option is to have the problem assigned to the student who requested the free pass become part of the take-home problem set i.e. in the above example if student B had taken a free pass then problem 3 would pass to the take-home problem set. This would be unfortunate if this problem addressed a particularly important or difficult concept. Perhaps a better option is to simply say that if a free pass is used, another student will present two problems i.e. in the above example if student B had taken the free pass then student A would present both problems 1 and 3. Student A may perceive this as an extra burden however the burden is on all class members, not individuals, to complete the problems and it is important that you stress this to the class. The perceived extra burden placed on fellow students may cause less free passes to be used.

The described structure works best if the problem session immediately follows the corresponding lecture so missed class time due to inclement weather or illness must be planned for. I would suggest (from experience) that rather than maintaining that a particular day of the week is ‘lecture day’ that you maintain the lecture and then problem structure. You might have to adjust homework due dates if a class is missed.

I restructured the two midterm exams and the final exam in order to reflect the format of class. The midterm exams used a hint-for-penalty approach in which, if requested, I gave the student a predetermined hint for an announced point deduction. This mimicked an in-class scenario in which one student could get a problem started but another was able to finish it. The hint was used on three occasions and in two cases the student was able to then complete the exam question. If you are in the habit of building detailed grading rubrics prior to administering midterm exams then this is not difficult to implement as your rubric will list the important steps with their associated points. Hints may consist of the correct way to approach a problem e.g. choose the estimator by minimizing mean squared error, or may consist of how to apply an approach e.g. how to calculate mean squared error. An advantage of this method is that you get a better sense of a student's weakness. For instance, upon being told how to approach the problem, their solution (or lack thereof) will indicate whether they can apply the approach.

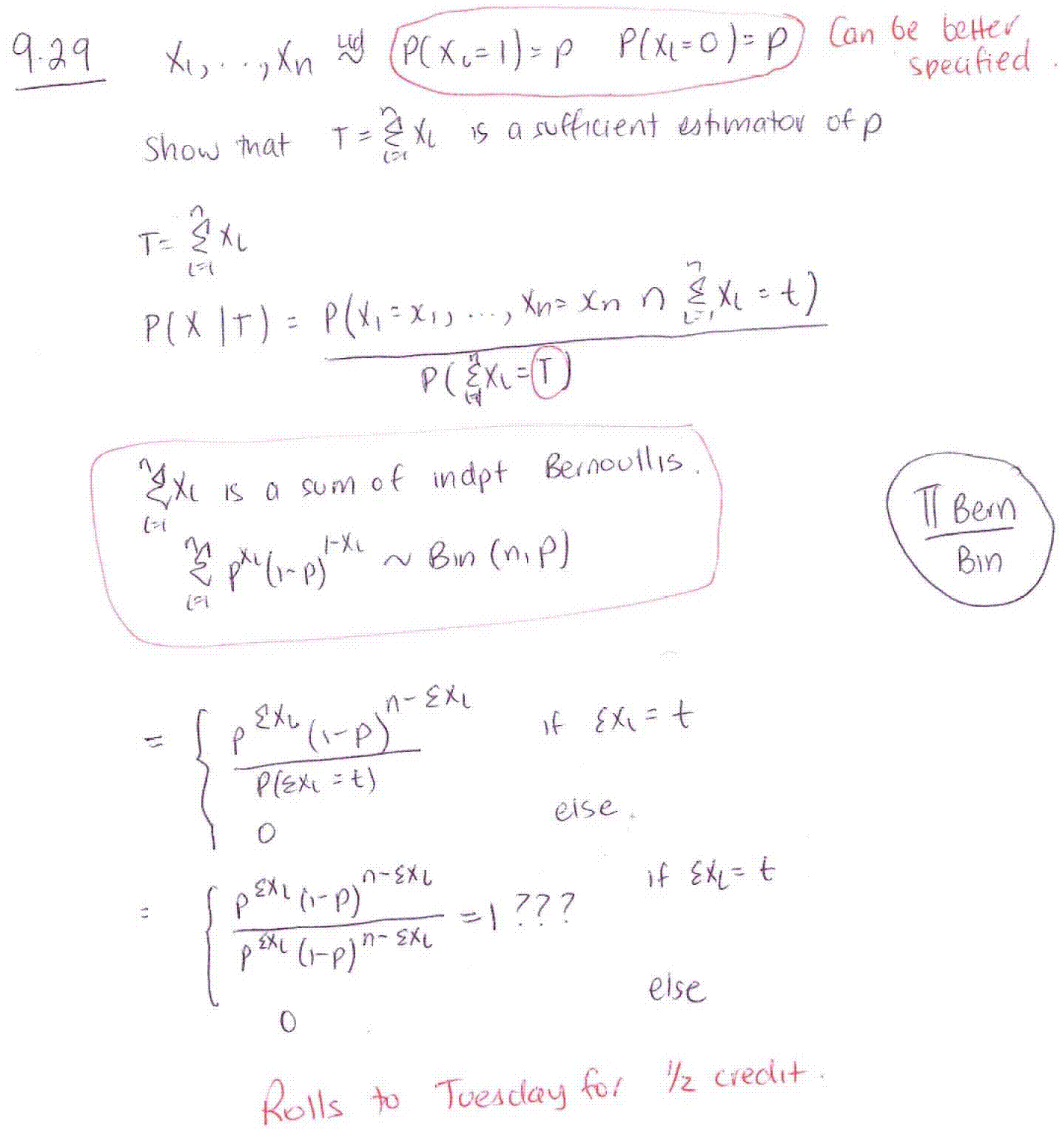

Figure 3: Example of edits made to an in-class homework problem for which students did not receive credit. All text in black ink is exactly as written by the students in class. Text in red ink

represents the comments made by the author in class.

The final exam was restructured using an idea presented in Weimer (2002). The class sat the final exam individually and then after their individual finals were collected they completed the same final again as a group. They had access to copies of their individual finals when completing the group final and the same time limit applied. The individual and group finals were graded at the same time and using the same rubric. This format added only one extra paper to the grading workload.

2.1 Student Assessment

Each weekly homework was comprised of both in-class and take-home problems. Two goals were considered in determining the emphasis that the in-class and take-home portions of the weekly homework would have on the final course grade. The first was to give students course credit for successfully completing the in-class work during class rather than out-of-class. The second was to weight the assigned take-home problems less than the assigned in-class work. The objectives behind these goals were:

1. Encourage students to take the in-class work seriously enough to prepare the solutions to the problems prior to coming to class so that completion of the problems during class was more likely to occur. This was important to me as the in-class work was my opportunity to get timely feedback on their level of understanding of material covered in the previous lecture. This also became important to the students as they realized that take-home problems were easier if they had completed the in-class problems.
2. Encourage the students to work together during class. Not all students are equally prepared or motivated to work with others, for instance, strong students may be less willing to work with weaker students as they may see little benefit to themselves.
3. Encourage the students to take the take-home problems seriously. This was important as they were instructed to work alone on these problems so that I could gauge individual understanding of the lecture material.

Grades alone will not address all of these objectives. You may have to speak to individual students who do not work well with others or refuse to participate. The strongest barrier to group work that I witnessed was the students' lack of desire to critique each other. They believed they would hurt the feelings of another student if they suggested the presence of or corrected a mistake. Upon noticing this issue I discussed with the students the need for them to critique each other's work and encouraged them to do so in a constructive manner. It did take some time for the class to get comfortable with this.

Assuming no free-passes were used, homework was graded using the following weighting scheme:

- If an assigned in-class problem was correctly completed (to my satisfaction) in class each student was given 10% of the credit for the current week's homework. There were four problems assigned so a total of 40% was available. If one of these problems was not completed in class each student could hand it in with the take-home problems for half credit (5%).
- 20% credit was given to all students if all four in-class problems were completed during class. This directly addresses objectives (1) and (2) above.
- The remaining 40% was from the take-home problem set (10% per assigned problem).

In this scheme the take-home problem set had equal weight to the in-class problem set (ignoring the 20% completion credit) addressing objective (3). The 20% completion credit was withheld once relatively early in the semester and prompted the class to consider preparing more than just the problem(s) they were individually assigned. You should consider the fact that the 20% completion credit will inflate the homework scores when determining your assessment scheme.

If a free-pass was used, the in-class work consisted of three problems (10% each if completed), the take-home work consisted of five problems (10% each) and the 20% credit was still given for completing the three in-class problems in class. If a student failed to attempt their problem and had previously used their free pass then they (and only they) received no credit for the in-class portion of the homework (and could score no higher than 40% on that homework).

It is very important that you spend time discussing the assessment system in class. I distributed the syllabus with the details on the first day of class and gave the students opportunity to ask questions in the following two classes. I would also suggest giving them scenarios to illustrate the grading scheme for homework, such as:

A. 0 free passes. 4 problems attempted and successfully completed in class. Base score is 60 ($4 \times 10 + 20$). The remaining 40 (4×10) are assigned based on the 4 take-home problems. Best score possible is 100.
B. 0 free passes. 4 problems attempted, 2 successfully completed in class. Base score is 20 ($2 \times 10 + 0$). The remaining 50 ($40 + 2 \times 5$) are assigned based on the 6 take-home problems. Best score possible is 70.
C. 1 free pass. 3 problems attempted, 2 successfully completed in class. Base score is 20 ($2 \times 10 + 0$). The remaining 55 ($50 + 1 \times 5$) are assigned based on the 5 take-home problems. Best score possible is 75.

A student's overall score on the final was a weighted average of their individual score (accounting for 75%) and the group score (the remaining 25%). Using this weighting individuals remain accountable for the largest portion of their final exam grade. This weighting penalizes students who score better individually than does the group. While this naturally encourages strong students to participate in the group exam, the size of the penalty was too large (in my opinion). Thus, students that scored more than five points (out of 100) higher than the group had half of the deducted points added back (reducing the weight of the group score from 25% to 12.5%).

The final exam as completed by the group of four students scored 10 points (out of 100) higher than the highest scoring individual final exam and the use of this format increased the (weighted) overall final scores by between 2.5% and 13%.

3. Informal Assessment of The Approach

I taught the first course in this two course sequence in fall 2007 to eight students using a teacher-centered format; four of these eight students continued on to the student-centered second course. This provided an interesting opportunity to compare the two approaches. At the conclusion of the second course a faculty associate of the Center for Faculty Innovation at James Madison University interviewed the four students that had been taught using both methods. The faculty associate was not known to the students and I was not present during the interview. All comments were anonymously collected and later reported to me. The students were asked "Is the format this semester (lecture/problem session) more effective than the format last semester (in the prerequisite course)?". Here are the responses (used with permission of the students) with my additions in square brackets:

> "Definitely. We're more involved, talking through the problems, really learning the material. I feel like all of the explaining we do with each other really makes the whole thing less of a solo endeavor – really helps our learning."
>
> "Last semester, we did homework and it was graded, but there wasn't the pressure to really learn this stuff. Here, we're working through problems in front of everyone. That really makes it real."
>
> "Another thing is that this system is really better with the kinds of problems we're doing. They are longer and harder – so you can miss stuff. When we're working out our problems on each Thursday [problem session], we can really help each other because we're all looking at the problem."
>
> "It is really great too, because the problems we do as a group are similar to the problems we work on solo – this really reinforces our learning. And the lectures help us to prepare our problems which keep that reinforcement going. The stuff she [the author] teaches we get to practice right away. That's really important."

The students were also careful to say that "there wasn't anything 'wrong' with the prerequisite course–just that this [student-centered] method was really ‘right’ for their learning". These comments suggest that the students found that the student-centered approach aided in their learning of the material.

As mentioned in the previous section the use of the group exam increased the overall final scores by at least 2.5% indicating that even the strongest student benefited from the input of their peers.

4. Discussion

My experience was that while this student-centered approach was more work than the teacher-centered approach, it was also more enjoyable and rewarding. The students and I agree that the student-centered approach is an effective alternative to a teacher-centered approach in a theoretical statistics class. One unanticipated advantage of the approach was the benefit of the immediate (two-day) feedback on how students were grasping concepts which allows more timely response to misunderstandings than, say, after a midterm exam. A second advantage was that I got to know individual students much better than in a teacher-centered approach because, presumably, I saw them thinking as individuals and interacting with others. I do not believe the student-centered approach described will work in every classroom but offer it as a starting point for those that wish to move away from a teacher-centered approach to teaching statistical theory. Classes with only four students are rare but I see no reason why a similar approach could not be used in larger classes.

A class size of four made this format easy to manage and adjustments would clearly have to be made to deal with larger classes. Indeed one student commented to this effect in the end-of-semester interview: "this semester’s system really works great with four people. I think it would be harder to do if there were more. But she [the author] should keep doing it this way". Possible ideas to consider would be to form groups and treat each group as an individual in the above approach. That is, each group would be assigned two problems to prepare with one to be presented. Depending on the size of your groups you may wish to give the groups more than two problems; more problems means more time required for preparation but also allows a greater number of concepts to be addressed and the potential to assign harder problems. The ideal number of groups (and therefore size of the groups) will be related to the length of the questions, the time allotted to the class and the amount of chalkboard space in the room. Larger groups have the advantage of reducing the pressure on any one individual; this may be desirable for lower level classes.

When using groups of students there will be details that will need to be decided. For instance, only one student can ultimately write the completed problems on the chalkboard so you could randomly assign one group member to be the ‘presenter’ in a particular week. Such role assignments are used with success in POGIL. In order to encourage all group members to take ownership of the problem and reduce pressure on the presenter your role may expand to questioning any member of the group on a detail of the solution. You may also wish to have group members assess each other’s participation and have a participation component to the overall course grade. This may improve group dynamics and discourage students from letting others do the work.

Don’t feel constrained to have every group present in class. If there are 10 groups in a class but you have less than 10 questions then assign each group some subset of the problems to prepare for in-class making sure to have each problem given to at least one group. Then on the day of presentation, randomly select a group to present each problem. You should be able to select a different group for each problem. The unselected groups are then given the roles of ‘discussants’. The discussants will have prepared a number of the problems and may have different answers or styles of solutions. Get them to point out potential problems as well as different approaches. With a large number of questions I would also suggest that you designate one or two students as ‘recorders’ who copy down the final solutions from the chalkboard. A digital camera can also be used for this.

I am not convinced that the restructured final exam format had any teaching moments in it beyond what had already occurred in class but it did conform better to the student-centered format used in class. I did find that this format allowed weak students to contribute less work on the group exam. A suggestion for improvement would be to have the students rate the participation of other students as well as their own and have these ratings contribute to the final exam score. In larger classes where small groups rather than individuals have prepared the in-class problems, you may wish to have the individuals take the final and then retake it in their small groups. I would not suggest that a large class work together to complete one final exam. This will increase the amount of grading involved e.g. there would be 40 final papers to grade if 30 students were placed in 10 small groups.

In the anonymous end-of-semester interview one student reported that "assigning us two problems [instead of one] is actually better. I have to look at the other problems and work harder, but I understand it better". This comment reflects the choice to switch from assigning each student one problem to prepare for class to one of two problems. If you want the students to understand each concept presented in the corresponding lecture you need to make them prepare problems on each concept. A more difficult alternative to this would be to have each problem address multiple concepts. My goal was to have the students understand each concept (to some degree) prior to their trying the take-home problems.

Throughout the semester, but especially at the beginning, you must resist the temptation to step in and help a student. This can be extremely difficult for the instructor but is crucial if the students are to learn to read and understand their text and notes and to look to their peers for help. Most students will enter a theoretical class and expect a teacher-centered lecture format so you may find that students perceive your refusing to step in as not helping them or that you have no role in the classroom. In order to keep morale high and to have the approach be effective, the importance of communicating to the students why you are using the student-centered approach can not be understated. Do remind the students why you are not helping them. Do reassure them that they do have the information to complete the problem. Do not give them the answers! It took approximately three weeks before the students in this class began operating independently of the instructor.

As discussed, there may be considerable resistance from the students to the approach (Parker, 1992; Weimer, 2002). There may also be resistance from other members of your department. I would encourage you to discuss your proposed student-centered approach with your academic head prior to implementing it in the classroom as resistance from students may result in poor teaching evaluations or complaints. Weimer (2002) directly addressed the issue of untenured faculty trying student-centered approaches in the classroom. As a tenure-track faculty member I was fortunate enough to have a supportive academic head and department that encourages innovative pedagogy. However I did keep colleagues up to date on how the approach was working and also had a faculty member from outside my department collect feedback from the students mid-semester, responded to the feedback, and made the feedback available to the academic head.

"Covering the content", a phrase not generally promoted by student-centered teaching advocates (Weimer, 2002), can be difficult in a student-centered course and this particular course was no different. Users of student-centered approaches such as the one described can be motivated to do so because the approach allows students to discover content for themselves and to build their confidence with the content and in their own abilities. With an approach similar to that described I have very fast feedback on the level to which students are understanding the content because I do not have to wait to grade a homework or a midterm exam. As such, I may revisit content more regularly than in a classroom that has less frequent feedback and this may slow down content coverage. I did not have difficulty covering the content in this second semester class and indeed I was able to cover some topics that I had not covered when teaching the class previously at another institution. This is, I believe, due to putting a greater emphasis on course planning particularly in how the problem sessions, take-home problems and lecture session in each week were related so that students developed the confidence to develop or expand some content by themselves.

I consider the student-centered approach discussed to be a success in the setting described and look forward to using similar approaches when teaching other theoretical classes. I believe that as long as you spend an adequate amount of time thinking about how best to use student-centered instruction in your class, are prepared to adapt your approach when faced with unexpected results, and maintain communication with the students, student-centered methods can have significant rewards.

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References

Black, K.A, (1993), "What to Do When You Stop Lecturing: Become a Guide and a Resource," *Journal of Chemical Education*, 70(2), 140-144.

Gonzalez, G. (2006). "A Systematic Approach to Active and Cooperative Learning in CS1 and its effects on CS2," *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education*, 133-137.

Hanson, D.M. (2006). "Instructors Guide to Process-Oriented Guided-Inquiry Learning," Lisle, IL: Pacific Crest.

Lewis, S.E., Lewis, J.E. (2005). "Departing from Lectures: An Evaluation of a Peer-Led Guided Inquiry Alternative," *Journal of Chemical Education*, 82(1).

Parker, E. (2007), "Thoughts about an Inquiry-Based Mathematics Course in Statistics," Austin, TX: The Educational Advancement Foundation.

Parker, G.E. (1992), "Getting More from Moore," *Primus*, 2, 235-246.

Parker, J. (2005), "R. L. Moore: Mathematician and Teacher," Washington, D.C.: The Mathematical Association of America.

Rossman, A.J., Chance, B.L. (2005), "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory," G. Burrill & M. Camden (Eds.) *Curricular Development in Statistics Education: International Association for Statistical Education 2004 Roundtable*, Voorburg, the Netherlands: International Statistical Institute.

Rossman, A.J., Chance, B.L. (2008), "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Applications, and Theory": http://www.rossmanchance.com/iscat/index.html.

Wackerly, D., Mendenhall, W., Scheaffer, R.L. (2002). "Mathematical Statistics with Applications," (Sixth Ed.), Pacific Grove, CA: Duxbury/Thomson.

Weimer, M. (2002), "Learner-Centered Teaching: Five Key Changes to Practice," (First Ed.), San Francisco, CA: Jossey-Bass.

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