Discovering (in) the Discipline: Going Beyond Statistical Literacy to Explore What Helps Students 'Think Like a Statistician'

Paper for the Proceedings of the 5th annual
International SUN Conference on Teaching and Learning
2006, University of Texas at El Paso

Dr. Lawrence M. Lesser, Associate Professor
Department of Mathematical Sciences
University of Texas at El Paso

Abstract

The author describes the details and results of redesigning his introductory statistics course at a mid-sized public university in the southwestern United States to give more insight into what it means to "discover (in) the discipline". The evaluation of this intervention is supported by various quantitative and qualitative data from students and a peer observer.

1. Introduction

The author recently came across the announcement for the International Sun Conference on Teaching and Learning, which proclaims, "For students to succeed at the highest levels, we must help them think effectively: they must not only be able to regurgitate facts, but be able to "think like a scientist" (or like a humanist, an accountant, a therapist or an engineer...) This year's conference theme -- Creating Inquiring Minds: How to get students to discover (in) the disciplines -- is designed to help us explore strategies for getting our students to show curiosity about the crucial questions of our disciplines, to think deeply and to discover the ways of thinking that we practice as experts in the field."

The author mindfully structured his fall 2005 semester's sections of introductory statistics to apply this general theme to the specific domain of statistics. Because the majority of the course's students were preservice elementary (and some preservice middle school) teachers, it was clear that the goal was not to prepare students to become full-fledged statisticians, but rather to help them appreciate the kind of thinking statisticians do, and thereby hopefully gain deeper knowledge and appreciation of the subject. An active, inquiry-based, critical thinking, "discover in the disciplines" approach seems to be aligned with all six recommendations of ASA (2005), and seemed especially promising for an audience which historically comes to class having perceived mathematics or statistics as unduly difficult, boring or intimidating.

Of course, the goal of learning how to think like a statistician is not limited to students in service courses, but also valuable even for people with fairly high levels of mathematical sophistication. For example, Warshaw (1996) writes: "…it's not enough to teach engineers the math – a large part of statistical education is aimed at teaching students how to 'think like a statistician'. It's not just learning math – it's learning how to approach a problem, how to assess the adequacy of a dataset, etc." Chance (2004) reports that the 2004 ASA Waller Education Award winner Ginger Holmes Rowell "reflected on the people and events that helped her, as a mathematician, think like a statistician and encouraged her to use words instead of formulas to convey concepts." Also, the suggestions for teaching statistical thinking given in Chance (2002) are aimed at non-majors, but "many statistics majors would also be well served by incorporation of these ideas in their introductory courses and reinforcement in subsequent courses."

2. Description of the Approach and Related Literature

One year earlier, the author had partially redesigned the introductory statistics course to have more of a statistical literacy focus, and this course revision included a new textbook: Utts (2005). The discovering-in-the-discipline focus was a vehicle for further redesign by giving students a more active role in encountering this material. Chance (2002) offers a sense in which thinking like a statistician goes beyond statistical literacy by including "the ability to see the process as a whole (with iteration), including 'why,' to understand the relationship and meaning of variation in this process, to have the ability to explore data in ways beyond what has been described in texts, and to generate new questions beyond those asked by the principal investigator. While literacy can be narrowly viewed as understanding and interpreting statistical information presented, for example in the media, and reasoning can be narrowly viewed as working through the tools and concepts learned in the course, the statistical thinker is able to move beyond what is taught in the course, to spontaneously question and investigate the issues and data involved in a specific context." Several problems were shared during the course which appeared to have multiple interpretations (e.g., datasets involving Simpson's Paradox, such as Lesser (2005)) to facilitate discussion by students that was not only lively and active, but also helpful in cultivating the habit of mind (e.g., see Section 3 of Chance (2002)) of finding the best way to think about data to answer a particular question. Such datasets shared may have challenged student beliefs, but as Pfannkuch (2005, p. 7) states: "A willingness to think beyond one's own beliefs at the metacognitive level should be part of students' learning experiences in the classroom."

Because the course's audience is preservice elementary (and some preservice middle school) teachers, there were also assigned readings and reflections based on activity-rich articles in *Statistics Teacher Network*, especially the Fall 2004 and Fall 2005 issues (see Related Websites). Further supporting their role as future teachers, we explored probability manipulatives (e.g., spinners, coins, cards, dice, quincunx), curriculum materials, and websites with applets (see Related Websites). Statistics were shown in the context of the field (elementary/middle school education) to which students aspired, including sample problems and score reports from state-mandated standardized tests (both for future elementary teachers and for elementary students).

Because technology is an integral part of the practice of real-world statisticians, technology was also incorporated into the course in many ways. Using a TI-84 Plus graphing calculator with overhead display panel, the instructor modeled many concepts such as lines of fit, scatterplots, histograms, descriptive statistics, probability simulations and choosing random numbers. Using a TI-73 overhead calculator, the instructor modeled additional graphics such as pie charts and bar graphs. There was also a "spreadsheets week" in which the instructor demonstrated all the major concepts of the semester using Excel spreadsheet software during one class period and the next class meeting was held in a special computer lab where students could all sit in front of their own terminals for their own hands-on exploration and practice (and analysis of the data they had collected for their term projects). Another assignment was using Internet applets (see Related Websites) to explore and construct various graphical summaries.

Each week, examples were discussed and critiqued from media sources (usually the city's daily newspaper or the university's weekly student newspaper). Some examples contained errors or omissions. Research results as reported in newspaper stories were discussed to ascertain if the underlying research strategy was an experiment, a prospective observational study, or a retrospective observational study. Published surveys were discussed to explore the wording, the margin of error, etc. Some students spontaneously brought in examples to share that they found in community and military newspapers.

The author's past experiences as a state government agency statistician were discussed in detail during 20 minutes of one of the class meetings, including both statistical and nonstatistical issues that arose in the context of analyzing, implementing, and explaining a method for estimating unknown quantities using tools such as simple linear regression (a topic students had recently studied in class).

At the first class meeting (August 22, 2005), there were anonymous data collected about the motivational quality of particular problems for a separate research study by this author. The very process of collecting this data was also treated as a learning experience as the instructor first discussed the purpose of the study, explained the need for IRB approval that had been obtained, passed out and discussed the consent forms, and then administered the surveys.

During the first week of class, the author also collected anonymous data using variables of general interest to students' backgrounds and lives, a questionnaire in the same spirit of Appendix 1 in delMas (2005). Some of the items are designed to demonstrate the need to rely on more than just personal intuition, such as in the ability to select a name "randomly" from a page from a telephone directory. Some of the items were used as vehicles to discuss later the real-life need to make judgment calls about missing data, data straddling two categories, data that may be erroneous (e.g., one respondent who reported spending 25 hours/week on a class almost surely meant on all classes combined), etc. This file of class responses was available at every class so that as topics were encountered throughout the course, there was almost always some part of the general class dataset that was could be used on the spot for illustrative purposes.

One of the homework assignments included having students design a sampling scheme to go to a large parking lot and estimate the percentage of cars that are red (Utts 2005, pp. 79-80). The following class meeting, there was a rich classroom discussion about some of the issues and questions that arose when students tried to implement their design, including the selection of the lot, the time, what counts as a car, what counts as red, what if cars enter or leave during the observation, etc. This supported some of the discussion about "operational definitions" from the "count the F's exploration" or "count the number of pages in the book" explorations (e.g., Melton 2004) done during another class period.

Doing their own data collection project on a topic they chose was a capstone experience for the students to do individually or in pairs (about 90% did individually). On a small scale, students had to follow all the basic steps of research, starting by submitting a proposal in which they specified details, including: their topic, nature and source of data to be collected, mode of collection, exact wording of questions, and mechanism to ensure anonymity or confidentiality. The instructor gave feedback on the proposal and then checked one of three categories: project approved as written, project approved if a specified change is made, or re-submission of proposal to address major specified concerns. The design of this assessment was informed by literature such as Short and Pigeon (1998), Halvorsen and Moore (2005), and Roberts (1992). This aspect is arguably one of the most important in the course in light of the observation by Joiner (1988, p. 53): "Most people who teach statistics have never practiced statistics. And even those who have practiced statistics seldom use it in their own lives. Most students get advanced degrees without ever having designed, carried out, and analyzed an experiment or something of importance to them. Thus few teachers and fewer students know what it is like to gather and analyze useful data." Reflections by students from this experience are included in Section 3.2.

Also in November, the College of Education (where the course's students were majors) held its annual fall symposium of faculty and student research, in the format of a big gallery session of posters. Students in the author's course were given a very minimal incentive (an extra quiz score in the event their course grade fell just shy of a letter grade cutoff) if they attended and wrote a reflection. The excerpts from these reflections suggest that for at least some students, this experience was (perhaps surprisingly) meaningful in a "discovering in the discipline"-kind of way, connected to their professional trajectories:

"I could definitely see myself presenting one of those posters sometime in my near educational future. My dream is to become an early childhood bilingual educator. I would really like to have the opportunity to research techniques, methods, activities, anything and everything that would prepare my bilingual students to succeed and to find different methods that would work better in my children's learning abilities."

"I arrived at the COE Fall Research Symposium without much enthusiasm, I'll admit. But, after walking around a bit and interviewing the presenters, I grew greatly interested in their work. As a future teacher, I saw myself in their shoes, researching ideas for the sole purpose of expanding education and touching lives…..When I become a teacher, I also would enjoy furthering my career by researching topics and ideas that could help my students."

3. Results

3.1 Survey of Students on this Topic

Below are the statements of an anonymous survey on “how statisticians work or think” administered to both classes on November 21, 2005. This date was chosen because the two remaining class meetings after the survey involved no “new material”, but rather time to work on and discuss and present their projects and review for the final exam. For each statement, students indicated one of 6 levels of agreement: strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree. [Dr. X stands for the instructor, the author of this paper.]

1.) Being part of Dr. X’s research study (the anonymous data collected from you the first day of class about how particular problems motivated you) was helpful in giving me insight into “how statisticians work or think”.
2.) Doing my own data collection project on a topic of interest to me has been helpful in giving me insight into “how statisticians work or think”.
3.) Analyzing the anonymous class questionnaire data (e.g., “hours/week you watch TV”, “hours/week you exercise”, “average price of one of your textbooks”, “region you grew up in”, etc.) several times to illustrate various concepts throughout the course was helpful in giving me insight into “how statisticians work or think”.
4.) Discussing Dr. X’s past experiences as a state government statistician…was helpful in giving me insight into “how statisticians work or think”.
5.) Discussing and critiquing examples from the media (e.g., [the city’s newspaper or the university’s student newspaper]) each week has been helpful in giving me insight into “how statisticians work or think”.
6.) The way our text (*Seeing Through Statistics*) is written with real-world examples and case-studies has been helpful in giving me insight into “how statisticians work or think”.
7.) Making connections to the elementary/middle school classroom such as manipulatives, activities, websites, and the articles from *Statistics Teacher Network* has been helpful in giving me insight into “how statisticians work or think”.
8.) Using technology (such as spreadsheets, Internet applets, graphing calculators, etc.) has been helpful in giving me insight into “how statisticians work or think”.
9.) This course would have been better if it had not included the above-mentioned ways to explore “how statisticians work or think” and just stuck to lecturing/practicing basic math content.

The results are presented in pooled form for simplicity, because the trends were similar in both classes and because both classes were taught by the same instructor with the same approach and at very similar times of the day (the classes were back-to-back periods each Monday and Wednesday afternoon). The 57 students who responded correspond to 86.4% of all the students enrolled in those 2 sections of the course. One of the survey’s written instructions was to leave an item blank if the student had no opinion or simply did not remember the activity mentioned in the question. The only item in which students left anything blank was item 4 (where 3 students did).

Statement	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly Disagree
1 (research participant)	42.1%	49.1%	8.8%	0%	0%	0%
2 (collecting data)	45.6%	42.1%	10.5%	0%	0%	1.8%
3 (class questionnaire data)	54.4%	42.1%	3.5%	0%	0%	0%
4 (statistician experiences)	25.9%	51.9%	16.7%	3.7%	1.9%	0%
5 (media)	47.4%	42.1%	8.8%	1.8%	0%	0%
6 (textbook)	31.6%	45.6%	22.8%	0%	0%	0%
7 (education connections)	61.4%	29.8%	8.8%	0%	0%	0%
8 (technology)	57.9%	33.3%	8.8%	0%	0%	0%
9 (overall)	3.5%	3.5%	1.8%	5.3%	14.0%	71.9%

The percentages of students who strongly agreed on the first 8 items average 46% and range from 26% to 61%. The percentages of students who agreed or strongly agreed on the first 8 items average 88% and range from 77% to 97%. Finally, the percentages of students who strongly agreed, agreed, or somewhat agreed average 99% and range from 95% to 100%.

If we assign the 6 category ratings numerical values (1, 2, 3, 4, 5, 6), we can then test the null hypothesis that a particular average rating is 3.5 (i.e., "neutral"). A Ryan-Joiner test for normality for each of the 9 questions yields that there is statistically significant ($p < .01$) evidence against normality only for questions #2 and #9, while the others have p-values > .100. So we can do a one-sample two-sided t-test (that the mean is 3.5) for questions 1, 3, 4, 5, 6, 7, 8 and we must do a one-sample two-sided Wilcoxon signed rank test (that the median is 3.5) for questions 2 and 9. The results are as follows:

Question #	1	2	3	4	5	6	7	8	9
Mean	1.67	1.72	1.49	2.04	1.65	1.91	1.47	1.51	5.39
Std.dev.	.636	.881	.571	.868	.719	.739	.658	.658	1.26

Question #	1	2	3	4	5	6	7	8	9
Test statistic	t = -21.76	W = 44.0	t= -26.57	t= -12.39	t= -19.42	t= -16.23	t= -23.27	t= -22.85	W = 1559.5
p-value	.000	.000	.000	.000	.000	.000	.000	.000	.000

It should be noted that items 1-8 were designed to assess the effectiveness of a particular course feature in meeting the particular goal of giving insight into how statisticians work or think. Item 9, however, is more of a "big picture" item to see whether or not that goal actually made the course better. The results were very strong on this last item, and perhaps might have been even stronger if any students did not notice the "reverse direction" of the scale on that question only and continued their pattern of answers on the left side of the scale. (Possible evidence supporting this conjecture: There was no evidence of changed responses in items 1-8. There were three instances of an answer changed – one circled and another circled then crossed out. In all three instances, the answer was changed in the direction of disagreement, by 3, 5, or 1 levels. In the instance of the 5-level change, there was an unsolicited written comment "tricky" accompanied by a smiley face.)

One observation suggested by the data is that a textbook (even a very progressive one) and the statistical experiences of an instructor (even when told enthusiastically) are not perceived to be as powerful or useful in giving students insight into how statisticians work or think, compared to pedagogical events that more directly involve students, their professional directions, or current events (more current than a textbook could have). It is not surprising that hearing about the author's experiences as a statistician were not as powerfully associated with discovering in the discipline as the experiences in which students themselves were involved in the collecting or analysis. Also, it may be hard to imagine any textbook being valued more highly than classroom discussions of datasets or media examples collected that very day.

3.2 Evidence from Student Projects

The data collection project on a topic of the students' choice (beyond the book) was a natural "capstone experience" of the course, and the writeups revealed evidence of a "discovering in the discipline" habit of mind in many individual students. This was most pronounced in the Discussion section of their project writeups, in which students were asked to "make any interpretations or conclusions you can from your data, discuss any limitations of your data or method, discuss any difficulties or judgment calls you encountered and how you handled them, and discuss what you might do differently next time."

Many of the writeups went beyond simply presenting results and reflected seriously about robustness and alternative interpretations. Because students each chose topics on their own, beyond anything in our textbook, they could not just mimic the textbook but truly had to activate their own habit of mind to produce reflections such as:

"One thing that I noticed was that it seemed that as we go further down the spectrum the ages seem to go up slightly….And if the outliers are removed from the categories the range of numbers is more pronounced."

"I guess that by inserting the option of having no opinion in one of my questions, it tended to sway students not to consider the issue more closely. I also believe that the time of day in which I conducted my survey also influence the outcome of the survey. For instance, the majority of the population which was surveyed in the afternoon classes really don't worry about parking because less students are present at that time and not to mention, it's an open campus in which students are allowed to park inside the campus."

"At the end of my project it is difficult to find any interpretations that are absolutely conclusive, yet I am sure that most first time data collections follow the same path….I believe that my conclusions were diluted because of the amount of surveys collected and due to the limitations of the questions I asked."

Because of a pending proposal for toll roads in our city, one student did analysis which included exploring the correlation between age and amount a person would be willing to pay for toll roads. She went beyond simply reporting the slight positive correlation: "I noticed is that older people were willing to pay more at the toll roads….The positive correlation may be due to confounding variables that as a person gets older the more income they have."

There was generally no readily accessible sampling frame, but some students tried valiantly and creatively to aim for randomness as best they could:

"I used 11 different places: church, restaurants, acquaintances, [local university] students, [local community college] students, my neighborhood, store 1, store 2, store 3, at a library, and at a public restroom. I also let the calculator randomly select 11 numbers that totaled 50, which is the number of surveys I was accountable for."

"I logged on to my school email system entitled webmail and selected students from the school directory. I tried getting students from every lettered section of the directory [i.e., from each letter of the alphabet], but when I would send the survey/questionnaire to their e-mail address I received several auto responses from inboxes that my message could not be received because that inbox was full."

"I used a random sample by going to different locations on campus and spreading out the surveys. I did 20 at the Union, 40 in class, 20 in the library and 20 at the student center. I also avoided asking people that were in the same groups to avoid similar answers."

One student actually used two different designs (survey and observational study) in the same project.

Also, while they were not specifically asked to, some students took the opportunity to reflect about the overall experience of doing this project. These comments suggest they had had (and appreciated) a "discovering (in) the discipline" experience:

"Doing all the work myself, I was able to grasp the ideas more and I realize that it isn't easy and it is not just a matter of putting a graph together. I am very grateful for this experience because it has given me some insight into the world of statistics!"

"As I look back, I realize I have learned the beginnings of statisticians. Not only did [I] enjoy the process, but I now have the desire to acquire more information. The possibilities are endless!"

"I never realized how hard it [is] to have to organize and simplify data (in the future, I will always respect statisticians for their unnoticed hard work). However, for every difficulty that arose, there were many times that I loved it!! I was able to become a statistician for at least a couple of weeks. In conclusion, there are many things I would do differently. For example, I would ask more than one hundred people (just in case not everyone answers the questionnaire correctly) and I would take more time analyzing the data I received. But all in all, this has been one of my most fascinating college experiences."

3.3 Peer Observation

A statistician was asked to do a peer observation of the author's teaching of this course that semester for purposes of overall assessment of teaching for a dossier. The colleague was not given further directions or specifically asked to look for the aspect of the course that is the subject of this article. The colleague visited an 80-minute meeting of the class (November 9), and returned one week later for 20 minutes to collect further information anonymously from the students without the author present. Students freely gave oral and written feedback to the peer observer (who served as moderator and note-taker for the oral focus group discussion) and were assured that the feedback would not be shared with the author until after course grades were turned in. The peer observer also reviewed copies of all course documents, including: syllabus, projects, homework problems, tests, quizzes, and textbook supplementary handouts. As a Fellow of the American Statistical Association, this peer observer is highly qualified to observe whether students indeed appear to be discovering in the discipline. The summary paragraph of the peer observer's report includes this observation: "Dr. X encourages the students to reflect on the material and ponder the relevance of statistics to research that affects their daily life. This step is essential to fostering a desire to learn more about the subject by internalizing a sense of its importance and by awakening the students' curiosity. Hopefully, these future teachers will convey this aspect of their learning experience to their own students."

3.4 End-of-Course Student Evaluations

As required by the university, anonymous end-of-course student evaluations were administered during the last two weeks of the course, with the instructor out of the room during the 20-25 minutes allotted for this, and students turning in the collection envelope directly to department staff. The author's sections yielded very positive student evaluations, with 56 students responding (84.8% of the students enrolled in both sections combined).

Effectiveness of the instructor in stimulating your interest in the subject:
Excellent (78.6%) Good (19.6%) Satisfactory (1.8%) Poor (0.0%) Very Poor (0.0%)

Relevance of class assignments
Excellent (69.6%) Good (28.6%) Satisfactory (1.8%) Poor (0.0%) Very Poor (0.0%)

Overall rating of the instructor
Excellent (76.8%) Good (21.4%) Satisfactory (1.8%) Poor (0.0%) Very Poor (0.0%)

Effectiveness of this course in challenging you intellectually
Excellent (50.0%) Good (39.3%) Satisfactory (10.7%) Poor (0.0%) Very Poor (0.0%)

Overall rating of this course
Excellent (50.0%) Good (44.6%) Satisfactory (5.4%) Poor (0.0%) Very Poor (0.0%)

The first three items came from the "the following questions refer to your instructor" section of the university evaluation form, while the next two came from the "the following questions refer to this course" section of the form. In general, the ratings were higher on the "instructor" part than the "course" part, which raises the question of how much of the "discovering in the discipline" approach is or can be systematically built into the course and how much is more a function of the more-or-less-already-in-place style and habits of the instructor. While the other sections of this course that semester – taught by other people who taught more traditionally without this deliberate "discover in the disciplines" approach, but who all covered the same chapters in the same textbook – were not rated as highly, it may not be possible to claim definitively that the difference was in the approach.

Keeping in mind the particular audience (mostly preservice elementary teachers) of this course, the positive response to the author's teaching is all the more striking considering the students' answers to these additional items on the end-of-course evaluation:

I took this course:
To fulfill a requirement (98.2%) as an elective (3.4%) for my own interest (0.0%)

Before taking this course, my level of interest in the subject was:
high (0.0%) average (5.4%) low (26.8%) unsure (64.3%)

4. Further Reflections

The interventions described in this article could go a long way towards addressing the critique (of science education, but applicable to many statistics courses) by Willis (1995, p. 1): "Hands-on experiences have typically been limited to 'cookbook labs' with outcomes known in advance, not real investigations. In most classrooms, science has been presented as an inert body of knowledge to be assimilated, rather than a process of inquiry and a way to make sense of our world." It may be the instructor's willingness to be a bit spontaneous in his/her teaching that plays a big role, modeling how to think out loud with just-collected data and even what to do when the technology does not work right away. In fact, a letter the author received from a fall 2005 student a month after grades were turned in specifically praised this in-the-moment style of teaching: "He could have easily just stood at the chalkboard every day and preached a lesson to us, as some professors do, not caring if things got monotonous. But he chose otherwise. Every class I walked in the door not knowing what to expect he was going to teach or in what fashion." One written peer observation comment was that "class responses to a question were used for data to compute another example on the fly", an example of modeling the process of how statisticians approach the collection and analysis of data in real time.

Acknowledgment
The author thanks his TA/Grader Peng Zhou, UTEP masters student in statistics, for entering the survey data (reported in Section 3.1) into a spreadsheet.

References

American Statistical Association (2005), "Guidelines for Assessment and Instruction in Statistics Education." Published on the World Wide Web at http://www.amstat.org/education/gaise/

Chance, B. (2002), "Components of Statistical Thinking and Implications for Instruction and Assessment". *Journal of Statistics Education* ,10(3), www.amstat.org/publications/jse/v10n3/chance.html.

Chance, B. (2004), "Minutes of the Statistical Education Section Business Meeting." Published on the World Wide Web at: www.amstat.org/sections/educ/minutes/bus04.html.

delMas, R. (2005), "Teaching Statistics to Under-Prepared College Students." In J. Garfield (Ed.), *Innovations in Teaching Statistics* (MAA Notes #65), pp. 51-63. Washington, DC: Mathematical Association of America.

Halvorsen, K. T. and Moore, T. L. (2005), "Motivating, Monitoring, and Evaluating Student Projects". In T.L. Moore(Ed.), *Teaching Statistics: Resources for Undergraduate Instructors* (MAA Notes #52), pp. 27-34. Washington, DC: Mathematical Association of America.

Joiner, B. L. (1988), "Let's Change How We Teach Statistics." *Chance*, 1(1), 53-54.

Lesser, L. M. (2005). "Illumination Through Representation: An Exploration Across the Grades", *Statistics Teacher Network*, 66, 3-5. [Also available at: http://www.amstat.org/education/stn/pdfs/STN66.pdf]

Melton, K. I. (2004), "Statistical Thinking Activities: Some Simple Exercises with Powerful Lessons." *Journal of Statistics Education*, 12(2). http://www.amstat.org/publications/jse/v12n2/melton.html

Pfannkuch, M. (2005), "Characterizing Year 11 Students' Evaluation of a Statistical Process." *Statistics Education Research Journal*, 4(2), 5-26. Published on the World Wide Web at: http://www.stat.auckland.ac.nz/~iase/serj/SERJ4(2)_pfannkuch.pdf

Roberts, H. V. (1992), "Student-Conducted Projects in Introductory Statistics Courses." In F. and S. Gordon (Eds.), *Statistics for the Twenty-First Century* (MAA Notes No. 26), pp. 109-121. Washington, DC: Mathematical Association of America.

Short, T. H. and Pigeon, J. G. (1998), "Protocols and Pilot Studies: Taking Data Collection Projects Seriously". *Journal of Statistics Education*, 6(1). www.amstat.org/publications/jse/v6n1/short.html

Utts, J. M. (2005), *Seeing Through Statistics (3rd ed.)*, Pacific Groves, CA: Brooks/Cole.

Warshaw, M. (1996), "Re: Can We Train Capable Undergraduate Statisticians?" Posting to Ed-stat on February 18, 1996. Accessed on November 25, 2005 at www.math.yorku.ca/Who/Faculty/Monette/Ed-stat/0293.html.

Willis, S. (1995), "Reinventing Science Education: Reformers Promote Hands-On, Inquiry-Based Learning". *Curriculum Update*, 14(3), 1-8.

Related Websites

Applets
http://www.shodor.org/interactivate/activities/tools.html#pro
http://illuminations.nctm.org/swr/list.asp?Ref=2&Std=4
http://nlvm.usu.edu/en/nav/topic_t_5.html

Statistics Teacher Network
http://www.amstat.org/education/STN/pdfs/STN64.pdf (fall 2004; issue 64)
http://www.amstat.org/education/STN/pdfs/STN67.pdf (fall 2005; issue 67)