Team-Based Learning in a Statistical Literacy Class

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Abstract

Team-based learning (TBL) is a pedagogical strategy that uses groups of students working together in teams to learn course material. The main learning objective in TBL is to provide students the opportunity to *practice* course concepts during class-time. A key feature is multiple-choice quizzes that students take individually and then re-take as a team. TBL was originally conceived by Larry Michaelsen (University of Central Missouri) for his business classes and has proven to be especially effective in training medical students. In this paper, we describe an adaptation of TBL for an undergraduate statistical literacy course.

1. Introduction

Using small groups to supplement traditional lectures is a valuable teaching technique in many disciplines, including statistics. Students engage actively in the learning process, either by working cooperatively on problems or discussing concepts (Garfield 1993; Keeler and Steinhorst 1995; Roseth, Garfield, and Ben-Zvi 2008). An instructor might use small groups casually and not assign a grade to group work or worry about group composition. In a more structured use of small groups, an instructor may dedicate a larger period of time to a group activity or worksheet, and he may even form the groups. One pedagogical strategy that uses structured group work is team-based learning. In this paper, we briefly describe the main features of team-based learning and how we adapted this strategy for an undergraduate statistical literacy course.

2. Team-Based Learning

Team-based learning (TBL) is a pedagogical strategy that uses groups of students working together in teams during class to learn and apply course concepts. Unlike the use of small groups described in the previous paragraph, teams are assigned permanently at the start of the course and are held accountable throughout the term for both their individual and team efforts. Thus, TBL falls under the broad definition of cooperative learning described in Garfield (1993).

The main learning objective in TBL is to provide students the opportunity to practice course concepts during class-time. A TBL course is designed to move away from an instructor-centered approach to learning where information flows from teacher to student to one where students come to class prepared to apply the concepts from their readings. In this paper we describe the main components of TBL, then discuss how we implemented TBL in a statistical literacy course.

Larry Michaelsen originally developed TBL for his business classes while at the University of Oklahoma in the late 1970's. He was motivated by the enrollment pressures in his department and wanted a way to effectively use small groups and active-learning in lecture halls of 120 plus students. He came up with a teaching strategy that has four essential ingredients (Michaelsen, Knight, and Fink 2004):

- **Teams** The teams, which are formed by the instructor, are large (5-7 students), diverse and permanent for the duration of the class. This team structure is designed to spread weak and strong students across all teams which, with properly crafted in-class activities, will also let the stronger students test their understanding of a topic as they explain it to the weaker students in their team during an activity.

  This structure should also motivate the weaker students to come prepared to contribute to the team activity and not always be the team-member who has not done the needed reading prior to class. The permanent structure of teams is designed to increase communication and trust between team members and, as the class progresses, encourage more open conversations between all team members, not just the confident and talkative students on a team. These well-developed teams can tackle more challenging problems than individuals or newly formed groups.

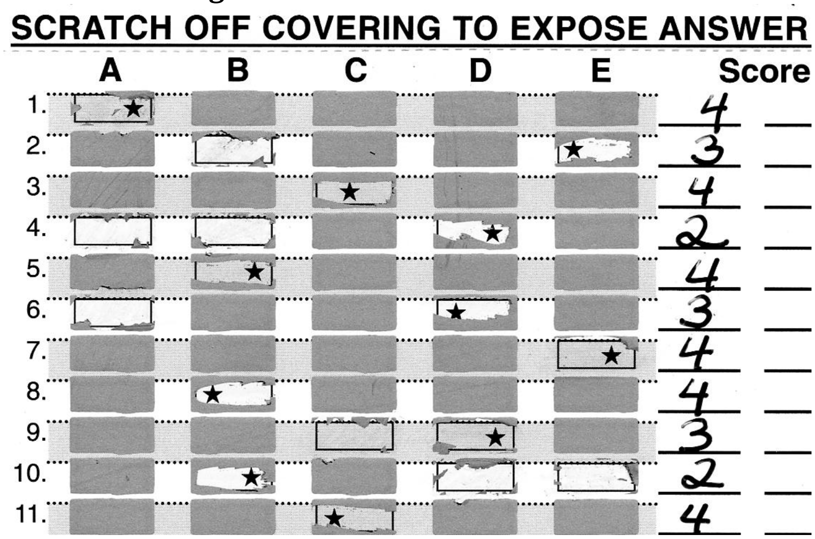
- **Accountability** Students must be accountable for the quality of their individual and group work. In particular, to make team-based collaboration effective, a student's contribution to the success of the team must be part of the course grade.

- **Feedback** Students must receive frequent and timely feedback from the instructor to assess both individual and team learning. Feedback on an in-class activity can take many forms such as simultaneously reporting answers to a question or giving students and teams immediate feedback while they work through quiz questions. Immediate feedback during group activities is also a key to the development of a successful team since the most vocal or confident student in a team is not always the team member with the correct answer. In Michaelsen's experience, once students realize that the most vocal student is not always the one with the correct answer, he [Michaelsen] saw quieter team members begin to assert themselves.

- **Assignment design** Group assignments must promote both learning and mutual team development. "In most cases, team assignments generate a high level of interaction if they require teams to use course concepts to make decisions that involve a complex set of issues and enable teams to report their decisions in a simple form" (Michaelsen and Sweet 2008). They note that well-designed activities usually satisfy the "4 S's" criteria: *significant* question or problem, *same* assignment, *specific* choices, and *simultaneous* reporting. They also advise that instructors should avoid assignments in which teams can divide up the tasks among team members.

In Michaelsen's implementation of TBL, a key feature is the Readiness Assessment Process (RAP): a course is organized into four or five major modules or units, and before each module students are required to read ahead in the textbook on this material. To ensure that the class has done the required reading, each student takes a multiple-choice quiz individually (Individual Readiness Assessment Test, or iRAT), turns in their answers, then re-takes the quiz as a team (Team Readiness Assessment Test, or tRAT). Team members must discuss each question and come to a consensus on the answer. They then use an Immediate Feedback Assessment Technique (IF-AT) card (Figure 1) on which they scratch off their choice for the correct answer. These sheets provide instantaneous feedback as well as partial credit since they can continue to scratch off choices until they arrive at the correct answer. A student's quiz score is then a weighted average of the iRAT and tRAT scores. The RAP is designed around the four TBL ingredients described above: individual accountability is assessed with the iRAT and team development and accountability is assessed with the tRAT. The tRAT also provides students with immediate feedback. Lastly, each quiz should be designed to assess knowledge of basic course content, but also should be challenging enough to promote a high level of discussion within each team.

Figure 1. IF-AT scratch-off card



Students scratch off their choice for each question until they arrive at the correct answer. Here, each problem is worth 4 points.

The IF-AT cards, made with options of four answer choices or five answer choices, are available for purchase from the website: www.epsteineducation.com. (A set of 500 cards, each with 10 questions, costs $85.00.) Alternatively, if IF-AT cards are not available, an instructor can instruct teams to rank their choices on a paper scorecard, then have teams grade their work with an answer key that is provided at the end of the quiz. Though feedback would not be instantaneous with each question, students would still receive nearly immediate assessment of their understanding of the material. Instructors with access to a course management system and computer labs could also build online quizzes that provide intermediate feedback to the student teams.

After students take the quiz, class time is then spent on applications of the material. The primary idea is to spend less class time lecturing on basic concepts and more class time letting students learn how to apply the concepts.

TBL has been implemented successfully in medical education as well as in law and business schools (Dana 2007; Mennenga and Smyer 2010; Vasan and DeFouw 2005). For instance, in an article in *Academic Medicine*, Koles, Stolfi, Nelson, and Parmelee (2010) report on the impact of TBL on the academic performance of second year medical students. On a high-stakes pathology-based exam, the authors compared scores on questions related to content associated with a TBL module ($n = 250$ students) to scores on questions unrelated to TBL modules ($n = 462$ students). Average score on TBL-related questions was significantly higher ($p < 0.001$) with the weakest students being helped the most.

In the early 2000's, Harkness, Heckard, Buchanan, and Herbison (2002) and Harkness, Buchanan, Heckard, and Rosenberger (2003) restructured the introductory statistics courses at Penn State University by implementing RAT's to ensure student preparedness before a learning unit. Students also worked on problem-based activities, often in a lab setting, in pairs or in groups. While these courses had some components of Michaelsen's TBL, in particular, the RATs and in-class activities, it is not clear from their description whether these groups were permanent for the duration of the course, or to what extent the *team* aspect was emphasized. Other TBL strategies, such as the *four S's* of assignment design, are not mentioned in the Penn State implementation.

3. TBL for a Statistical Literacy course

3.1 Background

Carleton College is a residential undergraduate liberal arts college of about 1800 students, located in Minnesota. We offer two to three sections of our statistical literacy course every year. The class size is typically between 30 to 35 students. Classes meet three times a week, 70 minutes on Mondays and Wednesdays, and 60 minutes on Friday, for nine and a half weeks. The audience consists of humanities or fine arts students wanting to satisfy a graduation requirement, as well as political science or sociology students taking the course as a prerequisite for a research methods course. Calculus is not a prerequisite for the course.

The course focuses on statistical concepts with emphasis on understanding and interpretation of statistical information, especially in the context of media reports and scholarly articles. The technical demands are minimal: some basic probability, calculating z-scores, 95% confidence interval for a proportion and the chi-square test statistic for a 2x2 table. We cover most of the material in the textbook *Seeing Through Statistics* by Jessica Utts (2005). The students use the statistical software program S+ (through the graphical user interface) to perform exploratory data analysis.

3.2 Implementation

Our implementation of TBL for our statistical literacy course has all of the main ingredients of TBL discussed in Section 2. The one alteration that we made was in the timing of the RAT quizzes. In Michaelsen's original conception of TBL, the RAP occurs at the beginning of a new module or unit with students taking the RAT to ensure that they have the basic background skills needed to start applying the new concepts. We decided, however, that we wanted the quizzes to assess more than the basic concepts in each unit, so we have made a crucial change by administering the quizzes *after* having covered the material (typically one quiz every two weeks). As indicated below, we utilize short online posts or quizzes to motivate class readiness. Despite this modification, we feel that we are still able to capture the true spirit of TBL.[1] In what follows, we describe the basic design of our statistical literacy course and provide more details about the some of the team activities and RAT quizzes used in our course.

On the first day of class, we explain the team-based learning concept and have the students take a practice tRAT quiz. We then explain that their course grade will be a weighted average of one midterm, a final exam, a data analysis project, participation, homework and the RAT quizzes (Table 1).

[1]Though we administer the quizzes *after* covering a block of material, we will continue to use the acronym RAT.

Table 1. Typical grading scheme

RAT quizzes (4)	25%
One midterm	25%
Final Exam	25%
Participation	10%
Report	12%
Homework	3%

The participation grade is based on attendance, pre-class posts to Moodle (a course management software), and the student's contribution to their team. The midterm, final, data analysis project and homework grades are based on individual efforts whereas the participation and RAT quizzes grades have both an individual and team component.

In order to pass the course (C- or better), students must earn a passing grade on the individual components of their grade. If and only if this criterion is met do we then factor in the team quiz scores into their course grade. This policy is enacted to alleviate the concern that good students often have about group work: weak or less industrious students riding on the coat-tails of their stronger or better motivated classmates (i.e. "I did all the work but everybody got the same grade"). We stress this policy throughout the term.

On the second day of the term, we form the teams of size five. We start by randomly assigning students to teams, then we usually make some adjustments to ensure the teams are balanced with respect to factors such as gender, class year, and major. These teams, which are permanent assignments for the term, meet in class each day that is not an exam or computer lab day.

Students are required to prepare for class by reading ahead in the book on material that will be covered in the next class. While the team-oriented structure of the class does encourage students to actually do this reading, we still find it useful to implement individual checks of student preparedness. Thus, to ensure that students have done the assigned reading, we check student preparedness using the Moodle course website. One term we required students to post questions or comments on the material on Moodle prior to coming to class. Moodle posts are factored into each student’s individual participation grade. We structure our lecture around the questions and comments submitted by the students. Typically, we lecture for about 20 to 30 minutes before breaking into team activities. After receiving mixed feedback from students on these posts, that the required posting encouraged reading but was not seen as a valuable learning tool to the students, we switched to requiring students to take short quizzes on Moodle prior to class. These three-question quizzes test basic content knowledge and are used to assess individual student preparation. The quizzes also provide feedback to students prior to class about their grasp of basic material. Instructors can then use quiz results to structure their lecture for that day and scores become part of the student's individual grade.

3.2.1 Activities

As mentioned above, on a typical day, we start with a 20 to 30 minute lecture, then have the students move into their groups for activities. We attempt to design many of our activities to have the "4 S's" criteria discussed in Section 2. The following describes an activity that illustrates the 4 S's idea.

Example 1: We provide the students with a newspaper article or a portion of a journal article. After giving them some time to read through the material, we pose several multiple choice questions about the reading to the teams. (We project the questions on a screen using Powerpoint slides).

For instance, we give the students a 2007 news article describing a study in the United Kingdom on a group of 10,000 government workers who were tracked for several years. In this study, researchers found that those who did not get enough sleep were more than twice as likely to die of heart disease compared to those who did get enough sleep. We ask: Which conclusion can be made from this study?

A. This was a retrospective study and the populations being compared were those who did and those who did not get enough sleep.
B. This was a prospective study and the populations being compared were those who did and those who did not get enough sleep.
C. This was a prospective study and the populations being compared were those who died from a heart attack and those who did not.
D. This was a retrospective study and the populations being compared were those who died of heart attack and those who did not.
E. This was a case-control study and the controls were those who did not die of a heart attack and the cases were those who did die of a heart attack.

After giving the students some time to discuss the question with their teammates, we instruct each team to write down their answer on mini whiteboards. On cue, they simultaneously raise their whiteboards so that all the students can inspect the responses. We then choose a team and ask them to defend their choice. This is done to avoid "answer drift" (Michaelsen and Sweet 2008) where later responding students change or modify their responses based on what has been said before, even if what was said before is incorrect. Simultaneous reporting forces every team to make a decision before they know the pattern of responses of the other teams.

For problems whose answers cannot be reduced to a simple choice, we might send team representatives to the blackboard to simultaneously report their answer. The following True/False question is an example that can use this type of reporting.

Example 2: True or False. If the boxplot of a data set is symmetric, then the stem-plot of the data set will also be symmetric. If true, justify your response; if false, provide a counterexample.

Another option for simultaneous reporting is the "gallery walk" (Michaelsen and Sweet 2008): teams write answers on large easel paper, then post these sheets on the wall. Students walk around the room to inspect the work, using post-it notes to make comments or ask questions.

In all of the examples above, the in-class discussions that ensue are lively and motivate the students to keep up with the material so that they may participate. These activities also provide *immediate feedback* to students so that they do not leave class with misconceptions about the material covered for that day.

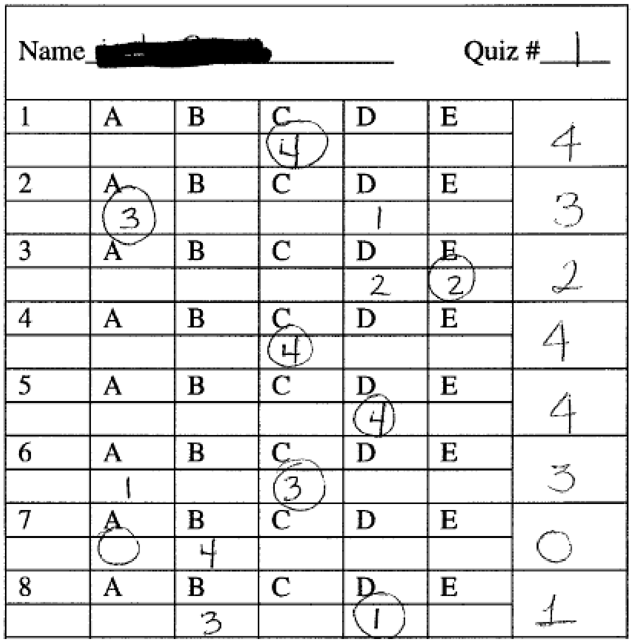
Other in-class activities, that may or may not involve simultaneous reporting, include running simulations or analyzing portions of journal articles. For technical topics such as basic probability or the normal distribution, we hand out worksheets and have the teams work collectively on the problems. We walk around the room to answer questions though, in general, students help each other out and do not require much input from us. When most of the teams have completed their worksheet, we choose one team to put the solutions on the blackboard. We can then use this time to clarify any particularly difficult ideas or common misconceptions. See the Appendix for a sample activity on understanding surveys and a sample worksheet on hypothesis tests.

All team activities are done in class. This forestalls a common complaint that students have about the difficulty in scheduling meeting times with their team members outside of class.

3.2.2 Quizzes

Approximately every two weeks (three to four chapters), we administered the quizzes with fourteen multiple choice questions, each worth four points. First each student takes the quiz individually. A student can earn partial credit by allocating the four points per problem in any way s/he wishes (see Figure 2). For example, if a student is confident that the correct choice is "C," he would place all 4 points under "C." But in a situation where a student is fairly certain the answer is "A," but is hesitant to rule out "D," she could allot 3 points to "A" and 1 to "D." The students appreciate earning partial credit on a multiple-choice quiz. More importantly, allowing for partial credit paves the way for discussion when the students re-take the quiz as a team. Teams are less likely to determine an answer by majority rule if individuals within a team displayed uncertainty in their answer by splitting points between two or more options.

Figure 2. Individual quiz answer sheet



Name [redacted] Quiz # 1

1	A	B	C	D	E	4
			(4)			
2	A	B	C	D	E	3
	(3)			1		
3	A	B	C	D	E	2
				2	(2)	
4	A	B	C	D	E	4
			(4)			
5	A	B	C	D	E	4
				(4)		
6	A	B	C	D	E	3
	1		(3)			
7	A	B	C	D	E	0
	( )	4				
8	A	B	C	D	E	1
		3		(1)		

Student can allocate 4 points in any manner he/she wishes. The circled choice indicates the correct response and the right column gives the points earned for each question.

We allot about 20 to 30 minutes for the individual quizzes after which the students turn in their answer sheets and move into their groups to retake the quizzes as a team using the IF-AT forms (Figure 1).

Sample question: A newspaper publishes a poll that says of 1010 Americans surveyed, 69% support the death penalty with a 3% margin of error.

A. If we repeatedly sample 1,010 Americans, in about 95% of these samples we would get a sample proportion between 66% and 72%.
B. We are 95% confident that between 66% and 72% of Americans support the death penalty.
C. We are 95% confident that between 66% and 72% of the people in our sample support the death penalty.
D. There is a 95% chance that between 66% and 72% of Americans support the death penalty.
E. There is a 95% chance that between 66% and 72% of Americans in our sample support the death penalty.

The discussions during the team quizzes are lively and intense. The students compare their answers with their teammates and when there are discrepancies, go through a thoughtful give-and-take, weighing the possible choices. The team scores are high---usually in the 90% range. The table below is typical: it displays the statistics for one quiz (56 points possible). For instance, in Team 6, the average of the five individual scores was 54.3% (the highest individual score was 75%), yet with the students working together, the team achieved a score of 98.2%.

Table 2. Team scores (percentage) on one quiz (out of 56 total points).

	Team						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Average individual score	69.2	73.7	81.3	71.8	61.1	54.3	64.3
Team Score	98.2	96.4	100	100	91.1	98.2	91.1
Average weighted score	87.7	88.4	93.4	90.1	80.6	82.8	77.9

In general, the team score is higher than the individual score of any given team member. In six TBL courses, there have been only a few instances where an individual scored higher than the team. The difference was small and did not affect the course grade of the individual.

As we noted earlier, a student's score for a quiz is a weighted average of the individual score and his or her team scores (typically 35% individual, 65% team).

4. Discussion

We have found team-based learning to be an effective teaching strategy that focuses on students practicing or applying statistical concepts in class. Although we spend some time lecturing on course content, we expect students to learn the basic concepts on their own and devote most of the class time on team assignments. By assessing students on both individual work and team work, students are motivated to come to class prepared and engage in the group activities.

Students have been very positive about team-based learning. Between the two authors, we have used TBL six times in the statistical literacy course. One of us (St. Clair) tabulated student responses in two sections. Of 50 respondents, 94% liked the TBL format. In addition, 76% thought the amount of lecturing by the professor was adequate, while 20% thought it was too much and only 4% thought it was too little.

Students comment that they enjoy working on teams ("Loved teams! This is weird because I do not normally like team work. In this class team work helped to understand the problem"), and they appreciate the immediate feedback that they receive from the in-class activities ("I liked that we were able to get instant feedback and teach one another"). Because in-class activities required that each team produce something, an answer, a graph, etc., "I was motivated to prepare for class every day because I did not want to let my teammates down."
Still, there are challenges in TBL. Weaker students still struggle with technical material and can feel too intimidated by the other team members to ask for help. In this case, the teachers need to

intervene and encourage the student to come to office hours for additional instruction. Occasionally, a team may have one member who will not engage with the rest of the group regardless of prodding and warning about the participation grade. By chance one team may end up with all very strong students. We have had instances where one group regularly finishes the entire activity 10 minutes before the rest of the class. We have not found a satisfactory way to solve this dilemma, though the students appear to be happy to spend the time chatting about non-class matters.

Faculty often worry that by spending more class time on activities rather than lecturing, less material will be covered. We have not found this to be the case. One of us (Chihara) has taught this course in a traditional lecture style as well as with TBL, and covered the same set of chapters. However, the initial set-up of TBL does require time and effort by the instructor: the entire course must be reconfigured, assignments or activities must be designed and multiple-choice quizzes must be written.

Despite these challenges and problems, the overall satisfaction level of the students and instructors is high. Students learn good habits such as reading the material before coming to class; they mention that time goes by much more quickly than when listening to lectures. We, the instructors, enjoy the high level of energy in the class and getting to know the students as we walk around the room to answer questions or clarify concepts.

With any new pedagogical technique or strategy, it takes a leap of faith to make a radical change in one's course design. At this point, we do not have any data for comparing student outcomes in TBL versus non-TBL statistical literacy courses. We believe that team-based learning is an exciting option for the statistical literacy course and potentially, for other statistics courses as well (for instance, the introduction to statistics course taught at the level of De Veaux, Velleman, and Bock 2009). Multiple choice questions for use in simultaneous reporting can still be written for the more technical courses. Example 3 shows a multiple choice question that would be suitable for a more technical course.

Example 3: Suppose nationally, about 90% of houses in any given city have smoke detectors. Let p denote the true proportion of houses with a smoke detector in any given city. Suppose in city A we have a random sample of n = 400 houses with $\hat{p} = 0.94$ and a 95% confidence interval (0.916, 0.964) and in city B, n = 4000, $\hat{p} = 0.92$, 95% confidence interval (0.911, 0.929). Suppose we wish to test H_0: p = 0.9 versus H_A: $p \neq 0.9$.

Question: For which city would the test be more statistically significant?

We also believe that team-based learning could successfully be implemented in much larger, traditionally lecture style statistics courses. Harkness et al. (2003) demonstrated the effectiveness of an active-learning and collaborative approach for large introductory level statistics courses at Penn State University. The classes met as a whole (about 240 students) once a week (RAT's were administered in this setting) and then broke up into smaller groups for computer-mediated workshops with both undergraduate interns and graduate teaching assistants helping out. Many other disciplines have successfully used TBL in large classroom settings (Lasserre 2009; Clark, Nguyen, Bray and Levine 2008). Michaelsen et al. (2004) offer many suggestions for TBL in large classes such as distributing handouts or collecting assignments in team folders to shorten materials-handling time, and re-emphasizing the importance of simultaneous rather than sequential reporting of results when dealing with many teams. We encourage interested instructors to read the book *Team-Based Learning* (Michaelsen et al. 2004) and visit the Team-Based Learning Collaborative website http://www.teambasedlearning.org to learn more.

Appendix: Sample Materials

Simultaneous Reporting Activity: Understanding Surveys

Understanding Surveys

Laura Chihara

Public Policy Polling (PPP)

Students are first asked to read about Public Policy Polling, a major polling company.
http://www.publicpolicypolling.com/aboutPPP/about-us.html

PPP claims that Interactive Voice Response (IVR) reduces interviewer bias to zero by using a recorded voice, thus eliminating the live human interviewer. The person surveyed records his/her answers by pressing keys on the phone keypad ("Press 1 for agree, 2 for disagree…"). Which of the following are disadvantages of IVR over a live phone interviewer?
(I) No ability to verify identity of speaker on the phone.
(II) Respondents desire to please.
(III) Age related response rate.
(IV) Higher break-off rate (hang ups).
(**A**) II ; (**B**) III; (**C**) III and IV; (**D**) I, III, IV; (**E**) All of the above.

"IVR technology…allows us to complete surveys faster, usually in one evening." This seems to suggest that PPP does not put in a lot of effort in callbacks - attempts to reach the respondent another day/time if there is no answer. Gallup will try from 3 to 7 times over several days to reach somebody.

Thus, compared to Gallup polls, surveys conducted by PPP may be
(**A**) less biased because PPP will not annoy people with lots of phone calls.
(**B**) more biased because PPP will have more women and older citizens in their sample.
(**C**) less biased because they survey everybody at the same time of day.

PPP uses a voter registration database for their sampling frame for most political surveys. For pre-election surveys on the Obama-McCain presidential race last fall:
(**A**) It is unlikely that there was any bias as long as PPP used a scientific sampling method to draw their sample.
(**B**) PPP polls may have underestimated support for McCain.
(**C**) PPP polls may have underestimated support for Obama.

Questions

The Sierra Club is sponsoring a survey in which several questions will be asked. Which survey design (i.e. question order) would they most likely prefer (A or B)?
(**A**) i. Have the recent increases in gas prices had or not had an impact on your family's budget?

ii. Do you support or do you not support drilling for oil in Alaska's National Wildlife Refuge (ANWAR)?
(**B**) i. Do you support or do you not support drilling for oil in Alaska's National Wildlife Refuge (ANWAR)?
ii. Have the recent increases in gas prices had or not had an impact on your family's budget?

Two poll questions from 2005

(Harris) Do you think that the law should allow doctors to comply with the wishes of a dying patient in severe distress who asks to have his or her life ended, or not?
(Pew Research) In some states, it is legal for doctors to prescribe lethal doses of drugs that a terminally ill patient could use to commit suicide. Do you approve or disapprove of laws that let doctors assist patients who want to end their lives in this way?
The responses were
(**A**) 70%, 29%,1% in one poll and
(**B**) 46%, 45%, 9% in another (Yes or Approve, No or Disapprove,
No Response/Don't know). Which was most likely the outcome for the Harris poll?

Which wording is the best?

(**A**) Would you say you are very likely, fairly likely, or not likely to vote in the national elections this coming November?
(**B**) This coming November, how likely are you to vote in the national elections? Would you say you are very likely, fairly likely, or not likely?
(**C**) Which of the following categories best describes how likely you think you are to vote in the national elections this coming November: very likely, fairly likely, or not likely?

Validity and reliability

An analyst is interested in Northfield's Target business climate in January. Every day at 2pm, he counts the number of cars in the parking lot and finds the average for the month. He will do this every January for several years.
(**A**) This measurement is valid and reliable.
(**B**) This measurement is not valid but reliable.
(**C**) This measurement is valid but not reliable.
(**D**)This measurement is not valid nor reliable.

Example Activity: Hypothesis tests

Where team is sent to the blackboard to present their responses.

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Worksheet-Hypothesis tests

Example 1. Suppose researchers conduct an experiment to see if ultra-marathoners could reduce respiratory infections by taking 600 milligrams of vitamin C daily. They find that 65% of the runners in the placebo group report the development of symptoms of upper respiratory tract infection after the race. This is significantly more (P< 0:01) than what the vitamin C supplemented group reports (38%).

Write down the hypotheses being tested.

Explain the conclusion (p-value) of this study to somebody who hasn't had statistics.

Example 2. Here is an excerpt from a journal article:
(a) write down the null hypothesis.
(b) is the author's statement consistent with the statistical finding?

From "Adolescent Sexual Behavior in the Two Ethnic Minority Samples: The Role of Family Variables" (Miller, Forehand, and Kotchick, 1999), "The number of times adolescents reported having intercourse correlated negatively with the age of first intercourse (r = -.15; p < 0:01)."

Example 3. Suppose a researcher conducts a one-sided hypothesis test and at the α=.05 level, rejects the null hypothesis. If instead, this had been a two-sided hypothesis, would the researcher come to the same conclusion?

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Example 4. The National Highway and Transportation Safety Administration (NHTSA) gives automobile tires temperature grades (A, B, C) to indicate heat resistance – the ability to withstand high temperatures that might cause blow-outs and tread separations.
The minimum grade acceptable is a C. Suppose a tire manufacturer is concerned that one of their models doesn't meet the minimum requirements for a "C".
The engineers conduct an experiment to test this:

H_0: Tires do meet the minimum requirements for heat resistance.

H_α: Tires do not meet the minimum requirements for heat resistance.

What are the Type I and Type II errors, and what are their consequences? (Explain in the context of this problem.)

Example 5. "Beneficial effects of high dietary fiber intake in patients with Type 2 diabetes Mellitus" (Chandalia, Abhimanyu, Lutjohann, von Bergmann, K., et al., 2000).
"The high-fiber diet reduced plasma total cholesterol concentrations by 6.7 percent (P=0.02), triglyceride concentrations by 10.2 percent (P=0.02), and very-low-density lipoprotein cholesterol concentrations by 12.5 percent (P=0.01)."
Write down the null and alternative hypotheses.

What Type of error could the researchers have made in this study? What might be the practical consequence of this error?

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