Two Learning Activities for a Large Introductory Statistics Class

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Abstract

In a very large Introductory Statistics class, i.e. in a class of more than 300 students, instructors may hesitate to apply active learning techniques, discouraged by the volume of extra work. In this paper two such activities are presented that evoke student involvement in the learning process. The first is group peer teaching and the second is an in-class simulation of random sampling from the discrete Uniform Distribution to demonstrate the Central Limit Theorem. They are both easy to implement in a very large class and improve learning.

1. Introduction

Teaching Statistics in a large class has some inherent difficulties. The distance between the instructor and a considerable portion of the audience is great and increases with class size. As a result, the instructor seems non-approachable and students are easily distracted. Intimidated by the large audience and the remote instructor most students hesitate to ask questions. This is particularly true in an Introductory Statistics course taken by students in their first year and/or of different quantitative reasoning skills.

Hands-on activities and/or cooperative learning techniques encourage student involvement and motivate classroom socialization (Johnson and Johnson 1985, Giraud 1997, Gourgey 2000). Therefore they are expected to counterbalance the negative effects of the large size on the learning process. Such techniques however imply extra work, the volume of which increases proportionally with class size. In a class of more than 200 students even techniques especially designed for a large Introductory Statistics class cannot be carried out unless there is sufficient teaching assistance (e.g. Magel 1996). As a result, most instructors of large classes resort to the standard lecture format. It is easier and safer (Benjamin 1991, Magel 1998) and in a very large class it seems to be the only feasible solution.

When department’s resources and organizational structure permit, the lecture portion of the course is completed with an exercises section in which the large class is split into smaller groups and exercises are
worked on usually in computer labs (e.g. Magel 1998). This small group session is conducted by graduate teaching assistants and allows the students to feel at ease asking questions. The computer laboratory, moreover, offers the opportunity for improved instruction and in this journal one may find helpful website information for computer software to support teaching (e.g. delMas, Garfield and Chance 1999).

There are many tertiary institutions however where an Introductory Statistics course is given in a class of more than 200 first year students of different quantitative reasoning skills without the support of a small group exercise session. Yet, even in a such an unfavorable setting, one may apply learning activities to motivate student involvement and enhance learning, without considerable amount of extra work. The two activities I propose here are easy to implement in a very large class and achieve a considerable improvement in learning by turning the disadvantage of excessive numbers to an advantage.

2. Activity 1: Peer Teaching

This activity simulates the small group exercise section of the course in the better-endowed departments. It has been designed to support the lecture part of the Introductory Statistics course taken by first year students of the Economics department in the Aristotelian University of Thessaloniki. The department traditionally has a very large number of first year students and a low budget. The course is designed to cover the standard Introductory Statistics course material i.e. beginning with Descriptive Statistics and gearing up to Hypothesis testing via Probability Theory and Probability Distributions, Simple Random Sampling and Sampling Distributions. Theory, examples and exercises are presented during the lecture but students’ participation is rather limited owing to excessive class numbers. The activity is organized as follows:

At the end of an entity which may be a whole part (for example the Descriptive Statistics part) or a chapter (for example the Discrete Probability Distributions) or even a section (for example the Normal Distribution section) students are given a worksheet as a practice assignment. This corresponds to the material covered and must be done by students individually outside the class. The worksheet given has a step-by-step structure containing questions ranging from the simple procedural to the more conceptual. Its purpose is to facilitate learning and it has no association with grades. The students are free to decide whether or not they work out the problems. Students who can complete the worksheet and feel confident that they can explain it to their peers subscribe as volunteer teachers. Then I arrange a preparatory meeting in order to organize the teaching teams and answer any questions they may have on the worksheet material.

During this meeting it is essential to create among all the participants an atmosphere of mutual support and collaboration, which will then be conveyed through their own group teaching. After all their questions have been discussed, students form teams of 2 or 3 members and undertake the task of explaining the worksheet material to a group of their peers. The number of teams varies according to class size but a rough ratio of one per 50 class members is workable as not all them attend all sessions. I do not interfere with the formation of the teams and students are free to choose their partners. Team members arrange their own meeting in which they agree upon their teaching style and undertake tasks. Sometimes first time participants request a meeting before “class”.

An essential part of this activity is to find the most suitable place and time, first for the preparatory meeting and then for the peer teaching. As my class is quite homogeneous and students have largely concurrent time schedules, it is easy for me to arrange the preparatory meeting in one of my tutorials, in my office. I understand that this is not the case in other institutions where the instructor might need to devote a class session for this teaching-the-candidate-teacher part. As students have already worked out the material, this meeting does not last for more than an hour.

A suitable time and place for peer teaching is less easy to find. It is convenient to place it in a class session but not in the large lecture halls because each team needs its own blackboard and the warm, friendly
atmosphere of a small room. Therefore, you need as many rooms as there are groups. Each team of students-teachers enters a room and students-students are self assigned to a group. It is better to arrange teaching in adjoining rooms so that students may change a group if they do not find it satisfactory. From my experience, however, this seldom takes place because collaboration within the teaching teams reduces variability in teaching quality. It is interesting to note that in repeated participations students tend to remain with the same teaching group. This observation points out that alternative timing and location schemes may be applied to convey at different organizational settings. For instance, in the universities that have a laboratory room for small group exercise session, the peer teaching activity may take the place of an exercise session with different timing for various groups.

Participation in this activity either as a student-student or as a teacher-student is optional and not associated with students’ grades. The grades of all students come from other individual assignments or from tests. However, most students do participate and enjoy it.

The advantages for the students participating as “students” are pretty obvious. The remoteness that discouraged them to ask questions vanishes not only because of the small group tutoring but also because of the age and style of their peers. They discuss and hear others discuss the material, they feel comfortable enough to even ask “stupid” questions, they have better encoding opportunities and thus learn more easily.

The advantages for students participating as teachers are less obvious. In the lecture I introduce the activity, I refer to an old professor of mine who kept saying “you cannot be certain whether you really know something unless you teach it or write a computer code for it”. Student teachers emphasize in our discussions how participation improves their own understanding. They have more and better contacts with the material and the interaction with their peers gives them motivation for deeper exploration. Moreover, they obtain a teaching experience under very favorable conditions: expectations of their peers are limited to the material of the worksheet, they have my guidance and support and the whole experiment is under my responsibility. The competition among the participating teams, however, makes “teachers” care for the quality of their instruction.

A peer teaching session should be planned every two weeks, which necessitates for the instructor an equal number of meetings with the student-teachers, each of about one hour. I have devoted a tutorial hour for this meeting and I was duly rewarded by their enthusiasm and the discussions emanating from their questions. If, however, you have to schedule those meetings during class hours, you shouldn’t think of them as “lost” because peer teaching may save you from the reviewing exercises part of your lectures.

2.1 Characteristics of the Activity

The activity described here is a cooperative learning activity i.e. a structured instruction strategy in which students work together in small groups to maximize their own and each other’s learning (Cooper, KcKinney adn Robinson 1991). It is therefore expected to promote learning and, compared to other cooperative learning activities proposed in the literature, it has the following advantages:

It is suitable for a very large class: As Giraud (1997) notes, the value of an instructional strategy is found in its ease of use and its effectiveness in a natural classroom setting. An activity, which is effectively applied in a smaller class, may not be workable in a class of more than 200 students. The activity of peer teaching may be effectively carried out even under the very disadvantageous conditions of one instructor and a very large class. As the class gets larger one may need one or more teaching teams but, by the law of large numbers, it is also likely that one finds more students ready to participate in a teaching team.

It guarantees scaffolding: Scaffolding occurs when learners are assisted by others in constructing knowledge (Giraud 1997) and, in the theory of cognition and learning, it is proposed as a means of increasing a group’s overall learning. The way groups are formed in this activity guarantees that scaffolding
takes place in each group, which may not be the case when the students are assigned to a group randomly as other instructors propose (Magel 1996).

*It allows “voting by foot”: The activity allows every student to choose if he/she wants to be a teacher or a learner or even not to participate in the activity; and roles may change in successive sessions. A high rate of participation is a vote for the activity. Students like it because in their words “it is like a game but it helps us to better understand”, “it is an opportunity to know us better”, “it makes Statistics fun”.

The activity also allows student-students to be self assigned in a group and not to be forced into it. This way students “vote by foot” the efficient teaching teams, which thus get immediate feedback from their peers.

2.2 Results

I have organized peer teaching for four years in classes ranging from 235 to 310 students. At the end of the semester students are asked to answer a questionnaire also containing questions about the peers teaching activity. The percentage of students that have not participated has never exceeded 10% of the subscribed ones. The percentage of students that have attended all sessions varies between 18% and 30%. From their answers it is derived that non-participants are students that have a good understanding of the material but do not wish to expose themselves to teaching. Therefore comparison between final grades obtained by participants and those of non-participants are meaningless for the assessment of the activity. No comparisons can also be affected between the student-students and the student teachers for similar reasons.

In the first year of application, I compared the grades distribution of the whole class with the respective distribution of the class in the previous year. In subsequent years, I thought that the quantitative skills of students might have changed because of changes in the system of student selection and I have used as a benchmark the distribution of grades in the Introductory Mathematics course. The two courses are taught in the same semester to exactly the same students and for years the two distributions of grades have been almost identical and rather symmetric. In the four years I have organized this activity as a complement to the lecture session, the distribution of the Introductory Statistics grades has behaved in a different way: the mean grade became higher and the distribution skewed to the left indicating that more students have achieved higher grades.

3. Activity 2: Hands-on Simulation of Sampling Distribution and the Central Limit Theorem

Sampling Distribution is considered to be the “curse” of any Introductory Statistics course. It is very difficult for beginning students to understand (e.g. Zerbolio 1989, Garfield and Ahlgren 1988) but essential for Statistical Inference. Previous experience supports evidence that a physical hands-on simulation activity may be most efficient in teaching sampling distribution: it provokes student interest and enthusiasm and promotes their understanding of sampling distribution and their reasoning on statistical inference. Moreover, it turns the “curse” into a satisfying teaching experience (Dyck and Gee 1998, Rossman and Chance 1999, Gourgey 2000). Computer simulations may enhance students understanding and help them to connect the ideas with technology (Rossman and Chance 1999). Yet they alone cannot guarantee that students develop the correct conceptual understanding of sampling distribution (Nickerson 1995, delMas et al. 1999).

Magel (1996) describes a hands-on activity in which students simulate the sampling distribution of the mean from a discrete uniform distribution, taking the values 1,2…10. She applies the activity in a class of 150 students, which she divides into groups of five. Each group uses a set of identical well-shuffled cards and produces three samples each of 10 random digits. The mean values computed in the resulting 90 samples are then used to work out the sampling distribution of the mean. Though the activity is proposed
for large Introductory Statistics class, it is not easy to apply in a class of 300 students where simultaneous work in small groups can easily become a flippant activity with very poor learning results. The activity I propose here is also a simulation from the discrete uniform distribution, but it is easy to apply even in a very large Introductory Statistics class. Moreover it is a hands-on demonstration of the Central Limit Theorem (CLT) which, in the absence of a computer lab offers a unique opportunity for students to grasp convergence to normality. In classes that are supported by a computer lab, the activity may be applied as a first step to the CLT. Computer simulations are often applied mechanically and there is a “black-box” air about them. When preceded by the real-time demonstration described here they may lead to a complete understanding of sampling distributions and of the CLT.

3.1 The Procedure

The activity is conducted in two stages each in place of a 60-minute lecture. In the first stage I invite students to think of an experiment in which digits 0, 1, ..., 9 are drawn randomly from an urn with replacement and of the corresponding discrete random variable $X$ and ask them to compute the mean and variance of $X$. Then I give them three sheets of differently colored paper and a page of random number table and ask them to draw random samples from $X$ by copying digits from the table.

The random numbers of the respective table are grouped into five digit sets which are grouped again in blocks of five. The handed page consists of ten columns and similarly ten rows of such random digit blocks. In order to ensure that students do not choose the same starting point I number the margin of both the rows and columns and ask them to select their starting block according to the last two digits of their Individual Identification Number i.e. the four digit identification number they get at enrolment and retain throughout their course of studies. The last digit will tally with the row of their block while the penultimate digit will tally with the column. Then they select a random point in their block from which to begin as well as choosing the direction they will take -going right, left, up, down or diagonally- so as to note the respective random digits. They register three samples of 10, 20 and 30 digits respectively and each sample is copied onto a sheet of paper of a certain color. Each sample begins from the point where the previous one left off.

Then they are given 15-20 minutes to compute the mean and variance of the respective sample. They have to compute the sample variance by dividing the sum of square deviations by $(n-1)$. The sheets are collected in three slips of different color, one for each sample size. Each slip represents a collection of random samples from the discrete Uniform Distribution and respectively a collection of values for the sample mean and variance. The larger the size of the class the higher the slip and, similarly, the larger the collection of values for the sample mean and variance. A team of volunteer students undertakes to collect the resulting 3 sets of data, to graph the histogram and calculate the mean and variance for each. It is clear that in the departments that can afford a computer lab session, this part of the activity may be given as an exercise to the whole class as in Magel (1996).

In the second stage, which is held during the next lecture, I begin by defining simple random sample of size $n$ as a set of $n$ independent and identically distributed random variables. Simple random sample has been treated more pragmatically in previous lectures where we almost always had to deal with just one sample. The hands-on simulation done in the previous lecture serves as a handy example to connect the two ways of treatment and clarify the relative ideas. It is made clear to the students that when they copy $n$ random digits, they simulate a process of drawing random samples from $X$ which may be described by the sequence of independent variables $X_1, X_2, \ldots, X_n$ all having the same distribution as $X$ and that the sample observed by each of them, denoted by $x_1, x_2, \ldots, x_n$, is just one realization of this process. Sampling variation is introduced very naturally, in terms of the previous section’s results, together with the related terms of sampling distribution and population distribution, parameter and statistic.
Then I distribute a sheet of paper depicting the three frequency distributions and the histogram of the sample mean corresponding to sample sizes of n=10, 20 and 30 digits, respectively. I sketch together a normal curve centered at $\mu = 4.5$. It is made clear that each one of the three frequency distributions is an empirical approximation of the corresponding sampling distribution. At this point it is easy to present the Central Limit Theorem (CLT) and students are invited to look at the normal curve on their sheet of paper as the limit distribution of the sample mean, corresponding to a certain large sample size, as the number of samples increases indefinitely.

The experiment was conducted four times and the number of samples collected varied from 210 to 295. In all cases the frequency histogram of sample means had a normal appearance at $n = 30$ and on 3 occasions even at $n = 20$. The mean of the sample means was almost identical to 4.5 and their variance very close to $8.25/n$. It is easy for the students to understand that in a problem of practice only one such sample would have been drawn. Comparing the three histograms of the sample mean one may easily see that the smaller the standard error of estimate $\frac{2.87}{\sqrt{n}}$ the more likely it is for a sample mean to be close to the population mean.

I also distribute a sheet of paper depicting the three sampling distributions of the variance. Students see that in all three distributions the mean is almost equal to 8.25 and thus it is easier for them to remember that unbiasedness of variance estimator requires dividing the sum of squared deviations by $(n - 1)$ and not by $n$. In this lecture no more theory about sampling distribution of variance is presented. However when, in subsequent lectures, I present the chi-square distribution as the sampling distribution of variance when sampling from normal populations, students have a clear idea that a chi-square distribution should not be assumed in all cases.

### 3.2. Characteristics of the Activity

From an instructional point of view the activity makes several references in theory presented at previous lectures and thus helps students to reinforce relative ideas. More specifically the activity:

- brings back to the students the idea of the mean and variance of a random variable together with the idea of a random variable describing drawing from an infinite population
- helps students develop a conceptual understanding of sampling variation and sampling distribution, necessary for the development of statistical reasoning on inference
- gives a good picture of the Central Limit Theorem
- reinforces the idea of an empirical distribution as an approximation of a theoretical one
- Helps students make a clear distinction between population distribution and sampling distribution. They often confuse them as it is also noted by Gourgey 2000
- gives an idea of the standard error of estimate and the way it decreases with the sample size.

### 3.4 Results

Hands-on simulations of sampling distribution for the mean or the proportion have been conducted in various settings by many colleagues who all agree that such an activity definitely improves students understanding, makes teaching of the subject a pleasant experience and improves the class climate. Moreover students all better conceive the lectures on point and interval estimation and hypotheses testing which follow. Most of these activities however are difficult to apply in a very large Introductory Statistics class because they need rather complicated instructions or imply multiple instruction material to be prepared in advance. The hands-on simulation activity described here demands just minimal material, elementary instruction and can be effectively carried out by the instructor alone even in a class of 300 students. Moreover it helps students gain a conceptual understanding of sample variation and sampling
distribution of the mean and variance and of the Central Limit Theorem.

4. Conclusions

Very large classes are cumbersome and frustrating and make it difficult for the instructor to “communicate his enthusiasm and excitement about statistics” (Hogg 1991). Large number of students together with limited resources is faced by many departments and they are likely not to decrease (Rumsey 1998). Yet, even in the most disadvantageous conditions of a very large class and no assistantship one may apply enhanced teaching techniques. The two activities proposed in this paper can be easily applied even with in excess of 300 persons and improve learning. One may hesitate to undertake activities that rely on students volunteering. Note, however, that lectures in large classes frustrate not only instructors but also students, so they are more than willing to participate in such activities and undertake tasks.

Appendix

The frequency distribution of the grades in Intro Math for the years 1999-2003 and Intro Stat, without peer teaching (1999), and after peer teaching (years 2000, 2001, 2002, and 2003).

| grades | Math99 | Stat99 | Math00 | Stat00 | Math01 | Stat01 | Math02 | Stat02 | Math03 | Stat03 |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1      | 0.012  | 0.037  | 0.023  | 0.026  | 0.038  | 0.029  | 0.035  | 0.013  | 0.019  | 0.006  |
| 2      | 0.109  | 0.082  | 0.064  | 0.038  | 0.032  | 0.023  | 0.013  | 0.049  | 0.048  | 0.006  |
| 3      | 0.221  | 0.170  | 0.238  | 0.062  | 0.227  | 0.032  | 0.212  | 0.036  | 0.141  | 0.078  |
| 4      | 0.131  | 0.161  | 0.114  | 0.074  | 0.124  | 0.068  | 0.166  | 0.062  | 0.121  | 0.093  |
| 5      | 0.253  | 0.243  | 0.276  | 0.167  | 0.251  | 0.198  | 0.254  | 0.128  | 0.263  | 0.168  |
| 6      | 0.171  | 0.155  | 0.197  | 0.218  | 0.213  | 0.278  | 0.169  | 0.226  | 0.247  | 0.261  |
| 7      | 0.050  | 0.088  | 0.035  | 0.185  | 0.056  | 0.172  | 0.075  | 0.243  | 0.089  | 0.146  |
| 8      | 0.040  | 0.034  | 0.035  | 0.140  | 0.023  | 0.091  | 0.035  | 0.138  | 0.045  | 0.149  |
| 9      | 0.009  | 0.015  | 0.011  | 0.050  | 0.020  | 0.077  | 0.026  | 0.069  | 0.022  | 0.065  |
| 10     | 0.000  | 0.009  | 0.002  | 0.032  | 0.011  | 0.026  | 0.009  | 0.032  | 0.003  | 0.028  |
| n      | 320    | 316    | 340    | 334    | 338    | 337    | 306    | 304    | 312    | 322    |
| mean   | 4.478  | 4.646  | 4.556  | 5.955  | 4.707  | 6.018  | 4.807  | 6.234  | 5.042  | 6.109  |
Figure 1. Histograms of grades in Intro Math and Intro Stat.
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