Use of a Microcomputer to Enhance the Coin Flip Probability Exercise in the General Biology Laboratory

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Simple, but effective, software should be available for microcomputer use in the classroom. I have heard over and over that there is not adequate software support for biology, and I have come to believe that this is, in fact, the situation. I believe that one way to combat this lack of available software is to produce software ourselves. Having viewed several biology software packages, I am certain that if we, as teachers, write our own software it will be as good as that on the market. And, there is a distinct advantage to writing one's own software. When you write your own software you can tailor it to your unique situation. Further, by developing a simple software package one is often stimulated to think of another, more complex use for the microcomputer in the classroom.

It is an attempt to encourage biology teachers to develop their own microcomputer software that is the primary purpose for this paper. The program described in this paper is not particularly sophisticated, or complex. It is not difficult, or fancy. It was designed to perform a particular task in my biology classroom, and it does that one simple task rather well. I share it with you for your use, and perhaps more importantly, to stimulate you to develop a better program, one that can do the same task better or one that can expand the focus of this program.

It is common to introduce the topic of genetics with a discussion of probability (1-3). Without a basic understanding of probability it is difficult or impossible to fully discuss the concepts of Mendelian genetics. In the laboratory, probability can be demonstrated easily using coins. However, there is a major limitation to flipping coins. Students can be asked to do a limited number of coin flips before they become weary and their flipping fingers get sore. But, it can be valuable for students to do fifty or one hundred flips, as many laboratory exercises recommend.

After flipping their coins, students can be asked to calculate their ratios of results. But, with such a small sample the likelihood of obtaining highly accurate results is small. And, obtaining results far from the theoretical expected results can cause more questions than it answers. One partial solution to this problem is to add all of the individual sets of data to produce a larger class sample. This almost always gives a sample result that more closely approximates the theoretical than the individual obtains (except in those rare cases where an individual happens to hit the theoretical result).

The concept of increased accuracy with increased sample size is all too often ignored. Using small numbers that can be obtained by manipulating coins provide a very small sample size and thus not very accurate results. Further, the time required to gather data from coin flips would be very substantial if there were a large enough number of flips to be statistically significant.

The computer program that I am about to describe is a simple one devised to show both the coin flip probability and the increased accuracy obtained when using an increased sample size. This program was originally written in Applesoft BASIC and will run on any Apple II or Apple IIe. There are no sophisticated programming techniques that restrict the use of this program to the Apple. It could be run on almost any computer with very slight modification. The program described here was not designed to stretch the limits of the computer. It was designed to provide data for students to analyze. And, the program is simple enough that almost anyone with any computer experience can design such a program.

A listing of the program is included in Table 1.

TABLE 1. Listing of the Probability Coin Flip Program for One Coin.

```
100 REM **COIN FLIP PROGRAM**
110 REM **M. FOOS, 11/12/81**
120 REM **TO DO SIMPLE PROBABILITY**
130 HOME: PRINT
140 PRINT "CLASSICALLY STUDENTS HAVE STUDIED"
150 PRINT "PROBABILITY BY FLIPPING COINS."
160 PRINT: PRINT "AS OUR ECONOMY IS CHANGING TO BECOME"
170 PRINT "MORE AUTOMATED, IT WOULD SEEM THAT"
180 PRINT "FLIPPING COINS WOULD ALSO BECOME"
190 PRINT "AUTOMATED."
200 PRINT: PRINT "THIS PROGRAM IS DESIGNED TO FLIP COINS"
210 PRINT "ELECTRONICALLY AND TO PRESENT THE"
220 PRINT "RESULTS OF THE FLIPS ON THIS SCREEN."
230 PRINT: PRINT "BECAUSE THE COMPUTER FLIPS THE COINS SO"
240 PRINT "RAPIDLY IT IS DIFFICULT TO SEE, IT WILL"
250 PRINT "ALSO COUNT THE NUMBER OF FLIPS IT DOES."
260 PRINT: PRINT "TO USE THIS PROGRAM ALL YOU HAVE TO DO"
270 PRINT "IS SELECT THE TOTAL NUMBER OF FLIPS YOU"
280 PRINT "WANT THE COMPUTER TO DO."
300 GOSUB 1000
600 HOME: N=0:H=0:T=0:PRINT: PRINT
606 PRINT "HOW MANY COIN FLIPS DO YOU WANT THE"
610 PRINT "COMPUTER TO DO? ENTER YOUR NUMBER AND"
612 INPUT "PRESS RETURN.";N
620 HOME: PRINT: PRINT
630 X=INT(RND(1)*2)
640 IF X=1 THEN PRINT "H";:H=H+1
650 IF X=0 THEN PRINT "T";:T=T+1
660 IF H+T=N THEN GOTO 680
670 GOTO 630
680 PRINT: PRINT CHR$(7): PRINT "   HEADS = "H"        TAILS = "T
690 TH=TH+H:TT=TT+T
700 GET X$
710 IF X$ = "X" THEN 730
720 GOTO 800
730 HOME:PRINT:PRINT:PRINT
740 PRINT "THE TOTAL NUMBER OF COIN FLIPS DONE IN"
750 PRINT "THIS LAB WAS ";TT+TH
760 PRINT:PRINT:PRINT "THE RESULTING DISTRIBUTION IS "
770 PRINT "LISTED BELOW:"
780 PRINT:PRINT "       HEADS = "TH"       TAILS = "TT
790 END
800 HOME
810 FLASH
820 PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
821 PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
822 PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
823 PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
824 PRINT "HHHHHTTTTTTTTHTHHHHHHHHTTTHHTTTTTTTTHHHH"
825 PRINT "HHHHHTHHHHHHTHTHHHHHHHHTHHHTHHHHHHHHTHHH"
826 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHTHHHHHHHHTHHH"
827 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHHHHHHHHHHTHHH"
828 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHHHHHHHHHHTHHH"
829 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHHHHHHHHHHTHHH"
830 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHHHHHHHHHHTHHH"
831 PRINT "HHHHHTHHHHHHHHTHHHHHHHHTHHHHHHHHHHHHTHHH"
```

TABLE 1.—Continued

```
832     PRINT "HHHHHTTTTTHHHHTHHHHHHHHHHTHHHTTTTTTTHHHH"
833     PRINT "HHHHHTHHHHHHHHHTHHHHHHHHHTHHHTHHHHHHHHHH"
834     PRINT "HHHHHTHHHHHHHHHTHHHHHHHHHTHHHTHHHHHHHHHH"
835     PRINT "HHHHHTHHHHHHHHHTHHHHHHHHHTHHHTHHHHHHHHHH"
836     PRINT "HHHHHTHHHHHHHHHTHHHHHHHHHTHHHTHHHHHHHHHH"
837     PRINT "HHHHHTHHHHHHHHHTHHHHHHHHHTHHHTHHHHHHHHHH"
838     PRINT "HHHHHTHHHHHHHHTHHHHHTHHTHHHTHHHHHHHHHH"
839     PRINT "HHHHTTTHHHHHHHTTTTTTTTHTTTHTTTHHHHHHHHH"
840     PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
841     PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
842     PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
843     PRINT "HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH"
844     GOSUB 1000
860     GOTO 130
1000    PRINT:INVERSE:PRINT"              <PRESS RETURN>
"
1001    NORMAL
1002    GET A$
1003    IF A$=CHR$(13) THEN RETURN
1004    PRINT CHR$(7): GOTO 1000
```

The program can be broken into three parts. The first part consisting of lines 100-300 is an introduction to the program. This kind of an introduction is especially important for students who have little or no working knowledge of the computer. It is designed to put them at ease and give them a starting point for using the computer. It helps them feel that they know what to do.

The second part of the program included in lines 600-790 actually makes the program work. In looking at this section it is obvious that several different things happen. In line 600 the screen of the computer's monitor is cleared and all of the counters are set to zero. The student is then asked to enter a number of coin flips to be done by the computer. Line 630 is the heart of this program. By using the computer's random number generator, a number is selected. This instruction designates that the random number selected be any integer less than two. Thus, the computer's random number must be either a 0 or a 1.

Lines 640 and 650 instruct the computer to print the letter 'H' if the computer selects a 1 and to print a letter 'T' if the computer selects a 0. These lines also add the number of times a 'H' and a 'T' have been printed.

Lines 660 and 670 instruct the program to continue printing 'H' and 'T' until the total number of letters printed equals the number requested by the student in the beginning. When the correct total numbers of letters has been printed, the computer prints the totals at the bottom of the screen as directed by line 680. Line 690 keeps a running total of all of the counts in the session.

The 'GET' command used in line 700 accepts a single character from the keyboard without using the <RETURN>. If a capital 'X' is pressed at this time, the computer will print the aggregate total of all of the runs in the session as dictated in lines 730-780, and will end the execution of the program (line 790).

The instructor will normally press this key after all of the students have received their data. It is possible that a random stroke could cause this to happen out of turn, but there is only a small probability.

Striking any key but the capital 'X' will cause the screen to show a flashing display. This third part of the program is listed in lines 800-843. This display is nothing more than a device to show that the computer is turned on and working. It lets the student know that no one is currently using the computer, and it is free for their use. It flashes on the Apple and could be enhanced to be colorful. It does not use either of the graphics modes of the Apple and is therefore directly adaptable to another brand of computer. However, the 'FLASH' command is a uniquely Apple command.

The last few lines 1000-1004 help to 'goof-proof' the program. These lines prohibit the input of any character other than the <RETURN> key when that response is requested. The buzzer also sounds if any character other than the <RETURN> is pressed.

By altering the lines 600-790 it is easy to modify this program to simulate flipping two or three coins simultaneously. These modifications, listed in Table 2 and Table 3 expand the usefulness of the program from the simple probability relationships one finds with a single variable to the consideration of two or three variables. This leads to the logical discussion of dihybrid and trihybrid crosses as well as the typical monohybrid cross. This simple modification expands the one program into three programs and thus increases its effectiveness.

TABLE 2. Modification for the Coin Flip Program for Two Coins.

```
600   HOME:N=0:HH=0:HT=0:TH=0:TT=0:PRINT:PRINT
606   PRINT "HOW MANY COIN FLIPS DO YOU WANT THE"
610   PRINT "COMPUTER TO DO? ENTER YOUR NUMBER AND"
612   INPUT "PRESS RETURN.";N
630   X= INT(RND(1)*4)
635   IF X=0 THEN PRINT "HH   ";:HH=HH+1
640   IF X=1 THEN PRINT "HT   ";:HT=HT+1
645   IF X=2 THEN PRINT "TH   ";:TH=TH+1
650   IF X=3 THEN PRINT "TT   ";:TT=TT+1
660   IF HH+HT+TH+TT=N THEN 680
670   GOTO 630
680   PRINT:PRINT CHR$(7): PRINT "HH="HH
682   PRINT "HT = "HT
684   PRINT "TH = "TH
686   PRINT "TT = "TT
690   A=A+HH:B=B+HT:C=C+TH:D=D+TT
700   GET X$
710   IF X$ = "X" THEN 730
720   GOTO 800
730   HOME:PRINT:PRINT:PRINT
740   PRINT "THE TOTAL NUMBER OF COIN FLIPS DONE IN"
750   PRINT "THIS LAB WAS ";A+B+C+D
760   PRINT:PRINT:PRINT "THE RESULTING DISTRIBUTION IS"
770   PRINT "LISTED BELOW:"
779   PRINT
780   PRINT "HEADS • HEADS = "A
781   PRINT "HEADS • TAILS = "B
782   PRINT "TAILS • HEADS = "C
783   PRINT "TAILS • TAILS = "D
790   END
```

TABLE 3. Modification for the Coin Flip Program for Three Coins.

```
600   HOME:N=0:A=0:B=0:C=0:D=0:E=0:F=0:G=0:H=0
602   PRINT:PRINT
606   PRINT "HOW MANY COIN FLIPS DO YOU WANT THE"
610   PRINT "COMPUTER TO DO? ENTER YOUR NUMBER AND"
612   INPUT "PRESS RETURN.";N
620   HOME:PRINT:PRINT
630   X=INT(RND(1)*8)
```

TABLE 3.—Continued

```
635  IF X=0 THEN PRINT “HHH ”;:A=A+1
637  IF X=1 THEN PRINT “HHT ”;:B=B+1
639  IF X=2 THEN PRINT “HTH ”;:C=C+1
640  IF X=3 THEN PRINT “HTT ”;:D=D+1
643  IF X=4 THEN PRINT “THH ”;:E=E+1
645  IF X=5 THEN PRINT “THT ”;:F=F+1
647  IF X=6 THEN PRINT “TTH ”;:G=G+1
650  IF X=7 THEN PRINT “TTT ”;:H=H+1
660  IF A+B+C+D+E+F+G+H=N THEN GOTO 680
670  GOTO 630
680  PRINT:PRINT CHR$(7)
681  PRINT “HHH= ”A
682  PRINT “HHT = ”B
683  PRINT “HTH = ”C
684  PRINT “HTT = ”D
685  PRINT “THH = ”E
686  PRINT “THT = ”F
687  PRINT “TTH = ”G
688  PRINT “TTT = ”H
690  TA=TA+A
691  TB=TB+B
692  TC=TC+C
693  TD=TD+D
694  TE=TE+E
695  TF=TF+F
696  TG=TG+G
697  TH=TH+H
700  GET X$
710  IF X$ = “X” THEN 730
720  GOTO 800
730  HOME:PRINT:PRINT:PRINT
740  PRINT “THE TOTAL NUMBER OF COIN FLIPS DONE IN”
750  PRINT “THIS LAB WAS ”;TA+TB+TC+TD+TE+TF+TG+TH
760  PRINT:PRINT:PRINT “THE RESULTING DISTRIBUTION IS”
770  PRINT “LISTED BELOW:”
779  PRINT
780  PRINT “HEADS • HEADS • HEADS = ”TA
781  PRINT “HEADS • HEADS • TAILS = ”TB
782  PRINT “HEADS • TAILS • HEADS = ”TC
783  PRINT “HEADS • TAILS • TAILS = ”TD
784  PRINT “TAILS • HEADS • HEADS = ”TE
785  PRINT “TAILS • HEADS • TAILS = ”TF
786  PRINT “TAILS • TAILS • HEADS = ”TG
787  PRINT “TAILS • TAILS • TAILS = ”TH
790  END
```

The simple computer program described here works well in a classroom with a discussion of probability and was designed primarily to be used in a first semester college biology course. It works well to provide a large number of coin flips very rapidly. This program will generate 100 coin flips in about three seconds; five thousand coin flips can be generated in two minutes and ten seconds. Larger samples can be generated by the computer if needed. Students may also compare their own actual coin flips to the computer. When students do smaller numbers of coin flips and compare their data with a larger number that the computer has generated, they almost always become aware of the greater accuracy of the larger sample.

This program makes it possible for an instructor to dwell on the increased accuracy of large sample sizes to provide accurate data approaching the theoretical results one would anticipate. Without such a laboratory example students often do not fully realize this relationship between the increased accuracy and the increased sample size. It is possible with this program to compare relatively large sample sizes for accuracy. Individuals could compare 1000 coin flips with 10,000 coin flips to determine the amount of increased accuracy with that amount of increase in sample size.

Also, it is often interesting for students to see the total results in the laboratory. Just the difference between one individual's sample size and the sample size of the entire class is often enough to be striking.

This is just one simple example of the use of a microcomputer to enhance a laboratory exercise commonly used in biology. There are without a doubt many other instances in which computer enhancement would lead to a better understanding of biological principles. I would like to challenge you to develop computer software that works for you, and then tell the rest of us.

Literature Cited

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