You can Learn a Lot about Teaching Undergraduates from Preschoolers

Dana Byrd

Texas A & M University at Kingsville

Gene Byrd

University of Alabama

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Introduction

Research on student learning and teaching requires a rigorously defined and well-tested task. In neuroscience research, the "Tower of London" puzzle is a well-tested problem-solving task requiring multi-step planning toward a solution. Also, enthusiastic participants with few confounding factors are needed. Four and five year-old preschoolers are starting multistep reasoning and provide good subjects. The Tower of London task with increased levels of complexity has been used up through older adults for cognitive ability testing.

One important well-substantiated finding of the preschooler research studies is that talking about future moves (rather than just making moves) greatly improves children's performance on the task. In an application of these neuroscience results to undergraduate science teaching, we carried out a preliminary modification of a University of Alabama on-line introductory astronomy laboratory course. We will discuss future strategies for on-line and regular undergraduate courses inspired by our results.

The Course

We modify an on-line introductory astronomy laboratory. Students are graded on in-class discussion, 12 modules, plus an observational notebook. The primary task of each module is answering a open-book multiple choice quiz on subject matter presented by lectures and text readings. Along the way there is something akin to ordinary class discussion via comments about particular questions, astronomical news, or other remarks about the course.

Students buy: lenses for a small telescope, spectroscopic grating glasses; a device to measure angular size and parallax; a cardboard "star and planet finder" and a computer planetarium program. In the course, they learn to build and use equipment, take measurements, do calculations and reach conclusions. Students submit digital camera photographs of their equipment, street light spectra, the moon, bright stars and planets as part of their observational notebook.

Students answered open book multiple choice questions after the lecture's,readings and observations. Finally, there is a closed-book multiple choice final exam. The course has a large set of specific learning objectives used in writing the lectures, observations, module quiz questions and closed-book final exam questions. For a more specific description of this course see the other paper by Dr. Gene Byrd in this conference proceedings.

The Course Experiment

We carried out a preliminary modification of the on-line introductory astronomy laboratory course taking into account these results. The primary task is answering a closed-book multiple choice exam. The course has a large set of specific learning objectives used in

writing the lectures and closed book final exam questions. In a preliminary application, short answer or brief essay questions were added to the course each related to the course learning objectives. The students were encouraged to prepare and submit as an extra credit assignment their answers to these questions as the course progressed. This would correspond to the preschoolers' "talking to themselves" about steps in the task.

We examined closed-book proctored final exam scores of two groups of students (separate classes, all online). The first group consisted of those who were given the opportunity to discursively answer questions based on the learning objectives used in writing the course (Learning Objective Questions, or LOQs). The students of the first group answered these LOQs for extra credit prior to taking the exam. The second group members were not given the opportunity to answer LOQs for extra credit, so they had no opportunity to answer them.

The Two Groups of Students

What was our sample like? The sample was N=41 participants in the two groups combined. Students were college age or older. There was no prerequisite for the course. Gender was assigned based on names. Twenty-four students were female. Sixteen students were male, and 1 was unidentifiable by name. There were 17 students in the NO Learning Objective Questions Group. and 24 students in the YES Learning Objective Questions Group.

The Statistical Analysis

Across the two groups, did the group of students who had the opportunity to answer the LOQ perform better on the final exam than those who did not? The mean (M) of the final exam scores for the sample of students who had the opportunity to answer the Learning Objective Questions were better than that for the sample of students who did not, LOQ group $M(SD)$ = 77.72 (15.97), No LOQ $M(SD)$ = 65.62(16.00) where the quantities in the parentheses are the standard deviations (SD). Using Student's t test, $t(39)$ = 2.39 which corresponds to a probabiliy p = 0.02 that the difference could occur randomly. **The LOQ group mean is significantly better than the no LOQ group.**
(See http://www.socialresearchmethods.net/kb/stat_t.php for a conceptual explanation of Student's t-test).

Within the class that was given the opportunity to answer the LOQ, are there differences in the final exam scores between those who answered the LOQ and those who did not? We investigate this in several ways. Comparing means, those who answered the LOQ (N=13) had lower mean exam scores, M (SD)=73.52(14.98), than those who did not answer the LOQ (N=11), M (SD) = 82.69(26.34). We think that this difference may have been due to self-selection by students who needed the extra credit.

There was a negative, but non-significant, correlation between choosing to answer the LOQ (given a value 1) and not answer the LOQ (given a value of 0) and exam score, such that those participants who answered the LOQ did more poorly on the exam than those who

answered the LOQ, If the correlation is significant , it might be due to self-selection by students of who needed the extra credit.

Finally, we looked at the exam scores as high, medium, and low performers, and the same pattern is clear. Again, this may have occurred because the lower-scoring participants desired the extra credit..

Top 3rd of Exam Grades (range 97.00%-89.92%)=38% completed LOQ.
Mid 3rd of Exam Grades (range 89.91%-76.59%) = 50% completed LOQ.
Bottom 3rd of the Exam Grades (range 76.59%-36.96%)= 75% completed LOQ.

Conclusions

Despite the size of our sample, the conclusions seem to be statistically clear. Across the two groups, students who had the opportunity to answer the LOQ performed better on the final exam than those who did not have the opportunity.

It also appears that the lower a student's final exam score, the more likely one is to have answered the LOQ. This makes sense as the lower-scoring students may desire the extra credit. However, since the final exam scores were better for the classes that had the LOQs available, answering and submitting does seem to benefit these students by raising their final exam scores. Answering the LOQs helps those students who really need help.

This project was only an initial application of a strategy based on earlier neuroscience "Tower of London" results. However, such strategies do improve class final exam averages particularly for those students who most need help. These results also show the efficacy of extra credit work, particularly for more poorly performing students. However, the extra credit task should be relevant to improving student understanding in the light of neuroscience and educational research.

Correspondence concerning this article should be addressed to
Dana Byrd, dana.byrd.phd@gmail.com, Assistant Professor, Department of Psychology and Sociology; Texas A&M University at Kingsville, Kingsville, Texas

Gene Byrd, Department of Physics & Astronomy, University of Alabama Tuscaloosa, AL 35487-0324. E-mail: byrd@bama.ua.edu

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