Transfer of Learning through Gender and Ethnicity

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Abstract. This brief report compared the performance by gender and ethnicity of 6720 students in an introductory course for the life science majors: Physics 7A and 7B. We compared performance between ethnicities and genders using Z scores taken by quarter. We also performed a binary analysis with achievement of a high grade in 7B as the dependent variable. The results indicate that on average males score higher than females in every ethnic group, and that the only statistically significant ethnic differences in our binary analysis were White and African American. The model indicated that being female reduced odds of achieving a high grade in 7B by one half. Odds were reduced by more than half for African Americans and increased by three halves for White. We also compared gender equity over 18 quizzes. Equity favored quiz questions that are more open ended; this is consistent with some earlier findings in studies of gender equity in introductory physics courses.

INTRODUCTION

At UC Davis, Physics 7 is an algebra-based course for life-science majors designed using an active-learning curriculum [1]. Our student population is about 65% female and 60% minority. 7A, the first course in the series, covers conservation of energy, thermodynamics, and fluid mechanics. 7B covers forces, kinematics, and Newton's laws. We have detailed data on over 6,500 students who have taken both 7A and 7B. This study is part of a larger research endeavor involving longitudinal studies [2] of transfer of learning. We are investigating what factors affect performance in introductory physics and which skills transfer to different courses such as mathematics, chemistry, and biology.

METHODS AND RESULTS

We collected data from 25 quarters of Physics 7 at UC Davis. From each quarter, we have students' scores on each of the four to eight quizzes, and each of the four to nine individual final exam questions. The data set includes records from over 8500 students from 7A and over 8000 students from 7B, with 6720 students having taken both quarters. We collected gender and ethnicity information for each of these 6720 students, resulting in a large longitudinal database.

To more easily compare performance across multiple quarters, we converted grades from quizzes, finals, and overall grades to Z scores, by quarter. We converted to Z scores before paring the dataset down to the 6720 students with data from both quarters, so although the mean by quarter is zero for the original data, the mean by quarter in our set of 6720 students may deviate from zero.

With a dataset including performance metrics, ethnic data, and gender, we began our analyses by testing the equity of grades by ethnicity and gender. To test the equity with regards to ethnicity, we plotted the mean course grades from 7A and 7B by ethnic group (Fig. 1). UC Davis allows self-identification to 15 ethnicities, but after viewing trends amongst the ethnic groups, we combined groups to make a more manageable six ethnicities. We split these six by gender to view trends by gender and ethnicity (Fig. 2).
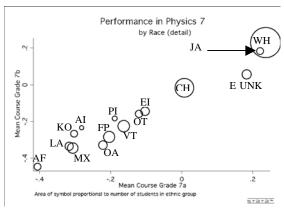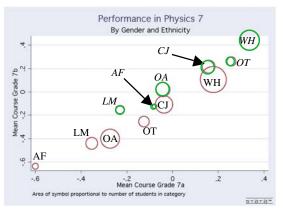

FIGURE 1. Here ethnic groups are plotted (weighted by population) in detail. Key: AF African American CH Chinese JA Japanese AI American Indian LA Latino MX Mexican OA Other Asian FP Filipino VT Vietnamese KO Korean PI Pacific Islander OT Other EI East Indian / Pakistani E UNK European Unknown WH White
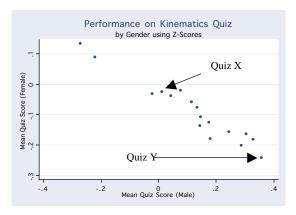
FIGURE 2. Six ethnic groups are split with male students labeled in italics. The ethnicity ordering is preserved with the exception on African American males. Key: AF African American CJ Chinese or Japanese LM Latino or Mexican OA Other Asian OT Other WH White

FIGURE 3. Performance on quizzes from 17 academic quarters is compared by gender. The extreme two points on the left are during summer sessions and have significantly smaller student samples. Two example quizzes, one equitable (Quiz X) and one inequitable (Quiz Y), are shown below.

To further analyze the gender equity, we scrutinized kinematics quiz data from Physics 7B. Though different quizzes are given each quarter, Quiz 3 (of four) always evaluates students' ability to analyze position, velocity, and acceleration graphs. Of the 25 quarters of available data, seven quarters had four quizzes (biweekly as opposed to weekly), and we only examined these quarters (5827 students). Quiz 3 is traditionally considered the least equitable quiz from 7B, and a t-test confirmed our prediction, with 10 of the 18 quarters having significantly different means by gender at the 95% confidence level. In each statistically significant case the males outperformed the females. Figure 3 shows the mean scores for females and males on Quiz 3. Because we are plotting deviations from the mean, correlations necessarily must be negative. Our graph is more non-linear than might be predicted because we were obliged to drop several students (mostly summer session students attending other schools) who took only 7B. One particularly skewed quarter was dropped from the plot for this reason.

For a non-graphical method of analyzing the importance of gender and ethnicity in our data, we performed a binary logistic odds regression (fit to Equation 1).

$$\text{High7} = C_{L7A}(\text{Low7A}) + C_{H7A}(\text{High7A}) + C_F(\text{Female}) + C_{WH}(\text{WH}) + C_{AF}(\text{AF}) + C_{OA}(\text{OA}) + C_{CJ}(\text{CJ}) + C_{LM}(\text{LM}) \tag{1}$$

Here "High7" is the logarithm of the odds of achieving in the upper third of students for 7B, "Low7A" =1 when the student's grade is in the lowest third of 7A (zero otherwise); "High 7A" is 1 for students in the highest third of 7A. "Female" is 1 if the student is female; "White" is 1 if the student is white and 0 otherwise, etc.

The coefficients of the fit are given in Table 1. Performance in 7A, gender, and being white or African American are the only statistically significant factors in determining success. Additionally, the magnitudes of the coefficients confirm that grades in 7A (-1.73 for low 7A and 1.85 for high 7A) are more important to success in 7B than gender or ethnicity, since the coefficient of fit for being female is only –0.688 and the largest magnitude for ethnicity is –0.810 for African American students.

DISCUSSION

The strong linearity in Figures 1 and 2 demonstrates that performance in 7A correlates strongly with performance in 7B across all ethnic groups. White students outperform all minority groups except the Japanese, but note that the scale of the graph exaggerates the differences, since the overall difference between the extremes is just over half a standard deviation. Figure 2 splits the ethnicities by gender, and in all 6 ethnic groups the males outperform the females. Males in the African American and Other categories exceed the females by over half a standard deviation, compared to 0.2 of a standard deviation in the remaining ethnicities, but note that these two ethnicities are the smallest (146 AF and 492 OT). By drawing a line through Mean7A=Mean7B, we can see that males generally perform better in 7B than 7A, and females perform better in 7A.

The two quizzes from Fig. 3 are given below. We noticed that the quiz with more gender equity appears to be the more difficult of the two. This coincides with some recent data in gender equity [3]. The males out performed the females on Quiz Y, which was mathematical in scope and deplete of physical intuition. A student could do well on Quiz Y without true functional understanding of the concept. Again this is in agreement with our previous observations on gender in introductory physics.

TABLE 1. Binary analysis coefficients

	Coef.	Std. Error	P>|z|	$e^{Coef.}$
Low 7A	1.730	0.116	0.000	0.177
High 7A	1.853	0.067	0.000	6.377
Female	0.688	0.065	0.000	0.503
WH	0.423	0.128	0.001	1.527
AF	0.810	0.314	0.010	0.445
LM	0.244	0.172	0.157	0.784
OA	0.182	0.140	0.194	0.834
CJ	0.120	0.139	0.391	1.127

Quiz X

Imagine you are riding in a bumper car moving at a constant velocity. You collide with a stationary bumper car, which slows you down, but you continue moving in the same direction. The other bumper car moves off in the same direction as you are moving, with a speed intermediate between your initial and final speeds. Assume all speeds are constant except during the actual collision. [Not shown: axes labeled x(t), v(t), and a(t)]

a) Sketch position, velocity, and acceleration graphs of the motion of the car **you are riding in**, covering the period before the collision, the collision, and after the collision. Make sure the time axes are the same for all three graphs. You will have to make choices regarding which physical direction you represent as being positive and where the physical origin is located.

b) On the same set of axes, **but using a dashed line**, sketch position, velocity, and acceleration graphs of the motion of the car **you are NOT riding in**, covering the period before the collision, the collision, and after the collision.

c) What is the direction of the net force on the car **you are riding in** (i) before, (ii) during, and (iii) after your collision with the other car? Give the direction with respect to your motion. Explain how this force is consistent with your graphs.

Quiz Y

The horizontal motion of an object is described by the v(t) velocity versus time plot shown (Fig. 4) below.

a) Calculate the values of acceleration for each time interval of the v(t) plot shown above.
$a_I(t) = \quad$ m/s^2; $a_{II}(t) = \quad$ m/s^2; $a_{III}(t) = \quad$ m/s^2; $a_{IV}(t) = \quad$ m/s^2.

b) Complete the properly scaled a(t) acceleration versus time plot that is consistent with the v(t) plot shown above. Use the dotted lines to align the time intervals on these plots.
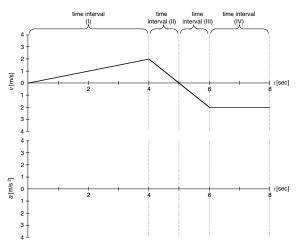

FIGURE 4. Figure for kinematics question on Quiz B

c) If the initial position x = 0.0 m, what is the position x of the object at t = 8.0 s

d) State the time interval(s) in which this object is speeding up in the negative direction, and explain how you know this from the v(t) graph above.

Future Research Directions

We are currently obtaining more information on all of our students, including grades from other university courses. With detailed information on a large sample of students we will be able to see more longitudinal trends. Some possible questions we seek to answer are:
1) How do course grades and timing of mathematics courses affect performance on mathematical tasks in physics?
2) Which other courses affect particular tasks in physics (e.g. how strongly does a course grade in Chemistry affect performance in thermodynamics?)
3) Is gender equity achievable at the introductory college physics level?
It is hoped that further research will detail some of these issues.

REFERENCES

1. W. H. Potter, C. J. De Leone, and L. B. Coleman, "What is the Physics 7 Course?" Paper presented at the 2000 NARST Annual Meeting
2. W. H. Potter, "Evidence that a Reformed Physics Course has Lasting Impact on Student Learning and Performance" Talk given at the Joint Meeting of APS California Section and AAPT N. California/Nevada Section, November 14 15, 2003, Lawrence Berkeley National Lab and University of California, Berkeley
3. Conversation with Wendell Potter, July, 2004