AC 2011-1332: WILL PRIOR EXPERIENCES HELP PREDICT APTITUDE TEST RESULTS?

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Introduction

Aptitude tests are often used as a predictor for more complex tasks. One of the most common aptitude test is the Scholastic Aptitude Test (SAT)[1] used to predict college performance. Another fairly common aptitude test is a mechanical aptitude test, which purports to measure ones mechanical ability. The most common of these ask students to determine what would happen if a particular set of circumstances were present, such as which direction would a particular gear turn in a system of gears. These responses are then used to determine if the student can mentally determine how physical objects operate. Similarly, an electrical aptitude test (EAT) would try to measure one's electrical ability. They would ask students to determine how electrical devices operate in different scenarios, or what may be wrong with a circuit if it is not working.

This study is part of a larger project to determine hands on ability. Previous studies have concentrated only on final lab grade and a lab practical score[2] . While the data on the electrical aptitude test was collected, the test itself has not been validated. In this project, each of the questions on the electrical aptitude test were themselves analyzed to determine if any one of them had a particular relationship to a particular prior experience, grades in the lab or on a lab practical, or an attitude. If the electrical aptitude test score was highly correlated with a known hands on ability measure, this could help validate the test constructed by the researchers. Identifying what prior experiences the students have had may also help determine the validity of the individual questions and lead to some idea about where hands on ability may come from- which is the ultimate goal of the project.

Background

The EAT was constructed by the researchers after they were unable to locate a validated test that could measure hands on ability. A copy is included in the appendix. A companion study, working with mechanical engineering students, was using a mechanical aptitude test for this purpose[3]. While there are a number of "electrical" aptitude tests available, most are specifically geared towards electrical maintenance jobs (i.e. vehicle electrical system repairs or electronics repairs) rather than general electrical knowledge.

This EAT test was constructed to try to cover a wide range of electrical and computer knowledge. It consists of 19 questions on a variety of topics in Electrical and Computer Engineering. There are 7 questions on circuits, 3 on electromagnetics, 3 on computers and digital systems, 3 on power and motors, and 3 on physics of energy. Many of the questions had diagrams or pictures as part of the question (such as question 2 that asks about the capacities of two shown batteries, or question 15, reading a multimeter with multiple scales). The test was multiple choice with 4 possible answers to each question. The initial goal was to ask questions that would not strictly rely on any specific course a student may have taken, but on understanding of electrical phenomena, similar to mechanical aptitude tests rely on understanding of mechanical devices.

Procedure

There were 174 students in an introductory electrical and computer engineering laboratory course who participated in this study. This lab introduces students to the basic instruments used in electrical and computer engineering and it is the first exposure to the electrical or computer engineering laboratory that students receive. The class is typically composed of 16 students that work individually on assignments that teach how to take measurements, construct circuits and use oscilloscopes, function generators, multimeters, and DC power supplies.

Students were given two surveys and two aptitude tests. One survey asked about prior experiences and another asked about attitudes toward engineering. In addition to the EAT, the students were also given a Mechanical Aptitude Test (MAT). All of these were multiple choice.

The first survey, the Prior Experience Questionnaire (PEQ)[4], consisted of 148 questions that tried to determine the background experiences of the student. It asked about activities at several ages: preschool, elementary and middle school, high school, and post high school. The students were asked to select the amount of experience they had with various actives on a scale of 1-4 with 1 being never experienced and 4 having very frequent experience.

The second survey was based on the Pittsburgh Freshman Engineering Attitude (PFE) survey[5]. This is a 51-question survey asking students to gauge their views on engineering and study habits. The students were asked how much they agreed with a given statement or how confident they were in a given ability. These were on a scale of 1-5. For questions of "Do you agree with this statement…" 1 was strongly disagree and 5 was strongly agree. For questions of "Rate your ability in …" 1 was not strongly confident and 5 was strongly confident.

There was no time limit to the surveys or aptitude tests and they were given online. Students did have the option to not answer questions but this did not generally happen. In addition, some students did not complete all four surveys.

With their consent, the participants grade point average (GPA), ACT and SAT scores when available, number of credits earned, lab grade and lab practical grade were added to the data.

Next, correlations were calculated on the gathered data. The EAT score and individual answers to EAT questions were specifically looked at to determine if there was a connection between the scores or answers and any particular prior experiences or attitudes. Then, using the results from these correlations, the most significant (smallest p-values) 4 or 5 PEQ/PFE/grade/score responses were examined. These data sets were split into two populations: those that answered the EAT question correctly and those that did not. These two populations were then examined using t-tests.

Results

Looking only at significant p-values below 0.05, the EAT Score is correlated with GPA, lab grade, and lab practical grade, with correlations coefficients of 0.21, 0.22, and 0.21 respectively. While these correlations are small, they are generally larger than most of the other significant correlations for each of those scores (with the exception of the lab grade, where it is smaller than most). The EAT Score itself is correlated with ACT science, math, and ACT composite scores with a correlation of about 0.3-0.4 depending on the EAT question.

Looking at each EAT question, EAT 1, 5, and 19 did not have enough students answer incorrectly to form a computable population and therefore no t-test could be performed.

Other questions showed that there were some significant (i.e. p-value less than 0.05) differences in the average answers between the students that answered the question correctly and those that answered incorrectly.

Some of the larger differences included:

For EAT 2: The question asked the difference in energy capacities between two batteries, of the same voltage, but one physically larger than the other. Those that answered correctly had an almost 1 point higher average (had 25% more experience) with electrical circuitry in high school, had 0.644 higher average experience with robotics, and had a lab practical score about 10% higher than those who answered incorrectly.

For EAT 3: The question asked if a light bulb would light up with the wires in a given configuration. Those students that had answered correctly had earned an average of 5.7 fewer credits than those whom answered incorrectly.

EAT 4: The questions asked if an incandescent or a florescent light bulb would get hotter. Those that answered correctly had an average ACT science score of 2.7 points higher than those who answered incorrectly.

EAT 6: The question asked, “The force that causes electrons to flow through a conductor is known as?” Again, ACT science and math scores were 2.7 and 2.1 points higher with those whom answered the question correctly. Student experience with high school physics also showed scores 0.44 higher.

EAT 8: Those who were able to describe how a relay worked were 0.51 points higher on average in their experience with hand tools in high school. They also answered 0.55 points higher in experience with arts and crafts in their preschool years.

EAT 9: When asked to define the term "hertz" those who answered correctly had 0.9 more confidence in their computer skills and .80 more experience in electricity or electronics after high school.

EAT 13: The question asked about potential energy of two cannon balls dropped from the same height. Those that answered correctly scored about 4 points higher on each part of the ACT Test: the math, science, English, and composite scores. They also had about 1 point more in their self-confidence in physics than those that answered incorrectly.

EAT 15: In asking the student to read an analog volt meter with a several different scales on it, those students who answered correctly had a higher confidence in chemistry by an average of 0.74 and also had higher ACT math scores of 2.5 points.

Analysis

The t-tests indicate that there is a significant difference between the average responses or scores for those student that answered questions right verses wrong on the EAT. It is also reassuring that many of the prior experiences or attitudes that have a higher average for those who answered a particular question correctly are intuitive (such as those who have a higher level of confidence in physics answer correctly), which may help in validating some of the questions of the EAT.

There were also several instances where the score on the mechanical aptitude test was significantly higher for those who correctly answered a particular question on the EAT. Since the MAT test has been validated, it seems reasonable to assume that better performance on it would also indicate better hands on ability (although maybe mechanical hands on ability) and therefore indicate that EAT question is also a good indicator.

ACT math and science scores also tended to be higher for people who answered a number of questions correctly. In contrast, there were no EAT questions where those two scores were higher for those who answered incorrectly.

Some EAT questions had noticeably more significant differences to questions from the PFE (attitudes survey) than the PEQ (prior experience survey). These did not always favor those with more positive attitudes toward engineering. There were also a fair number of sports and physical education experiences that favored the group answering particular EAT questions incorrectly.

Conclusions

Several of the EAT questions had t-test results which are significant showing those who answered correctly generally had more experience in at least two particular items. Also, the correct group generally had higher ACT scores than the incorrect group.

This, coupled with the MAT score differences, may indicate that at least some of the EAT questions are reasonable judges of hands on ability. However, there is still a need for testing additional students to try to improve the statistical significance of the results for some questions.

Future Work

Additional data on the EAT would hopefully establish similar t-test results of the questions where the population of students is too small to do a t-test. These would continue to help validate the EAT as a useful tool in measuring hands on ability in electrical and computer engineers.

References

1. The College Board, "SAT", http://sat.collegeboard.com/sat, 2011.

2.VanArsdale, C., A. Pereira, L. Bohmann, Miller, M., W. Helton,, "What do prior experience and student attitudes say about ECE lab ability?" *Proc. of the ASEE Annual Conference*, Louisville, KY, 2010.

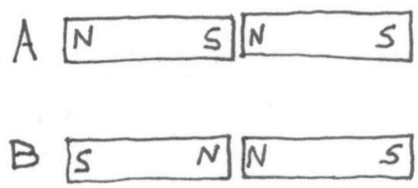
3. Miller, M., A. Pereira, M. Hutchins, W. Helton, L. Bohmann, C. VanArsdale, "Correlations between Mechanical Aptitude, Prior Experiences, and Attitude Toward Engineering," *Proc. of the ASEE Annual Conference*, Louisville, KY, 2010, paper no. AC 2010-1652.

4. Deno, John A.; "The Relationship of Pre-College Experiences to Spatial Visualization Ability of Beginning Engineering Graphics College Students", Ph.D. Dissertation, The Ohio State University, Ohio, USA,1994

5. Besterfield-Sacre, Mary; Atman, Cynthia J.; Shuman, Larry J. "Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering". *Journal of Engineering Education*, April 1997 PP. 139-149

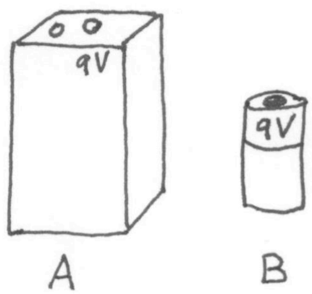
Electrical Aptitude Test

1.



Which of these pairs of magnets will stick together in the positions they are in?
(A) Drawing A
(B) Drawing B
(C) Both Drawings

2.

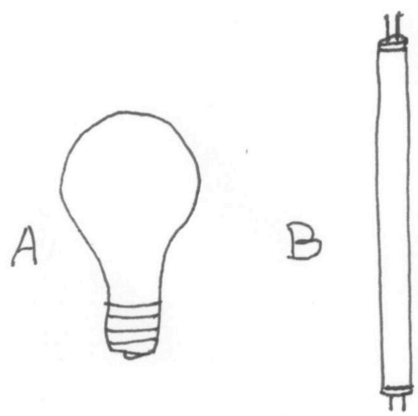


Which battery has the higher energy capacity?
(A) Battery A
(B) Battery B
(C) There's no difference

3.

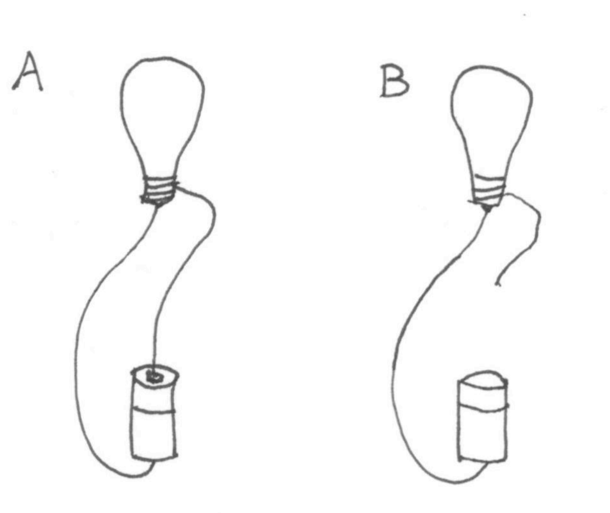
Will this bulb light up?
(A) Yes
(B) No
(C) Can't Tell

4.



Which light bulb gets hotter?
(A) A
(B) B
(C) Can't Tell

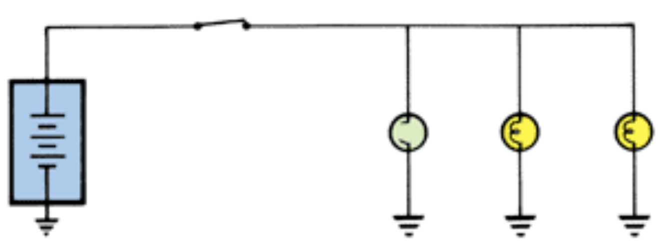
5.



Which bulb will light up?
(A) Drawing A
(B) Drawing B
(C) Both

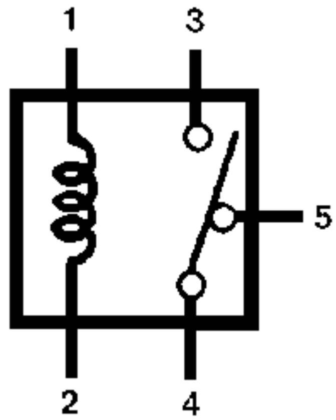
6. The force that causes electrons to flow through a conductor is known as:
(A) the power.
(B) the current.
(C) the voltage.
(D) the resistance.

7. Several lamps are connected in parallel to a voltage source. If one lamp burns out, all of the other lamps:



(A) will go out.
(B) will get brighter.
(C) will not be affected.
(D) will get dimmer.

8. In this relay:



(A) Terminal 1 is connected to terminal 5 until energized, then terminal 1 is connected to terminal 4..
(B) Terminal 3 is connected to terminal 5 until energized, then terminal 3 is connected to terminal 4..
(C) Terminal 4 is connected to terminal 5 until energized, then terminal 4 is connected to terminal 3.
(D) Terminal 4 is connected to terminal 3 until energized, then terminal 4 is connected to terminal 5.

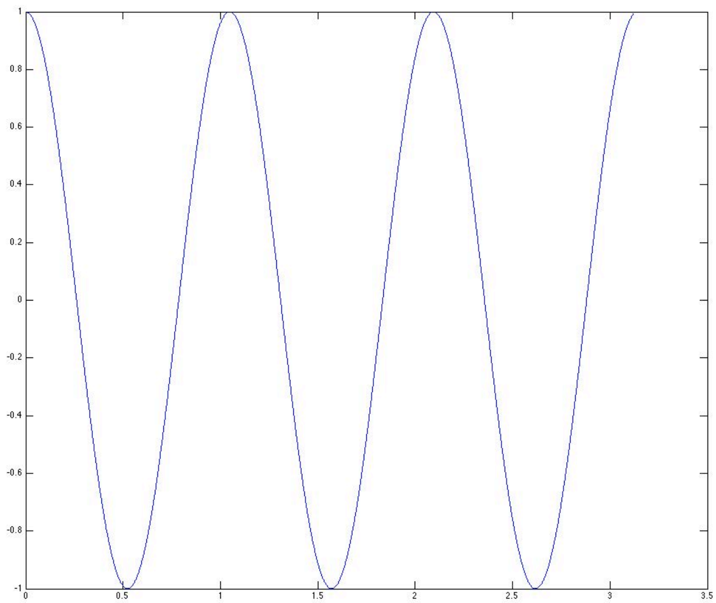
9. The computer can read but not change information stored in:
(A) ROM
(B) RAM
(C) KRAM
(D) None of the above

10. One cycle per ________ equals 1 hertz:
(A) second
(B) minute
(C) revolution
(D) any of the above

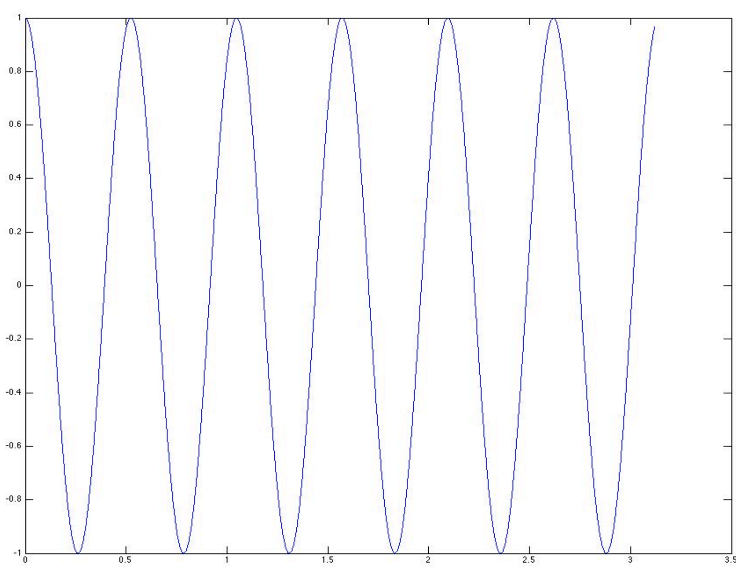
11. A digital signal:
(A) is either on or off
(B) has a continuously varying voltage
(C) has values from 0-2
(D) none of the above

12. Which signal can transmit more information if both signals are sent for the same amount of time.

(A)



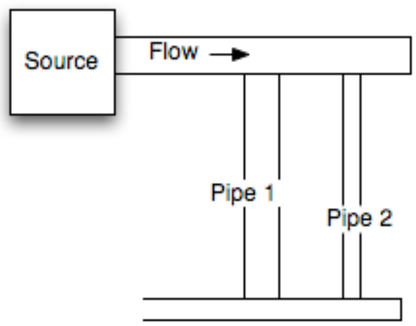
(B)



13. If two identical cannon balls are held in the air at different heights, which has more potential energy:

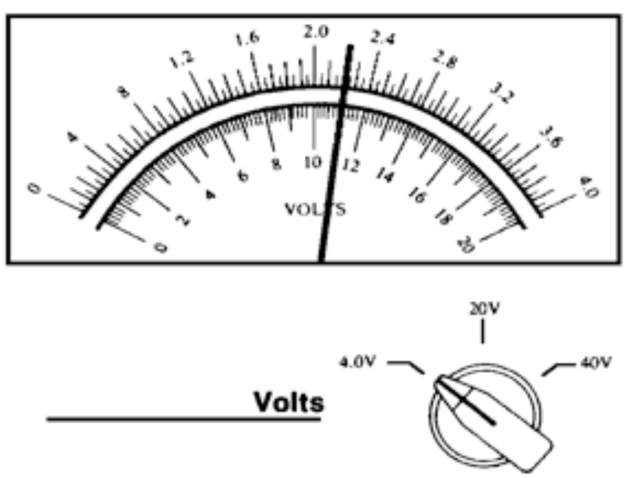
(A) the higher one
(B) the lower one
(C) They have the same potential energy

14. Given the same pressure at the source, which pipe has a higher flow through it



(A) Pipe 1
(B) Pipe 2
(C) They have the same flow

15. The analog volt meter reading show below is:



(A) 11.0 Volts
(B) 22.0 Volts

(C) 2.2 Volts
(D) .22 Volts

16. Two identical motors are each turning a different load. Motor 1 has a load of 15ft-lbs. Motor 2 has a load of 30ft-lbs. What is the most likely true statement?
(A) Motor 1 is not functioning correctly
(B) Motor 2 is overloaded
(C) Motor 2 is drawing more power
(D) Both motors 1 and 2 are using the same amount of power

17. A break or interruption in an electrical circuit is:
(A) an open.
(B) a short.
(C) a ground.
(D) none of these.

18. If a conductor is moved through a magnetic field:
(A) heat is created.
(B) voltage is created.
(C) the magnetic field is increased.
(D) the magnetic field is decreased.

19. Wires can get warm when current flows through them. Why?
(A) Exposure to air causes the insulation to warm.
(B) As the current flows through the wire, energy is lost as heat.
(C) Wires conduct better when they are warm.
(D) Electrical equipment is not insulated.