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Uluslararası Genel Ortaöğretim Sertifikası ve Uluslararası Bakalorya Diploma Programlarında Bilimsel Akıl Yürütme ve Fen-Matematik Alan Bilgisi İlişkisi

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Makale Bilgisi	**ÖZ**
Geliş Tarihi: 13.05.2020 *Kabul Tarihi*: 17.02.2022 *Basım Tarihi*: 30.06.2022	Bilimsel akıl yürütme becerileri, öğrencilerin bilimsel yeterliliklere hâkim olmalarına, karmaşık kavramları anlamalarına ve bunları çeşitli gerçek yaşam bağlamlarında yetkin bir biçimde kullanmalarına yardımcı olur. Bu beceriler, öğrencilerin uluslararası öğretim programlara hazırlanması için önemlidir. Özellikle, ortaöğretimdeki uluslararası programlarda, alan bilgisi ve öğrencilerin bilimsel akıl yürütme arasındaki ilişkiyi inceleyen literatürde sınırlı sayıda çalışma olması sebebiyle, bu araştırma öğrencilerin Uluslararası Genel Ortaöğretim Sertifikası ve Uluslararası Bakalorya Diploma Programındaki (IBDP) fen ve matematik dersleri başarıları ile bilimsel akıl yürütme yetenekleri arasındaki ilişkiyi incelemeyi amaçlamaktadır. Araştırma IGCSE ve IBDP uygulayan ulusal bir okulda yürütülmüştür. Çalışmada bilimsel akıl yürütmeyi ölçmek için Sınıfiçi Bilimsel Akıl Yürütme (CTSR) kullanılmıştır. Öğrencilerin CTSR'deki performansları ile IGCSE ve IBDP'deki fen-matematik derslerindeki başarı düzeyleri Pearson korelasyon ve Kendall'ın tau-b korelasyon testi kullanılarak analiz edilmiştir. Sonuçlar, fen-matematik alan bilgisi ile bilimsel akıl yürütme arasında orta düzeyde bir ilişki olduğunu ortaya koymuştur. **Anahtar Sözcükler:** IGCSE, IBDP, Fen Eğitimi, Matematik Eğitimi.
	Makale Türü: Araştırma Makalesi

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Relationship between Scientific Reasoning and Scientific-Mathematical Content Knowledge in International General Certificate of Secondary Education and International Baccalaureate Diploma Program

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ABSTRACT

Scientific reasoning skills help students master scientific competencies, understand complex concepts, and equip them with the abilities to apply concepts and competencies in a variety of real-life contexts. These skills are important for students' preparation to the international education programs. Since there are limited studies in the literature that examine the relationship between students' content knowledge and scientific reasoning, especially in the international programs in secondary education, this research aims to investigate the extent to which the students' achievement in the International General Certificate of Certificate (IGCSE) as well as students' achievement in their science and mathematics courses in the International Baccalaureate Diploma Program (IBDP) correlate to the students' scientific reasoning abilities. The research was conducted at a national school with IGCSE and IBDP programs. The study used Classroom Test of Scientific Reasoning (CTSR) to measure the scientific reasoning. The students' performances in the CTSR and their levels of achievement in science and math in the IGCSE and IBDP were analyzed using Pearson's correlation test and Kendall's tau-b correlation test. The results revealed that there is a moderate correlation between scientific reasoning and content knowledge in science and mathematics.

Keywords: IGCSE, IBDP, Science Education, Math Education.

Article Type: Research Article

1. INTRODUCTION

Human beings use reasoning in every part of their lives for gaining knowledge or understanding, questioning information, and making myriad decisions. Reasoning, one of the essential parts of critical thinking, is also used to justify the accuracy of information to strengthen the academic research (IBO, 2015). Strong scientific inquiry and reasoning skills allows individuals to become, scientifically knowledgeable and aware of the scientific and technological developments around them and engaged in science and technology.

The Program for International Student Assessment (PISA, 2006) defines scientific reasoning as an un-detachable part of science education. Therefore, scientific reasoning takes an important role for students to improve achievement in academic studies. Scientific reasoning skills also help students to master scientific competencies, understand complex concepts, and equip them with the abilities to apply the concepts and competencies in a variety of real-life contexts. These skills are important for students' preparation to the international programs. For example, higher scientific reasoning skills help students perform better in a course and in structuring their individual investigation process in their international curricula studies.

The development of scientific reasoning skills provides students with a mastery of important tasks in science and math education, but scientific reasoning need to be facilitated through right intervention methods (Engellmann, Neuhaus, and Fischer, 2016). As for these intervention methods, Van der Graaf, Van de Sande, Gijsel, and Segers (2019) investigated the effectiveness of direct instruction of scientific reasoning and teacher training of verbal support for strengthening the scientific thinking abilities in an elementary school context and found that both approaches strengthened different components of scientific reasoning abilities. Similarly, Wu, Weng, and She (2016) examined how scientific reasoning ability, and various scaffolding forms influenced students' science knowledge and scientific inquiry achievements. The study revealed that types of scaffolding significantly influenced students' scientific inquiry abilities. Finally, Yanto, Subali, and Suyanto (2019) analyzed the effectiveness of the three levels of inquiry (structured, guided and free inquiry) to improve the students' scientific reasoning skills compared to the conventional method. The research results indicated that these three levels of inquiry were more effective than the conventional method in improving the students' scientific reasoning skills. Nevertheless, there are still limited studies that examine the relationship between content knowledge and students' scientific reasoning skills (Bao, et al., 2009), especially in the implementation of the international programs in the secondary education context.

Literature Review

Often educators teach students the content knowledge of their subjects without intentional references to the development of scientific thinking skills. Oftentimes, they think that content knowledge alone helps to improve students' scientific reasoning abilities. Yet, one study on assessment of scientific inquiry states that scientific reasoning allows students to apply the scientific understandings gained in different disciplines to the real life (Bybee, Mccrae, & Laurie, 2009). Several studies have also revealed that there is a mutual progression on students content knowledge and their ability reason scientifically (Ding, 2018).

That said, there are a few studies on analysis of the relationship between students' scientific reasoning abilities and their cognitive abilities or academic subject content knowledge in each schooling period. With regard to the young age group, Van Niekerk (2019) studied on the development of scientific reasoning of preschool children and discussed that the emergence of scientific reasoning in the preschool years could be improved by preschool teachers through nurturing Habits of Mind and Habits of Body of young children. In the elementary context, Schiefer, Oschatz, Golle, Trautwein, and Tibus (2016) studied scientific reasoning of elementary school children and its relations to cognitive abilities. In their regression analysis, they found that cognitive abilities as well as epistemic beliefs predicted children's scientific inquiry performances. In the middle school context, Stender, Schwichow, Zimmerman, and Härtig (2018) investigated the influence of scientific reasoning skills on students' conceptual learning gains in physics during an inquiry-learning activity. The results of their study showed that students require specific scientific reasoning skills to learn science content from inquiry activities. In the high school context, Rani (2017) explored the relationship between reasoning ability and academic achievement among secondary school students. The result of the study showed that there was significant high positive correlation between reasoning ability and academic achievement among secondary school students.

Various studies were also conducted in the literature about the relationship between students' scientific reasoning skills and their problem solving skills. For example, Fabby and Koenig (2015) examined the relationship of scientific reasoning with Physics problem solving. Using Lawson's Classroom Test of Scientific Reasoning and the Taxonomy of Introductory Physics Problems, they found out that students with higher reasoning abilities perform equally well across problem levels while students of lower reasoning abilities struggle in solving problems that depend on higher conceptual understanding. Similarly, Hejnova, Eisenmann, Cihlár, and Pribyl (2018) did research on the correlations among problem solving and scientific reasoning as well as correlations among problem solving and scientific reasoning with students' school performance in mathematics and physics. They found out one component of problem solving (the ability to use the existing knowledge) strongly correlates with scientific reasoning (proportional reasoning, control of variables and probability reasoning). Lastly, Tajudin and Chinnappan (2015) explored relationship between scientific reasoning skills and mathematics problem solving among a cohort of Malaysian students. Their study revealed that there was a positive relationship, but the level of correlation was moderate.

Contrary to the lack of studies in different schooling periods, many studies were conducted in relation to the scientific reasoning abilities in tertiary level. Ding, Wei, and Mollohan (2016) undertook research to identify whether higher education improves students' scientific reasoning skills. Using Lawson's Classroom Test of Scientific Reasoning with 1,637 Chinese students in different years of study, different fields, and different university tiers, they found that regardless of which major or university students entered, their scientific reasoning measured by the Lawson's Classroom Test of Scientific Reasoning showed little variation across the entire 4 years of undergraduate education. Another study conducted by Jensen, Neeley, Hatch, and Piorczynski (2017) investigated scientific reasoning ability as a possible factor in Science, Technology, Engineering and Mathematics (STEM) retention. Using the Lawson Classroom Test of Scientific Reasoning, again, they found that reasoning ability correlates with high-level performance and final course grades for the STEM major university students. Thompson, Bowling, and Markle, (2018) evaluated the efficacy of the ACT Mathematics subject exam and Lawson's Classroom Test of Scientific Reasoning in predicting success in a major's introductory biology course at the university level. They found that the both scientific reasoning and ACT Math are significant predictors of student success for the Biology course. Cracolice and Busby (2015) undertook another study that focused on the relationship between scientific reasoning abilities and chemistry exam performance. Finally, their study revealed the scientific reasoning ability was significantly correlated with university students' performance on the American Chemical Society Division of Chemical Education Examinations Institute First Term General Chemistry Examination. As it is clear, all these studies and others existing in the literature conducted on the scientific reasoning abilities were mainly concentrated on the tertiary education.

Therefore, this research aims to investigate the extent to which the students' achievement levels in the Cambridge International General Certificate of Certificate (IGCSE) extended science (Physics, Chemistry and Biology) and mathematics (additional) as well as students' achievement levels in their Physics, Chemistry, Biology and Mathematics courses in the International Baccalaureate Diploma Program (IBDP) correlate to the students' scientific reasoning abilities.

The IGCSE program is one of the most recognized qualifications around the world. The IGCSE courses aim at developing vital educational skills, including recall of knowledge, oral skills, problem solving, initiative, team work and investigative skills. IGCSE provides a series of syllabi and assessment programs to cover the two years of education between the ages of 14 and 16. The examination caters for a wide ability range and has a seven point scale of grades: A, B, C, D, E, F and G.

The aim of the IGCSE science and mathematics program is to prepare students to become responsible citizens who are aware of the technological and scientific advancements. The program also intends to prepare students further for science education. The students who complete the IGCSE program are expected to transfer the information gained in one discipline to another discipline and make necessary interdisciplinary connections (IGCSE, 2018). At the research school, since the students are academically strong in math and science, they take extended science and additional math courses, which are more challenging in terms of their scope of content knowledge, rather than relatively less challenging core science and core/international math courses. These courses are taught and assessed in alignment with the IGCSE syllabus and rubrics.

The International Baccalaureate (IB) aims to develop inquiring, knowledgeable and caring individuals who work collaboratively to create a better and more peaceful world through intercultural understanding and respect. The IB provides challenging programmes (i.e. Primary Years Program, Middle Years Program, Diploma Program, Career related Program) of international education and rigorous assessment to help students across the world to become active, compassionate and lifelong learners (The IB, n.d). The IB Diploma Programme is portrayed in the shape of a hexagon with the six academic areas around a core. The IBDP requires students to take one course from six subject groups, which are Group 1: Studies in Language and Literature, Group 2: Language Acquisition, Group 3: Individuals and Societies, Group 4: Science, Group 5: Mathematics, and Group 6: The Arts. In order to form their course combination, students are required to take one course from each of the six subject groups. For example, students are required to take at least one Group 4 (Physics, Chemistry, Biology, Sports, Exercise and Health Science, Environmental Studies and Computer Science) and Group 5 (Mathematics) subject. Students choose one subject from each of subject groups 1 to 5, thereby ensuring breadth of experience in Languages, Humanities, the Experimental Sciences and Mathematics. The courses students take are taught and assessed in alignment with the IBDP syllabus and assessment rubrics. In addition, students must fulfil the requirements of the three compulsory components that lie at the core of the hexagon: the Extended Essay, Theory of Knowledge and the Creativity, Activity and Service (CAS).

During the Diploma Program (DP), students are asked to conduct academic research in Science and Mathematics courses. For instance, the IB requires students to conduct an internal assessment in each science course they choose to study. The IB states that this assessment "enables students to demonstrate the application of their skills and knowledge and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught" (IBO, 2012, p. 110). The DP's Internal Assessment requires students to generate a hypothesis and evaluate the data. Students are expected to conduct an individual investigation and transfer the knowledge gained in the academic disciplines to the research they conduct. Individual Investigation component in the DP (conducted in each science course) requires students to identify local problems which have global significance. In an individual investigation, students are expected to follow the scientific method which includes asking a subject-specific question, doing the background research, constructing the hypothesis, testing the hypothesis with an experiment, checking to see if the procedure is working, analyzing data and draw conclusions, and communicating the results.

2. METHOD

Research Context

The current study utilized only quantitative tools for analyzing the phenomenon under research. The school where the research was conducted is a private co-educational high school located in eastern Turkey. The school implements the Turkish national curriculum of Ministry of Education and two international curricula, namely the International General Certificate of Secondary Education in (IGCSE) grades 9 and 10 and the International Baccalaureate Diploma Program (IBDP) in grades 11 and 12. The case school where all the research participants come from is a selective school. Students are admitted with a two stage high school admission examination and high achieving students are given academic merit scholarships.

Participants

Research participants are 55 students from the 9th grade of the IGCSE program and 24 students from the 11th grade of the IBDP. Both groups of of these 9th and 11th grade students (N=79) were admitted to the school with a similar admission exam, thus they are homogenous in terms of their academic skills. Grade 9 participants were selected bacasue they were the only group which have just started to the IGCSE program. All of the grade 9 participants invited to take part in the study and 55 of them accepted to participate. Grade 11 students were selected because they were the only group which have just completed the IGCSE program. Twentyfour of them accepted to take part in the study.

Data Collection Tools

The instrument called Classroom Test of Scientific Reasoning developed by Lawson (2000) was used to measure of students' scientific reasoning skills in current study. This instrument was chosen by the researchers as the instrument was previously verified with a group of high school students. The aim of the Classroom Test of Scientific Reasoning is to measure the ability to apply aspects of scientific and mathematical reasoning to analyze a situation to make a prediction or solve a problem (Lawson, & Lawson, 2000). This test assesses set of skills which are crucial for scientific literacy (Hanson, 2016). Lawson's test was developed in 1970s and updated in 2000. The test is a 24-item test (see Appendix A). The selected items intend to assess proportional reasoning, combinatorial reasoning, probabilistic reasoning, isolation and control of variables. This instrument is known to be a practical tool for assessing a unidimensional scale of scientific reasoning. The instrument has also proved be have a good overall reliability for the whole test (Bao, Xiao, Koenig, and Han, 2018).

Data Collection

The test was administered to the participants (grade 9 and 11 students) in the fall term of 2018-2019 academic year at the same time to avoid possible interaction among the students. The participants were given an optical answer sheet and an optical reader was used for evaluation of the optical forms. The participants were given 60 minutes to answer the test.
The data were also collected from the grade 9 and grade 11 sample group students' grade point average scores for their levels of achievement in the IGCSE and IBDP science (Physics, Chemistry and Biology) and mathematics courses. These data were retrieved at the end of the spring term of the 2018-2019 academic year from the electronic grading system (e-school) of the school, with the consent of the school administration.

Data Analysis

The data were analyzed inferentially in SPSS using Pearson's Correlation.. As part of exploration of continuous variables for normality, Kolmogorov-Smirnov test was conducted as well as Skewness and Kurtosis values and histograms were checked. Kolmogorov-Smirnov values were insignificant for all the variables that have been collected for grade 9 students which includes results of the scientific reasoning test, IGCSE Physics, IGCSE Chemistry, IGCE Biology and IGCSE Mathematics at the end of the first term. Skewness and Kurtosis values also have been checked for each variable. Skewness values were ranged from -910 to .165 while Kurtosis values ranged from -.700 to .810. Analysis of Kolmogorov-Smirnov test and Skewness / Kurtosis values provide us with an information that the data show a normal distribution (Tabachnick & Fidell, 2013). The same procedure has been applied for checking for normality for the data for grade 11 student's which includes results of scientific reasoning test, IBDP Physics, IBDP Chemistry, IBDP Biology and IBDP Mathematics at the end of the first term. Skewness values ranged from -.657 to .092 and Kurtosis values ranged from -1.515 to -.084. Also, the results of analysis of Kolmogorov-Smirnov test shows that all the variables were normally distributed.

Validity and Reliablity

The classroom test of Lawson's scientific reasoning test was developed in order to measure psychological parameters. The test was developed by series of classroom demonstrations. The items on the test have strong degree of reliability (Lawson, 2000).

Ethical Considerations

Before conducting the test, the lead researcher contacted the owner of the test, Antony Lawson, for consent. Lawson allowed the researchers to use the Classroom Test of Scientific reasoning skills for this research. Also, necessary permissions and consents were taken both from the school administration of the case study school and the parents of the participating grade 9 and grade 11 students.

3. FINDINGS

Findings of the analysis and pearson corrleation will be presented in this section. Degree of relatipnships between students achievement in Lawson's scientific reasoning test and subject content knowledge in IGCSE and IBDP science lessons will be given for grade 9 and grade 11 students respectively.

Pearson correlation was computed to find out the relationship between grade 9 students' scientific reasoning skills and content knowledge in Physics, Chemistry, Biology and Mathematics courses, as shown in Table 1. Results of the Pearson correlation revealed that there is a statistically significant correlation between students' scientific reasoning skills and content knowledge in Physics $r=.56$, $p< .000$; a statistically significant correlation between students' scientific reasoning skills and content knowledge in Chemistry $r= .48$, $p< .000$; a statistically significant correlation between students' scientific reasoning skills and content knowledge in Biology $r= .57$, $p< .000$ and a statistically significant correlation between students' scientific reasoning skills and content knowledge in Mathematics $r= .54$, $p< .000$.

Table 1.
Pearson Correlation results for grade 9 students

		Scientific Reasoning	IGCSE Biology	IGCSE Chemistry	IGCSE Physics	IGCSE Mathematics
Scientific Reasoning	Pearson Correlation	1	.574**	.484**	.563**	.535**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	55	55	55	55	55

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Pearson Correlation was computed to find out the relationship between grade 11 students' scientific reasoning skills and content knowledge in Physics, Chemistry, Biology and Mathematics courses, as shown in Table 2. Results of the Pearson correlation revealed that there is a statistically significant correlation between students' scientific reasoning skills and content knowledge in Physics r=.46, p< .039; a significant correlation between students' scientific reasoning skills and content knowledge in Chemistry r= .55, p< .002; a significant correlation between students' scientific reasoning skills and content knowledge in Mathematic r= .32, p< .040, yet Pearson correlation did not yield a statistically significant correlation between students' scientific reasoning skills and content knowledge in Biology r= 41, p< .103.

Table 2.
Pearson Correlation results for grade 11 students

			SR	Physics	Chemistry	Biology	Mathematics
Pearson Correlation	Scientific Reasoning	Correlation Coefficient	1.000	.455*	.552**	.414	.318*
		Sig. (2-tailed)	.	.039	.002	.103	.040
		N	24	13	18	10	24

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

4. RESULTS, DISCUSSIONS AND SUGGESTIONS

One of the major aims of science education is to improve students' scientific reasoning ability which is specifically connected with being able to understand scientific concepts in depth, deal with complex scientific problems and make deliberate scientific decisions in real life (Ding, 2018). As scientific thinking is one of key abilities in students' daily life, the current study aimed to investigate to what extent scientific reasoning skills of grade 9 and 11 students are related to student's level of achievement in terms of scientific and mathematical content knowledge in IGCSE and IBDP science and mathematics courses at the school. The research utilized Lawson's Classroom Test of Scientific Reasoning which assesses different domains in scientific reasoning, namely, hypothetical-deductive reasoning, proportional reasoning, correlational reasoning, probabilistic reasoning, and control of variables (Lawson, 2000).

Considering the correlation between Lawson's Classroom of Test of Scientific Reasoning and IGCSE science and math courses, the results revealed that there is a moderate correlation between the classroom test scientific reasoning and content knowledge in science and mathematics in both groups (grade 9 and grade 11 groups). These results may suggest that the IGCSE and IBDP programs helped students develop some scientific reasoning skills over the course of implementation of the programs. Besides, the correlation found between scientific reasoning and content knowledge science and math courses in the current research supports the findings of the existing literature (Fabby and Koenig, 2015; Hejnova, et al., 2018; Rani, 2017; Stender, et al., 2018; Tajudin and Chinnappan, 2015).

On the other hand, the researchers note that there can be other academic and non-academics factors which affect reasoning skills of students such as extracurricular activities, non-IGCSE courses, physical exercise and maturity. Due to the fact that science education does not require to involve scientific reasoning (Kuhn, 2011), students coming from different middle school backgrounds may have been exposed different teachers and teaching backgrounds. However, Ding (2018) investigated the progression of scientific reasoning abilities of students from elementary school through tertiary level and found out that progression of scientific reasoning abilities of students did not show an uptrend up to grades 8 and 9. Therefore, even though there are many factors such as school environment, education philosophy, ideology and social environment (Wang, et al., 2009) which may affect scientific and mathematical reasoning skills of students, the benefits of studying IGCSE and IBDP science and math education in the development of scientific reasoning skills should not be disregarded.

Science curricula in IGCSE help students to understand and involve in the advanced technological world and inquire in scientific world and scientific developments. Students in IGCSE programs are introduced about foundational scientific concepts. At the end of their study, they develop and maintain necessary skills for further studies such as college preparation. Furthermore, the Diploma Program science and mathematics courses help students to further their scientific and mathematical skills to a higher level by allowing them to inquire about scientific method, how scientists work, and hone their skills by using their skills in practical works and/or relating their knowledges with complex real life issues.

One of the limitations of the study was that that the sample size is relatively small in this research. In order to conduct further future studies on this area, it is suggested that researchers can look for ways to increase the sample size Furthermore, the researchers note that IGCSE and IBDP should not be assumed as the sole source of scientific reasoning abilities of the students. Students take many other courses during the IGCSE and IBDP years that may affect their scientific reasoning abilities. Hence, the researchers recommend that multiple methods of assessing students' scientific and mathematical reasoning skills are applied for an in depth analysis of the phenomenon under consideration.

Research and Publication Ethics Statement

Necessary ethical considerations were also followed to undertake this research such as permission to do this research from the school administration and consents of the participants to be involved in this research. Participant consent form was prepared in order to obtain the permission of the participants.

Contribution Rates of Authors to the Article

Dinçer Akış made substantial contribution to collection of data and analysis of data, Dr. Akın Metli contributed to introduction, literature review and method sescion of paper. Both authors contributed evenly to the conclusion section of the manuscript.

Statement of Interest

The authors whose names are listed certify that they have no affiliations with or involvement in any organization or entity with any financial in the subject matter or materials discussed in this manuscript.

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APPENDIX

This section includes the appendix according to the structure of the research.

CLASSROOM TEST OF SCIENTIFIC

REASONING

Multiple Choice Version

Directions to Students:

This is a test of your ability to apply aspects of scientific and mathematical reasoning to analyze a situation to make a prediction or solve a problem. Make a dark mark on the answer sheet for the best answer for each item. If you do not fully understand what is being asked in an item, please ask the test administrator for clarification.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

1. Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece. *Which of these statements is correct?*

a. The pancake-shaped piece weighs more than the ball
b. The two pieces still weigh the same
c. The ball weighs more than the pancake-shaped piece

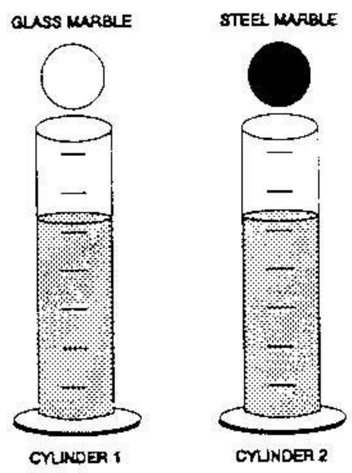
2. *because*

a. the flattened piece covers a larger area.
b. the ball pushes down more on one spot.
c. when something is flattened it loses weight.
d. clay has not been added or taken away.
e. when something is flattened it gains weight.

3. To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape.

Also shown at the right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one.

When the glass marble is put into Cylinder 1 it sinks to the bottom and the water level rises to the 6th mark. *If we put the steel marble into Cylinder 2, the water will rise*

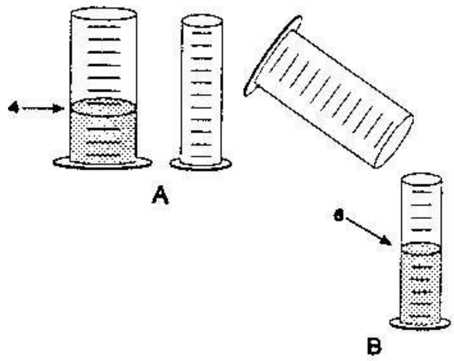


a. to the same level as it did in Cylinder 1
b. to a higher level than it did in Cylinder 1
c. to a lower level than it did in Cylinder 1

4. *because*

a. the steel marble will sink faster.
b. the marbles are made of different materials.
c. the steel marble is heavier than the glass marble.
d. the glass marble creates less pressure.
e. the marbles are the same size.

5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).



Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. *How high would this water rise if it were poured into the empty narrow cylinder?*

a. to about 8
b. to about 9
c. to about 10
d. to about 12
e. none of these answers is correct

6. *because*

a. the answer can not be determined with the information given.
b. it went up 2 more before, so it will go up 2 more again.
c. it goes up 3 in the narrow for every 2 in the wide.
d. the second cylinder is narrower.
e. one must actually pour the water and observe to find out.

7. Water is now poured into the narrow cylinder (described in Item 5 above) up to the 11th mark. *How high would this water rise if it were poured into the empty wide cylinder?*

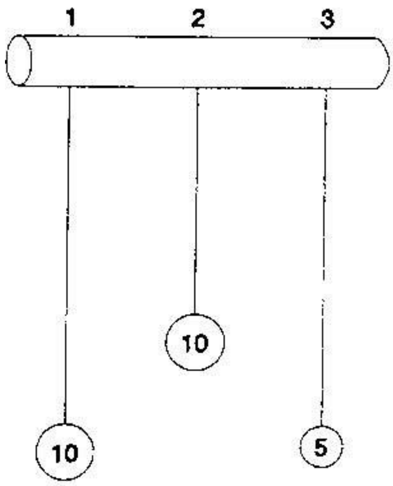
a. to about 7 1/2
b. to about 9
c. to about 8
d. to about 7 1/3
e. none of these answers is correct

8. *because*

a. the ratios must stay the same.
b. one must actually pour the water and observe to find out.
c. the answer can not be determined with the information given.
d. it was 2 less before so it will be 2 less again.
e. you subtract 2 from the wide for every 3 from the narrow.

9. At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is
attached to the end of String 1. A 10 unit weight is also attached to the end of String 2. A 5 unit weight is attached to the end of String

3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.



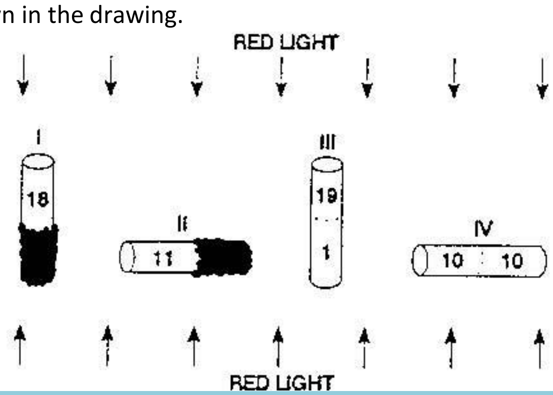
Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. *Which strings would you use to find out?*

a. only one string
b. all three strings
c. 2 and 3
d. 1 and 3
e. 1 and 2

10. *because*

a. you must use the longest strings.
b. you must compare strings with both light and heavy weights.
c. only the lengths differ.
d. to make all possible comparisons.
e. the weights differ.

11. Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to red light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.



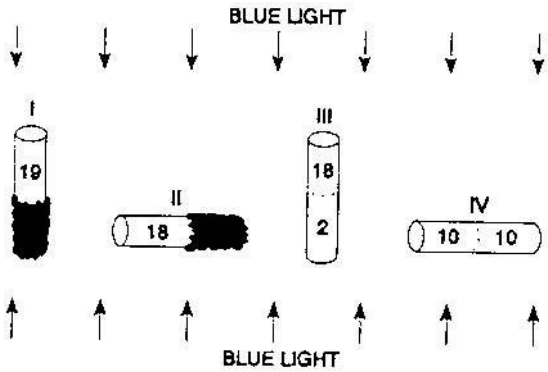
This experiment shows that flies respond to (respond means move to or away from):

a. red light but not gravity
b. gravity but not red light
c. both red light and gravity
d. neither red light nor gravity

12. because

a. most flies are in the upper end of Tube III but spread about evenly in Tube II.
b. most flies did not go to the bottom of Tubes I and III.
c. the flies need light to see and must fly againstgravity.
d. the majority of flies are in the upper ends and in the lighted ends of the tubes.
e. some flies are in both ends of eachtube.

13. In a second experiment, a different kind of fly and blue light was used. The results are shown in thedrawing.



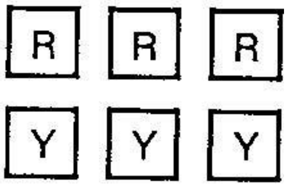
These data show that these flies respond to (respond means move to or away from):

a. blue light but not gravity
b. gravity but not blue light
c. both blue light and gravity
d. neither blue light nor gravity

14. because

a. some flies are in both ends of eachtube.
b. the flies need light to see and must fly againstgravity.
c. the flies are spread about evenly in Tube IV and in the upper endof Tube III.
d. most flies are in the lighted end of Tube II but do not go down in Tubes I and III.
e. most flies are in the upper end of Tube I and the lighted end of Tube II.

15. Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape, however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. *What are the chances that the piece is red?*

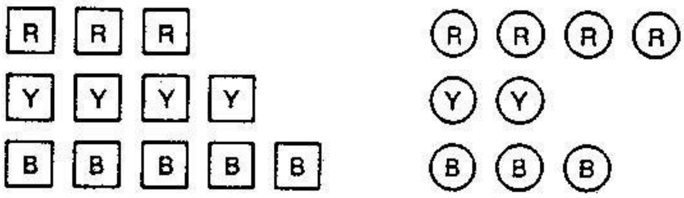


a. 1 chance out of 6
b. 1 chance out of 3
c. 1 chance out of 2
d. 1 chance out of 1
e. cannot be determined

16. *because*

a. 3 out of 6 pieces are red.
b. there is no way to tell which piece will be picked.
c. only 1 piece of the 6 in the bag is picked.
d. all 6 pieces are identical in size and shape.
e. only 1 red piece can be picked out of the 3 red pieces.

17. Three red square pieces of wood, four yellow square pieces, and five blue square pieces are put into a cloth bag. Four red round pieces, two yellow round pieces, and three blue round pieces are also put into the bag. All the pieces are then mixed about. Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece.



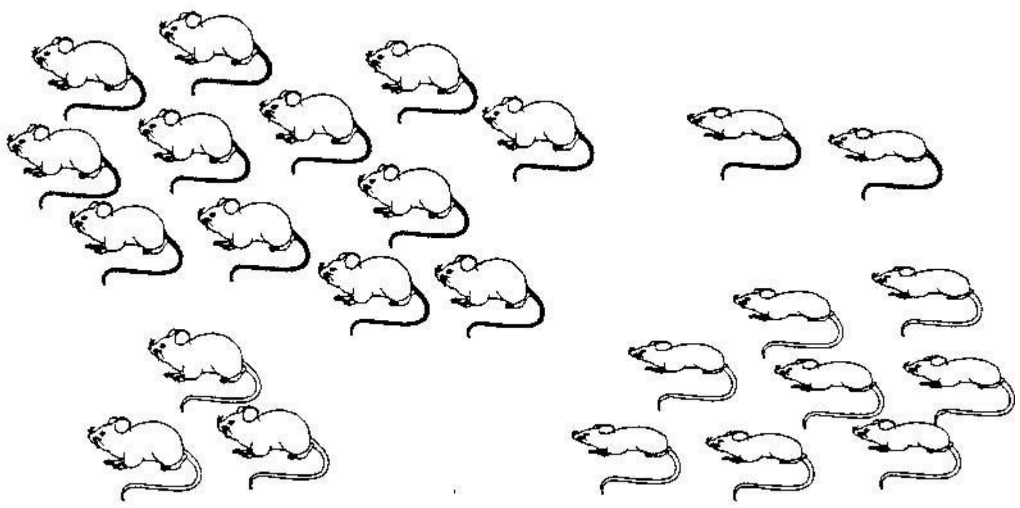
What are the chances that the piece is a red round or blue round piece?

a. cannot be determined
b. 1 chance out of 3
c. 1 chance out of 21
d. 15 chances out of 21
e. 1 chance out of 2

18. *because*

a. 1 of the 2 shapes is round.
b. 15 of the 21 pieces are red or blue.
c. there is no way to tell which piece will be picked.
d. only 1 of the 21 pieces is picked out of the bag.
e. 1 of every 3 pieces is a red or blue round piece.

19. Farmer Brown was observing the mice that live in his field. He discovered that all of them were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the colo r of their tails. So he captured all of the mice in one part of his field and observed them. Below are the mice that he captured.



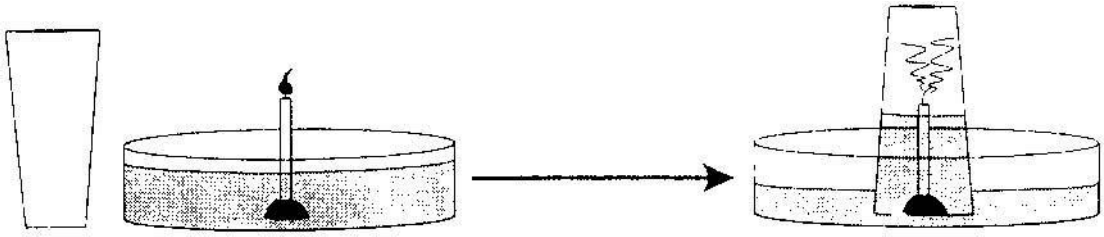
Do you think there is a link between the size of the mice and the color of their tails?

a. appears to be a link
b. appears not to be a link
c. cannot make a reasonable guess

20. *because*

a. there are some of each kind of mouse.
b. there may be a genetic link between mouse size and tail color.
c. there were not enough mice captured.
d. most of the fat mice have black tails while most of the thin mice have white tails.
e. as the mice grew fatter, their tails became darker.

21. The figure below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of wate r. When the glass is turned upside down, put over the candle, and placed in the water, the candle quickly goes out and water rushes up into the glass (as shown at theright).



This observation raises an interesting question: Why does the water rush up into the glass?

Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

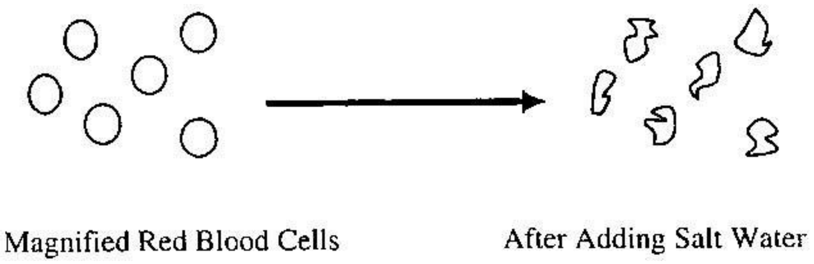
Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). *Using some or all of the materials, how could you test this possible explanation?*

a. Saturate the water with carbon dioxide and redo the experiment noting the amount of water rise.
b. The water rises because oxygen is consumed, so redo the experiment in exactly the same way to show water rise due to oxygen loss.
c. Conduct a controlled experiment varying only the number of candles to seeif that makes a difference.
d. Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the burningcandle.
e. Redo the experiment, but make sure it is controlled by holding all independent variables constant; then measure the amount of waterrise.

22. What result of your test (mentioned in #21 above) would show that your explanation is probably wrong?

a. The water rises the same as it did before.
b. The water rises less than it didbefore.
c. The balloon expands out.
d. The balloon is suckedin.

23. A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.



This observation raises an interesting question: Why do the red blood cells appear smaller?

Here are two possible explanations: I. Salt ions (Na+ and Cl-) push on the cell membranes and make the cells appear smaller. II. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.

To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller

24. What result of the experiment would best show that explanation II isprobably wrong?

a. the bag loses weight
b. the bag weighs the same
c. the bag appears smaller