Development of a Test of Scientific Argumentation

Bruce B. Frey
University of Kansas
USA

James D. Ellis
University of Kansas
USA

Janis A. Bulgren
University of Kansas
USA

Jana Craig Hare
University of Kansas
USA

Marilyn Ault
University of Kansas
USA

Abstract

Please address all correspondence to: Bruce Frey, Educational Psychology, School of Education, University of Kansas, Lawrence, KS 66045, bfrey@ku.edu

Key words: *argumentation, scientific argumentation, classroom assessment*

Introduction

The skill of *argumentation* is recognized as a crucial factor for student success in school and beyond. The ability to integrate knowledge and ideas, delineate and evaluate claims and arguments, and assess the reasoning used in arguments is central to the *Common Core State Standards* (National Governors Association, 2010), particularly related to literacy in science and technical subjects. Indeed, *scientific argumentation* specifically (being able to develop and analyze scientific claims, supporting the claim with evidence from investigations of the natural world, and explaining and evaluating the reasoning that connects the evidence to the claim) is a critical component of both the *Framework for K-12 Science and Engineering* (National Research Council, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013) which emphasize that science students must be able to engage in this process. Ultimately, the goal is that students learn to apply scientific practices to everyday challenges and develop defensible ways to convince others of the truth of a conclusion (Lawson, 2003). Most broadly, many argue that scientific argumentation is a fundamental aspect of scientific literacy for all citizens (Driver, Newton, & Osborne, 2000) and at a global level, students must engage in this type of higher

order thinking to compete in the world economy of the 21st century (Conley, 2008; Heller & Greenleaf,2007).

Consequently, science teachers are beginning to include the process of scientific argumentation among classroom objectives. This has been difficult, however, which may be due to both relatively low student ability to think critically and to low instructional quality. Data from national assessments such as the National Assessment of Educational Progress suggest that most young Americans do not have a firm mastery of higher-order thinking skills (National Center for Educational Statistics, 2012). In addition, Duschl and Osborne (2002), Erduran and Jimenez-Alexandre (2008), and Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson (2013) highlighted the lack of quality instruction on scientific argumentation and discourse in science classrooms for several decades. Sadler (2004) suggested that the difficulties in teaching argument analysis may be due, in part, to the complex interrelationships between socio-scientific issues and the nature of science. Innovative instruction is needed to reverse these trends, and quality teaching is driven by quality assessment. This study presents the results of an effort to develop a quality assessment approach for *scientific argumentation*.

Review of the Literature

Argumentation as a reasoning process has been defined by Toulmin (1984) as consisting of six parts. Argumentation centers on a <u>claim</u>, a position being taken. There is <u>evidence</u> (or *grounds*) that support the claim. There is a link between the evidence and the claim. Toulmin refers to this <u>chain of reasoning</u> as a *warrant*. The quality and type of the reasoning involved in that chain or reasoning is <u>backing</u>. Arguments include a <u>rebuttal</u> (or reservations) that identify exceptions to the claim or present counter-arguments. Finally, the claim itself might include <u>qualifiers</u>, explicit limits or conditions that are part of the presented
claim.

Using this conceptual framework, Bulgren and Ellis (2014) identified aspects of argumentation specific to science suggested in the literature (e.g.,Duschl & Osborne, 2002; Jimenez-Alexandre & Erduran, 2007; Khine, 2012; Sadler, 2004; Sandoval & Millwood, 2007), especially following the recommendations of Driver, Newton, & Osborne, (2000) who noted the need to emphasize the correctness of judgments about arguments in addition to the structure of an argument.

Scientific argumentation was defined by Bulgren and Ellis as a practice with these components:

- identifying a claim as presented in a written document or inquiry activity and analyzing the claim for *qualifiers*;
- identifying evidence, labeling the type of evidence, and judging the quality of the evidence;
- identifying the reasoning that led to the claim, labeling the type of reasoning and judging the quality of the reasoning;
- presenting rebuttals or counterarguments; and

- drawing a conclusion about the claim, and explaining the reasoning that supported the conclusion.

Bulgren, Ellis, and Marquis (2012) collaborated with science teachers and demonstrated that an instructional procedure including graphic devices that were strategically tied to these scientific argumentation components was very effective for middle-school science students. Classrooms implementing this approach performed much better in evaluating scientific claims and arguments compared to traditional classrooms.

There are a few assessments available for researchers or classroom use that measure critical thinking skills or rhetorical analytical abilities that are somewhat similar to scientific argumentation (Ennis , 2000). These assessments tend to be general-content critical thinking tests using content from a number of subject matter areas or everyday life, or multi-aspect critical thinking tests that assess more than one aspect of critical thinking. Others require scoring by experts or trained assessors of lengthy written responses. A third type of instrument is designed to assess respondents' syllogistic, logical reasoning ability. While the best of these approaches might capture some aspect of scientific argumentation, no measures of scientific argumentation as defined by Toulmin's (1984) theoretical framework (or otherwise) are available. Further, few of the existing assessment approaches for measuring the related constructs described here are practical for use by classroom teachers and most researchers because of the administration time, cost (some of these measures are only commercially available) or scoring requirements. Therefore, there is a need for a teacher-friendly and valid test of scientific argumentation, and the present study presents a new instrument to meet that need, the *Test of Scientific Argumentation*.

Methods

The development of the *Test of Scientific Argumentation* coincided with the stages of development for an online multiplayer game for middle school science students. The game, *Reason Racer*, was the result of a *National Science Foundation* grant-funded project to produce a game with specific game features in order to engage middle school students in introductory knowledge of and thinking related to scientific argumentation (Ault, Craig-Hare, Frey, Ellis & Bulgren, in press). Bulgren and Ellis' (2014) framework was used to identify the specific instructional objectives and outcomes for the game.

Though *Reason Racer* itself included mini-assessments (along with other indicators) as part of the competitive game play aspect of the activity, a broader measure of scientific argumentation skill was needed to assess the effectiveness of the game. The purpose of the measure, however, went beyond the evaluation needs of the grant. The goal was to create a generalizable instrument that would be useful and practical for secondary-level science teachers, as well as researchers and program evaluators interested in assessing scientific argumentation.

Table of Specifications

A table of content specifications was produced for the measure that paralleled the Bulgren and Ellis (2012) scientific argumentation framework (with its key components of claims, qualifiers, evidence and reasoning, and so on) that had also been used in the *Reason*

Racer game. Because the game developed in two iterations, so did the test. At the end of stage one, a version of the game was completed and its effectiveness evaluated using a pilot version of the scientific argumentation instrument. This version of both the game and the test included some, but not all of the critical skills of scientific argumentation. Included in this first version of the test were items meant to measure:

- the ability to distinguish among a *claim*, *fact* and *opinion*,
- the ability to distinguish among *authority*, *logic* and *theory* as possible reasons one accepts a claim, and
- the ability to identify *qualifiers* in a claim.

After this first stage of the game and the test were evaluated, additional components were added to the game activities, and additional sections were added to the test, in order to fully capture all the critical aspects of scientific argumentation. These additions and changes were made to the table of specifications for the content of the final version of the test:

- questions were added assessing the ability to distinguish between *rebuttal* and *counter-argument*
- questions were added assessing the ability to evaluate the strength or *quality of reasoning* used when judging a claim
- *data* was added as a fourth option when distinguishing among *claim*, *fact* and *opinion,* and,
- a stand-alone section was added assessing the ability to identify whether a statement is a *claim* or *not a claim*.

Construct Definition
        The definition of *scientific argumentation* that guided the development of this measure is that provided by Bulgren and Ellis as an extension of Toulmin's (1984) construct of *argumentation.* It is described earlier. The terms used in describing the critical components of scientific argumentation were defined as concretely as possible by the research team. These definitions guided item development and appeared in test directions, along with examples. They are shown in Table 1.

Table 1

Construct Definitions Used in Test Development

Term	Definition
claim	*A statement about the natural world based on scientific observation intended to persuade another person* Claims often describe the relationship among two or more variables.
fact	*Something that is observable* Facts describe reality.
opinion	*A personal belief that may or may not be based in fact* A view or judgment that individuals form about something

data   *Observations of an object or event that are quantifiable or qualitative*
                Data can be expressed as numbers or words.

qualifier   *Important word or short phrase used in a claim to narrow the focus of the claim*
                A word or phrase that increases or decreases the quality (or "amount") of ideas or
                things.

authority   *A trusted source of information*
                If you believe a claim because of authority, it means you trust the source of the
                claim because of their reputation, expertise or your trust in them.

logic   *A set of rational rules for making reasonable conclusions*
                If you believe a claim because of logic, it means that you have concluded it's true
                after examining the claim using careful thought and reason.

theory   *Generalized organized statements which explain natural phenomena*
                If you believe a claim because of theory, it means you have applied a scientific,
                technical explanation of how or why something might happen.

rebuttal   *A statement that a claim is wrong based on evidence and reasoning.*
                Rebuttals disagree with a claim, but do <u>not</u> make a new claim.

counter-   *An alternative claim based on reasoning and evidence.*
argument   Counter-arguments make a new claim which disagrees with the first claim.

quality of   *The degree to which evidence and logic supports a claim.*
reasoning   Reasoning is a <u>chain</u> of related thoughts or statements. Each chain of reasoning
                ends with a conclusion. With good reasoning, the "links" in the chain support the
                conclusion. The underlying reasoning can be based on authority, logic or theory.

Item Development

The development, pilot testing, and analysis of items, their revision and placement into subscales occurred at two different points in time focusing on different parts of the instrument. However, the general sequence of events for item-writing, analysis of item characteristics and ultimate item selection was essentially the same.

Content experts were trained and asked to write an initial pool of items. For phase one, the experts were a small number of middle school science teachers. This initial pool of items was edited by a member of the research team with test development expertise. Next, those 110 items were then rated independently by two other members of the research team with knowledge of Toulmin's view of argumentation. Fifty-six items were rated by both experts as providing "good examples" of the intended construct (e.g. a claim, logic, authority, finding, theory, etc.). They

were selected for pilot testing. For phase two, items were written by the three members of the research team who had been involved in phase one (the test development expert and the two scientific argumentation experts). As with phase one, these 60 new items were vetted by the scientific argumentation experts (they did not rate their own items). The 43 items rated as "definitely an example" of the intended construct were retained.

Pilot Testing

Items which were retained after expert review were administered online to samples of middle school science students for analysis. Items developed during phase one were given to about 1100 students. Difficulty indices (the proportion of students getting an item correct) were computed for all items and reliability analyses were conducted to identify items which would work well together on their intended subscales. This first phase was for an intended test with three subscales (*Claim, Fact or Opinion*; *Authority, Logic or Theory*; *Qualifiers*) and 30 items were chosen which reliably assessed those three components of scientific argumentation. Phase two pilot testing added 43 new items (for the three new subscales covering three additional components) to the refined pool of 30 from phase one. Because the *Claim, Fact or Opinion* subscale was reformatted to include a fourth alternative, *Data*, this necessitated the replacement of two items from the original subscale with items from the new pool for which *data* was the correct answer. Consequently, 71 items were administered in phase two to a fresh sample of 83 middle school science students. To reflect an authentic classroom experience, this time the test was administered in a paper-and-pencil format and hand-scored. Fifty-four of these students also took the *Cornell Critical Thinking Test, Form X* (Ennis, Millman & Tomko, 2005), a commonly used measure of analytic reasoning, as a validity check. One would expect moderate correlations between scores from the two tests.

Results

The goal of test development was to produce an instrument which would provide a reliable and valid measure of the ability to engage in scientific argumentation for both practical classroom use and for use by researchers. For practical classroom use, a test must be as short as possible, without sacrificing reliability. As the larger pool of items had been developed using a procedure that would promote validity, the emphasis at the item analysis stage was on reliability. All six subscales, and their associated items, were analyzed using an iterative process designed to produce subscales with as high a reliability coefficient (coefficient alpha) as possible. With the competing goal of having as few items as necessary on each subscale, an objective of a 36-item instrument with six 6-item subscales was chosen.

Descriptive statistics from the sample of middle school science students, reliability (as estimated by coefficient alpha) and correlations with the *Cornell Critical Thinking Test* were calculated and are shown in Table 2.

Table 2

Descriptive Statistics, Reliability and Validity for the Test of Scientific Argumentation

	Number	Reliability	Validity

	of Items	Mean	SD	Coefficient	Coefficient[1]
Full Scale	36	.68	.22	.82	.59**
Claim, Fact, Opinion, or Data subscale	6	.74	.23	.49	.40**
Qualifiers subscale	6	.84	.28	.87	.45**
Authority, Logic, or Theory subscale	6	.61	.30	.70	.28*
Rebuttal or Counterargument subscale	6	.54	.29	.62	.20
Claim or Not a Claim subscale	6	.72	.35	.88	.34*
Quality of Reasoning subscale	6	.71	.26	.59	.55**

Note. Scores are shown as "proportion correct". N = 83 middle school science students. [1]Correlation with *Cornell Critical Thinking Test, Form X*, N = 54. *$p \leq$ .05 ** $p \leq .01$

The difficulty level for the full scale was 68%, which means that the average student in the pilot sample got 68% of the questions correct. Difficulty on the subscales ranged from 54% to 84%. The test was given to students before any instruction in scientific argumentation. Reliability, as estimated by Cronbach's coefficient alpha, for the full scale was very good, α = .82. Most of the subscales demonstrated adequate to very good reliability, with the *Claim, Fact, Opinion or Data* subscale showing poor reliability, α = .49.

Some of the students took the *Cornell Critical Thinking Test* concurrently with the *Test of Scientific Argumentation*. Scores from the *Cornell* were correlated with full-scale and subscale scores as an indication of whether the two measures assess similar constructs. The correlation between the full-scale *Test of Scientific Argumentation* and the *Cornell* was moderate (r = .59, N = 54, $p \leq$ .001). Correlations between the *Cornell* and subscale scores ranged from small (r = .20, non-significant) to moderate (r = .55, $p \leq$ .001).

Discussion

The *Test of Scientific Argumentation* appears to be a reliable and valid instrument for assessing the skill of scientific argumentation. Its design, choices made during development, and analysis of pilot data provide support for this.

Reliability
The item format, multiple-choice questions, allows for objective scoring which promotes score reliability. Reliability estimates using pilot data suggest that the test and several of its subscales produce reliable scores. The total score was very reliable (*Scientific Argumentation* = .82), as were two subscale scores (*Claim or Not a Claim* =.88, *Qualifiers* = .87). Other subscale scores, however, produced much lower reliability coefficients (.70, 62, .59, and .49). This suggests that the total score is a useful indicator for both classroom use and research use. It should produce scores precise enough to measure change over time or to observe differences between groups. For classroom use, where the test's purpose might be to make decisions about individual students, the full score and the *Claim or Not a Claim* and *Qualifiers* subscales may be used as stand-alone indicators. The other subscales, however, should probably only be used by

themselves for group evaluation, as is the case for most researchers, and is often the case for teachers. Subscales and the total test could have been made more reliable by including more items on the measure, but a longer test would have been less practically useful for classroom teachers.

Validity

Validity refers to the extent to which a test is useful for its intended purpose. The intended purpose for the *Test of Scientific Argumentation* was as a practical assessment of scientific argumentation for secondary-level science students.

Several lines of evidence suggest that the final instrument meets that purpose. First, the underlying construct meant to be reflected in the items was well-defined and driven by a comprehensive theoretical framework. Toulmin's theory of *argumentation* as a generalized process with several critical components (Toulmin, 2003; Toulmin, Rieke & Janik, 1984) applied specifically to *scientific argumentation* by Bulgren and Ellis (2014) provided a coherent structure for identification of necessary subscales and for item development. Second, items were written by content experts. Middle school science teachers and scholars in scientific argumentation wrote and vetted all questions. Third, the pilot data used for final item choice and instrument revision was collected from a sample which represented the intended primary population for the measure (secondary-level science students untrained in scientific argumentation). Fourth, data from that sample suggest that the *Test of Scientific Argumentation* produces reliable scores. This supports validity, as scores which are substantially random cannot assess any underlying construct. Finally, scores from the *Test* correlate with an existing well-researched instrument (*Cornell Critical Thinking Test*) which measures a similar construct.

An additional validity argument for the *Test of Scientific Argumentation* comes from its use as part of an evaluation of the educational online game, *Reason Racer* (Ault, Craig-Hare, Frey, Ellis & Bulgren, in press). An earlier form of the test, which contained just three subscales (*Claim, Fact, or Opinion*; *Qualifiers*; *Authority, Logic or Theory*) was used as the primary dependent variable in a study of the effectiveness of the game in terms of increasing scientific argumentation as an ability. Scores on the measure were increased significantly. This suggests that those three subscales do assess the underlying construct of scientific argumentation that the intervention was designed to affect.

Recommendations

The *Test of Scientific Argumentation* is shown in the Appendix. It is recommended for use by classroom teachers, program evaluators and researchers. It was designed primarily for secondary-level science teachers who need a practical, brief, but reliable, and valid assessment of scientific argumentation they can use to evaluate their students and the effectiveness of their own teaching. Scientific argumentation is a key critical thinking skill emphasized in national teaching standards and in *Common Core*. The *Test of Scientific Argumentation* is also suitable for research and evaluation use. The total scale, and several subscales by themselves, are reliable enough to analyze change and group differences and the instrument was derived from a coherent theory.

The theoretical foundation and statistical evidence support the *Test of Scientific Argumentation* as a valid and reliable instrument for use by science educators and researchers.

References

Ault, M., Craig-Hare, J., Frey, B., Ellis, J., & Bulgren, J. (In Press). The effectiveness of *Reason Racer*, a game designed to engage middle school students in scientific argumentation. *Journal of Research on Technology in Education.*

Bulgren, J.A., & Ellis, J.D. (2012). Argumentation and evaluation intervention in science classes: Teaching and learning with Toulmin. In M.S. Kline (Ed.), *Perspectives on scientific argumentation: Theory, practice, and research* (pp. 135-154). New York, NY: Springer.

Bulgren, J., Ellis, J., Marquis, J. (2014) The use and effectiveness of an argumentation and evaluation intervention in science classes. *Journal of Science Education and Technology*, *23*(1), 82-97.

Conley, D. T. (2008*). College knowledge: What it really takes for students to succeed and what we can do to get them ready*. New York, NY: John Wiley & Sons.

Driver, R., Newton, P., & Osborne, D. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*, 39-72.

Ennis, R. H. (2009). *An annotated list of critical thinking tests.* Retrieved from www.criticalthinking.net/TestListRevised11-27-09.pdf

Ennis, R. H., Millman, J., & Tomko, T. N. (2005). *Cornell critical thinking tests administration manual.* Pacific orove, CA: Midwest Publications.

Erduran S, and Jimenez-Alexandre M P (2008) *Argumentation in science education*: *Perspectives from classroom-based research*. New York, NY: Springer.

Heller, R., & Greenleaf, C. (2007). *Literacy instruction in the content areas: Getting to the core of middle and high school improvement.* Washington, DC: Alliance for Excellent Education.

Jimenez-Alexandre, M. P., & Erduran, S. (2007). Argumentation in science education: An overview. *Contemporary Trends and Issues in Science Education, 35*(1), 915-933.

Khine, M. S. (2012). *Perspectives on scientific argumentation.* New York, NY: Springer.

Lawson, A.E. (2003). The nature and development of hypothetico-predictive argumentation with implications for science teaching. *International Journal of Science Education, 25*(11), 1387-1408.

National Center for Education Statistics (2012). *The Nation's Report Card: Science 2011 (NCES 2012–465).* Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Governors Association. (2010). *Common core state standards for English language arts & literacy in history/social studies, science, and technical subjects*. Washington, DC:National Governors Association Center for Best Practices and the Council of Chief State School Officers.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices,Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.*Washington, DC: National Academies Press.

Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013).Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching*, *50*(3), 315-347.

Sandoval, W. A., & Millwood, K. A. (2007). What can argumentation tell us about epistemology?. In S. Erduran and M. P.Jiménez-Aleixandre (Eds). *Argumentation in science education* (pp. 71-88). Springer Netherlands.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research on Science Teaching, 4,* 513-536.

Toulmin, S. (2003). *The uses of argument*. Cambridge, UK: Cambridge University Press.

Toulmin, S., Rieke, R., & Janik, A. (1984). *An introduction to reasoning.* Upper Saddle Ridge, NJ: Prentice Hall.

Appendix
Test of Scientific Argumentation

These questions are all about science. They aren't questions to find out how much people know, but they are questions about the way people talk and write when they are being scientists. For each set of questions, we will give you definitions of some science words. Use these definitions and follow all the directions when answering the questions.

Definitions

claim	*A statement about the natural world based on scientific observation intended to persuade another person* Claims often describe the relationship among two or more variables. **Example: A lack of sleep has caused obesity in American teenagers.**
fact	*Something that is observable* Facts describe reality. **Example: The earth is 93,000,000 miles from the Sun.**
opinion	*A personal belief that may or may not be based in fact* A view or judgment that individuals form about something **Example: Our principal said that too much testing in schools is bad for students.**
data	*Observations of an object or event that are quantifiable or qualitative* Data can be expressed as numbers or words. **Example: The obese teenagers in the study slept less at night than other teenagers.**

In science, statements can be claims, facts, opinions or data. For each of the statements below, circle whether it is a claim, fact, opinion or data. Important: For this test, you don't need to know whether a statement is <u>actually true</u>; just decide if the statement is <u>stated</u> as a fact, claim, opinion, or data.

1. Sound is a mechanical wave.	claim	fact	opinion	data
2. *Colgate* toothpaste will increase enamel density.	claim	fact	opinion	data
3. A diet high in whole grains will lead to a healthier heart.	claim	fact	opinion	data
4. Gravity pulls objects towards the center of mass.	claim	fact	opinion	data
5. A recent typhoon in the Philippines had wind speeds as high as 235 miles per hour.	claim	fact	opinion	data
6. I believe teenage drivers should not be allowed to use cell phones.	claim	fact	opinion	data

Definition

qualifier	*Important word or short phrase used in a claim to narrow the focus of the claim* A word or phrase that increases or decreases the quality (or "amount") of ideas or things. Examples: *very, some, partly, almost, kind of* Example of a claim with a qualifier: Friction is **usually** a negative force.

In each statement below, circle the qualifier.

Be sure to circle only the word or short phrase that is the qualifier, not the words around it.

7. The recent changes in climate are probably due to humans' use of carbon-based fuels.
8. Almost all obese teenagers are sleep deprived.
9. Dumping medical waste into rivers can sometimes lead to gender imbalance in frogs.
10. Some frogs will change their sex when they are placed in a single-sex population.
11. Some dogs make good hunters.
12. The removal of topsoil usually doesn't allow for successful farming.

Definition

claim	*A statement about the natural world based on scientific observation intended to persuade another person* Claims often describe the relationship among two or more variables. **Example: A lack of sleep has caused obesity in American teenagers.**

For each of the statements below, circle whether it is a claim or not a claim.

13. Mars orbits the sun in 687 days.	Claim	Not a Claim
14. The hardest element is carbon in the form of a diamond.	Claim	Not a Claim
15. Students who study more tend to get higher grades.	Claim	Not a Claim
16. At birth, the human body contains several billion cells.	Claim	Not a Claim
17. Neon atoms contain ten protons and ten electrons.	Claim	Not a Claim
18. Listening to classical music helps preschoolers learn more quickly.	Claim	Not a Claim

Definitions

authority	*A trusted source of information* If you believe a claim because of authority, it means you trust the source of the claim because of their reputation, expertise or your trust in them. <u>Example of a Claim Supported by Authority</u> **A good breakfast probably leads to a greater ability to focus. I believe this because the American Medical Association says that the lack of a good breakfast causes an inability to concentrate.**
logic	*A set of rational rules for making reasonable conclusions* If you believe a claim because of logic, it means that you have concluded it's true after examining the claim using careful thought and reason. <u>Example of a Claim Supported by Logic</u> **Salt intake likely causes high blood pressure. I believe this because those with high salt content have higher blood pressure than those with low salt content even if they are equal on other possible causes such as age and weight.**
theory	*Generalized organized statements which explain natural phenomena* If you believe a claim because of theory, it means you have applied a scientific, technical explanation of how or why something might happen. <u>Example of a Claim Supported by Theory</u> **Seafloor spreading caused continental drift. I believe this because if the seafloor spread, it would produce enough force and produce enough material to move the land masses, as well.**

Thinking like a scientist, you might believe a claim for many different reasons:

- You might believe something because an **authority** says so.
- You might believe something because **logic** supports your belief.
- You might believe something because a **theory** supports the belief.

These are all good reasons for believing something. For each set of statements below, circle whether the scientist believes the claim because of **authority**, **logic** or **theory**. The scientist might believe something for many different reasons, but which reason does the scientist give?

19. Wetlands are a necessary part of many environments. I believe this because wetlands support different types of organisms, provide a place for migrating birds to rest and feed, and provide water for the animals living in the surrounding area to come and drink.	authority	logic	theory
20. Video games condition children to violence and cause them to act more violently in real life. I believe this because according to the *American Psychological Association*, children who are overexposed to violent video games are more likely to develop violent tendencies than those who are not.	authority	logic	theory
21. Eating genetically modified organisms may cause	authority	logic	theory

	diseases. I believe this because the World Health Organization cites the possibility of gene transfer from genetically modified organisms to the digestive tract or intestinal flora of humans as a possible health concern.	

authority	*A trusted source of information* If you believe a claim because of authority, it means you trust the source of the claim because of their reputation, expertise or your trust in them. <u>Example of a Claim Supported by Authority</u> **A good breakfast probably leads to a greater ability to focus. I believe this because the American Medical Association says that the lack of a good breakfast causes an inability to concentrate.**
logic	*A set of rational rules for making reasonable conclusions* If you believe a claim because of logic, it means that you have concluded it's true after examining the claim using careful thought and reason. <u>Example of a Claim Supported by Logic</u> **Salt intake likely causes high blood pressure. I believe this because those with high salt content have higher blood pressure than those with low salt content even if they are equal on other possible causes such as age and weight.**
theory	*Generalized organized statements which explain natural phenomena* If you believe a claim because of theory, it means you have applied a scientific, technical explanation of how or why something might happen. <u>Example of a Claim Supported by Theory</u> **Seafloor spreading caused continental drift. I believe this because if the seafloor spread, it would produce enough force and produce enough material to move the land masses, as well.**

Thinking like a scientist, you might believe a claim for many different reasons:

- You might believe something because an **authority** says so.
- You might believe something because **logic** supports your belief.
- You might believe something because a **theory** supports the belief.

These are all good reasons for believing something. For each set of statements below, circle whether the scientist believes the claim because of **authority**, **logic** or **theory**. The scientist might believe something for many different reasons, but which reason does the scientist give?

22. The use of a tablet computer reduces the risk of carpal tunnel syndrome. I believe this because I read it in an editorial in the *Journal of Medicine.*	authority	logic	theory
23. People that eat the recommended amount of fiber are at less risk of heart disease. I believe this because cholesterol can clog arteries and lead to heart disease. It is thought that soluble fiber can soak up cholesterol, allowing the body to get rid of some of it.	authority	logic	theory

24. Electric cars are more dangerous than gasoline-powered cars. I believe this because electric cars are built of lighter-weight material. Lighter-weight materials do not protect the driver well in accidents. That lack of protection will lead to more injuries.	authority logic theory

Definitions

Rebuttal	*A statement that a claim is wrong based on evidence and reasoning.* Rebuttals disagree with a claim, but do <u>not</u> make a new claim. <u>Example of a Claim and a Rebuttal</u> **Claim: A lack of sleep has caused obesity in American teenagers.** **Rebuttal: There is actually only a small relationship between obesity and amount of sleep.**
Counter-Argument	*An alternative claim based on reasoning and evidence.* Counter-arguments make a new claim which disagrees with the first claim. <u>Example of a Claim and a Counter-Argument</u> **Claim: A lack of sleep has caused obesity in American teenagers.** **Counter-Argument: Obesity causes the lack of sleep in American teenagers.**

For each pair of statements below, there is a claim and a response. Circle whether each response is a **rebuttal** or a **counter-argument.**

25. **Claim:** The latest flu outbreak will cause economic problems because of the cost of the vaccine. *Vaccines can be distributed very inexpensively.*	rebuttal counter-argument
26. **Claim:** Transplanting donor brain cells will repair traumatic brain injuries. *Intensive cognitive training has better results than transplanting brain cells in repairing brain injuries.*	rebuttal counter-argument
27. **Claim:** Objects always fall at a rate of acceleration equal to 9.8 meters/second/second. *A skydiver with a parachute falls slower than that.*	rebuttal counter-argument
28. **Claim:** Soil, light, water, and air are required for plants to grow. *Plants grow in the deep ocean where there is little light.*	rebuttal counter-argument
29. **Claim:** The four seasons are caused by the change in distance from the earth to the sun during earth's orbit around the sun. *It is the tilt of the earth on its axis as it orbits the sun which causes the four seasons.*	rebuttal counter-argument
30. **Claim:** Heavy objects sink in water.	rebuttal counter-argument

| *Ships weigh many tons and they float.* | |

Definition

	The degree to which evidence and logic supports a claim. Reasoning is a <u>chain</u> of related thoughts or statements. Each chain of reasoning ends with a conclusion. With good reasoning, the "links" in the chain support the conclusion. The underlying reasoning can be based on authority, logic or theory. **Example of a good or strong chain of reasoning:** I've raised many fish over the years. Every time I have forgotten to feed them for a couple weeks, they have died. Therefore, it is likely that goldfish need food to live. **Example of a bad or weak chain of reasoning:** Researchers found that giving mice double the dose of a drug could cure a form of bone cancer. The study included 871 mice. So, this treatment will likely work on humans.
Quality of Reasoning	

For each chain of reasoning, indicate whether the quality of reasoning is **strong** or **weak.** Use your best judgment.

31. Studies have shown that parents and children get on each other's nerves more as the children get older. These studies surveyed thousands of parents and their children. Therefore, short conversations, particularly between mothers and daughters, should replace longer conversations.	Strong	Weak
32. The velocity of a rolling tennis ball gradually decreases. Newton's theory says that an object in motion stays in motion with the same speed unless acted upon by an unbalanced force. Friction is a force. So, it is probably friction that slows down the tennis ball.	Strong	Weak
33. Mrs. Washington's class worked in three groups to test how fertilizer affects plant growth. Each group planted 10 plants in containers. One used no fertilizer, one used a small amount of fertilizer, and one used a lot of fertilizer. They found that those plants with a small amount of fertilizer grew biggest. So, the class concluded that fertilizer containing iron worked better than fertilizer containing nitrogen.	Strong	Weak
34. Kelly did an experiment and flipped a penny nine times. The first three times the penny turned up tails, the next three times the penny turned up heads, and on the last three flips the penny turned up tails. Kelly saw the pattern and concluded that on the next flip the penny would be most likely to turn up heads.	Strong	Weak
35. Last year, a large percentage of car crashes were caused by the driver using a cell phone. Also, surveys find that most drivers admit that they are distracted while driving and using their phones.	Strong	Weak

Therefore, using cell phones while driving is dangerous.	
36. A friend of yours on Facebook posts that an inventor has created a new technology that when attached to the gas line of a car will double your gas mileage. The inventor says that the reason that the device hasn't been available before now is because major gasoline companies have prevented the information from getting to the public. You decide that the device probably works.	Strong Weak

Thank you for your work!

Test of Scientific Argumentation

Answer Key

Items are scored 0/1 for right/wrong.

1. Fact

2. Claim

3. Claim

4. Fact

5. Data

6. Opinion

7. probably

8. almost

9. sometimes

10. some

11. some

12. usually

13. Not a Claim

14. Not a Claim

15. Claim

16. Not a Claim

17. Not a Claim

18. Claim

19. Logic

20. Authority

21. Authority

22. Authority

23. Theory

24. Logic

25. Rebuttal

26. Counter-argument

27. Rebuttal

28. Rebuttal

29. Counter-argument

30. Rebuttal

31. Weak

32. Strong

33. Weak

34. Weak

35. Strong

36. Weak