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Understanding the Nature of Chemistry and Argumentation: the Case of Pre-service Chemistry Teachers

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ABSTRACT

The incorporation of perspectives from the philosophy of science in science education has been advocated for several decades (e.g. Duschl, 1990). Yet the overlap of science education research with revived efforts in the application of philosophy of science to science education has been minimal (Kauffman, 1989). For instance, minimal attention has been paid to how disciplinary orientations to knowledge and knowledge construction particularly as suggested by specific philosophies of science can contribute to the theory and practice of science education (Erduran, 2001). Within this framework, it is not surprising that chemical education literature has barely addressed the applications of philosophy of chemistry in chemical education (e.g. Erduran&Scerri, 2002). Argumentation studies, on the other hand, have emerged as a key area of research in science education in recent years (e.g. Erduran& Jimenez-Aleixandre, 2008) emphasizing the role of theory and evidence in the justification of knowledge claims of science. In this paper, we aim to bring together these two distinct bodies of literature in order to investigate domain-specific ways of reasoning and argumentation in science, particularly focusing on the patterns for pre-service chemistry teachers. We illustrate an empirical study conducted with 114 pre-service teachers from various subject areas using questionnaires on the NOS and argumentation. Our analysis illustrates comparisons of different cohorts of pre-service science teachers with respect to their understandings of NOS and argumentation. The results indicate that there are significant correlations between some aspects of NOS (e.g. nature of scientific knowledge) and argumentation for chemistry pre-service teachers.

KEYWORDS: The Nature of Chemistry, Argumentation, Pre-service Chemistry Teachers

Kimyanın Doğası ve Argümantasyonu Anlama: Kimya Öğretmen Adayları ile bir Durum Çalışması

ÖZET

Son yıllarda, bilim felsefesine dayalı bakış açılarının bilim eğitimi ile birleştirilmesi savunulmaktadır. (örn; Duschl, 1990). Fakat bilim eğitimindeki araştırmaların bilim eğitiminde bilim felsefesinin uygulaması ile örtüşmesi minimum seviyede kalmıştır

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(Kauffman, 1989). Örneğin özellikle belirli bilim felsefelerinin önerdiği gibi disiplinlerin bilgi ve bilginin yapılanmasına yönelimlerinin bilim eğitimindeki teori ve uygulamalara nasıl katkı sağlayabileceğine daha az düzeyde dikkat edilmiştir (Erduran, 2001). Bu çerçevede, kimya eğitimi alan yazınının kimya felsefesinin kimya eğitimindeki uygulamalarına çok az değinmesi şaşırtıcı değildir (örn; Erduran & Scerri, 2002). Diğer yandan, son yıllarda teori ve kanıtın bilimde bilgi iddialarının doğrulanmasındaki rolünü vurgulayan argümantasyon çalışmaları, bilim eğitiminde anahtar bir araştırma alanı olarak ortaya çıkmıştır (örn; Erduran & Jimenez-Aleixandre, 2008). Bu çalışmada, bilimde argümantasyon ve alana özel akıl yürütme yollarını özellikle kimya öğretmen adaylarına özgü kalıplara odaklanarak incelemek için, bu iki ayrı alan yazını bir araya getirmeyi amaçladık. Farklı alanlardan gelen 114 öğretmen adayından Bilimin Doğası ve Argümantasyon anketleri aracılığı ile topladığımız veriler ile bu deneysel çalışmayı açıklamaya çalıştık. Analizlerimiz farklı gruplardaki öğretmen adaylarının bilimin doğasını ve argümantasyonu anlamalarının kıyaslanmasını göstermektedir. Çalışmanın sonuçları kimya öğretmen adayları için bilimin doğasındaki bazı faktörler ile (örneğin bilimsel bilginin doğası) argümantasyon arasında anlamlı bir korelasyonun bulunduğunu göstermiştir.

ANAHTAR KELİMELER: Kimyanın Doğası, Argümantasyon, Kimya Öğretmen Adayları

INTRODUCTION

We have argued on numerous occasions that chemical education theory and practice would benefit from perspectives on chemical knowledge including argumentation (e.g. Erduran, 2007). The main thesis underlying these arguments is that the applications of "Nature of Science" (NOS) perspectives in science education have not captured sufficiently the premises of the study of domain-specific aspects of science. This observation is not surprising. As the key discipline informing NOS in science education, philosophy of science itself has been, on the whole, rather domain-general in its approaches to scientific knowledge. The foundations of philosophy of science were set by individuals who focused on physics in their analyses of science (e.g. Carnap, 1928/1967; Hempel, 1965) favouring the unification of the sciences through a set of common explanatory frameworks. In this paper, we argue that philosophy of chemistry, the relatively new sub-branch of philosophy of science, holds the potential to inform the theoretical and practical bases of chemical education. In particular, we wish to advance the position that domain-specific approaches to science education can elucidate useful information for improving science education. For instance, how knowledge claims are substantiated through reasoned evidence – ie. argumentation - in a particular knowledge domain could, in principle, provide some indicators for structuring argumentation practices in the classroom.

REVIEW OF LITERATURE

Nature of Chemistry: Perspectives from Philosophy of Chemistry

Numerous philosophers of science (Scerri & McIntyre, 1997; van Brakel, 1994) are challenging the perspective that physics can serve as an exemplar in describing knowledge in other sciences. There is growing support that chemistry deserves a distinct epistemology (Scerri & MyIntyre, 1997; van Brakel, 2000). A new field, philosophy of chemistry, has emerged since the mid 1990s (Bhushan & Rosenfeld, 2000). In light of these developments in philosophy of science, the following questions can be asked. As chemical educators, how do our definitions of chemical knowledge compare to those recently raised by philosophers of chemistry? How are we defining chemical knowledge for the classroom? What chemical knowledge do we want teachers and students to learn? What are some other aspects of chemical practices that should be prioritised for teaching and learning? These questions are not only critical to ask at a time when scholarship in chemical epistemology is increasing but they also offer an exciting challenge in application to everyday classrooms. One could consider the applicability of philosophical concepts in the formulation of research questions in chemical education and the interpretation of empirical data that are collected from school-based research contexts. The issue then becomes, how can philosophy of chemistry enrich the theoretical and empirical study of education? For example in our recent work on argumentation (Erduran et al., 2004), we have used the scheme developed by philosopher Stephen Toulmin (1958) for the coding of verbal data from classroom conversations and student group discussions. In other words, the philosophical framework on argument has been applied to discourse analysis of empirical data from the classroom. The translation of theoretical ideas such as 'claim' or 'warrant' from Toulmin's framework such that they can be reliably identifiable in empirical data has been a critically challenging component of our work. In a similar fashion, the applications of philosophy of chemistry in chemical education research are bound to be full of challenges but also exciting new territories.

Argumentation and Science Education

In the past decades, science education researchers have placed strong emphasis to the role of argumentation in science teaching and learning (e.g. Erduran & Jimenez-Aleixandre, 2008). Argumentation, the processes of justification of claims with evidence (Toulmin, 1958) has been promoted as part of conceptual and epistemic goals of science learning (Duschl & Osborne, 2002). There is evidence that engaging in argumentation discourse is an effective way for students' development of conceptual understanding in science (Driver, Newton, & Osborne, 2000; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; von Aufschnaiter, Erduran, Osborne & Simon, 2008). Students' perceptions of science are influential in their learning and achievement in science (Koballa, Crawley, & Shrigley, 1990). Some research indicated that there is a relationship between students' attitudes towards school science and their learning or achievement in science (e.g., Simpson & Oliver, 1990; Osborne, Simon, & Collins, 2003). The factors affecting students' perceptions of science might be also thought as parts of discourse in the classroom because Gee (1990) defines Discourse with "big D" as the combination of language with other social practices. In a classroom environment, encouraging students' involvement in discourse of questioning, justifying, and evaluating both their and others' explanations could support construction of knowledge in their mind (Duschl & Osborne, 2002). The implication is that students should be supported in their involvement of classroom scientific discourse in an active way. There is limited understanding of how students' perceptions of argumentative discourse is related to their understanding and construction of arguments (e.g. Kaya, Erduran & Cetin, 2010). In addition, while substantial research focused on qualitative analyses of argumentation, there is an inadequacy of research conducted using quantitative methods on argumentation in the literature (Erduran, 2008).

The purpose of this paper is to illustrate what a particular group of learners (ie. student teachers or pre-service teachers) themselves understand of NOS and argumentation. The case for incorporating chemical epistemology in teacher education has been argued elsewhere (e.g. Erduran, Aduriz-Bravo, & Mamlok-Naaman, 2007). Our intention is to elicit if there are any differences between cohorts of pre-service teachers who are training to teach different subjects. Underlying this approach is the assumption that disciplinary orientations through the learning of the subject already make an impact in how pre-service teachers conceptualise 'science,' 'knowledge' and 'arguments.' Our position is that such differences can further be clarified with the introduction of disciplinary epistemologies so as to empower the teachers in their own understanding of their subject, which is likely to improve their classroom teaching practice (Erduran et al., 2007).

METHODOLOGY

Sample

The sample of the study was composed of 114 pre-service teachers based in several universities in Turkey (63 male, 51 female). The ages of these students were varied from 19 to 26 with a mean of 22. The major subject areas of the participants were elementary mathematics education (43.9 %), chemistry education (15.8 %), physics education (9.6 %), computer education and instructional technologies (CEIT) (30.7 %). Most of the students were in their third (36.8 %) and fourth (36.0 %) year. 1.8 % of the participants were in their first year, 20.2 % of them were in their second year, and 3.5 % of them were in their fifth year. All students participated voluntarily in this study.

Instruments

Two instruments developed by Sampson & Clark (2006) were used and they are both included at the end of this paper. The *Argumentation Test* was translated into Turkish by researchers. In order to find the reliabilty of the instrument, the test was applied to 447 students in a pilot study. The consistency in the responses among the test items was calculated by using Cronbach alpha coefficient as 0.68 which showed that the internal consistency of the insrument was sufficient.

The *Nature of Science As Arqumentation Questionnaire* (NSAAQ) involves four subscales. In the first subscale the questions are about the nature of scientific knowledge. Second subscale is related to the methods that can used to generate scientific knowledge. There are six question in each of these scales. In the third subscales there are seven questions on what counts as reliable and valid scientific knowledge. The last subscales involves seven questions adressing the social and cultural embedded nature of scientific practice.

FINDINGS

The results of both questionnaires are summarised in Table 1. CEIT students had the lowest mean of argumentation test scores whilst the other cohorts shared a similar mean. The overall NSAAQ mean scores across the different cohorts were similar. One of the outcomes of the analyses was the correlations between students' argumentation scores and their scores in each dimensions of NSAAQ. In the first category the questions were related to nature of scientific knowledge.

Table 1. *Overview of results for NSAAQ and Argumentation Test.*

Department		**N**	**Min**	**Max**	**Mean**
Elementary Math.	Argumentation	50	4	24	12.68
	NSAAQ-total	50	59	112	84.88
	NSAAQ-Scale 1	50	12	27	19.42
	NSAAQ-Scale 2	50	12	26	20.64
	NSAAQ-Scale 3	50	13	31	21.90
	NSAAQ-Scale 4	50	14	32	22.92
CEIT	Argumentation	35	3	19	9.78
	NSAAQ-total	35	58	103	80.80
	NSAAQ-Scale 1	35	12	26	19.23
	NSAAQ-Scale 2	35	14	25	19.29
	NSAAQ-Scale 3	35	7	24	18.29
	NSAAQ-Scale 4	35	16	31	23.03

Table 1. *Overview of results for NSAAQ and Argumentation Test (contd)*

Department		**N**	**Min**	**Max**	**Mean**
Physics	Argumentation	11	8	16	11.55
	NSAAQ-total	11	65	115	87.82
	NSAAQ-Scale 1	11	14	27	19.27
	NSAAQ-Scale 2	11	16	25	20.63
	NSAAQ-Scale 3	11	17	33	23.27
	NSAAQ-Scale 4	11	16	34	24.18
Chemistry	Argumentation	18	6	20	12.83
	NSAAQ-total	18	62	107	85.72
	NSAAQ-Scale 1	18	14	24	19.00
	NSAAQ-Scale 2	18	16	27	22.11
	NSAAQ-Scale 3	18	13	29	20.82
	NSAAQ-Scale 4	18	15	30	23.22

As indicated in Table 2 the correlations between the elementary mathematic education and chemistry education students' scores on argumentation test and the first subscale of NSAAQ (ie. nature of scientific knowledge) were significant.

Table 2. *Correlation between Argumentation Test Scores and NSAAQ- Scale 1 Scores with respect to the major subject areas.*

Department			Argumentation	NSAAQ-Scale 1
Elementary Math.	Argumentation	Pearson Correlation	1	,646**
		Sig.	-	,000
		N	50	50
	NSAAQ-Scale 1	Pearson Correlation	,646**	1
		Sig.	,000	-
		N	50	50
CEIT	Argumentation	Pearson Correlation	1	,340
		Sig.	-	,046
		N	35	35
	NSAAQ-Scale 1	Pearson Correlation	,340	1
		Sig.	,046	-
		N	35	35
Physics	Argumentation	Pearson Correlation	1	,265
		Sig.	-	,431
		N	11	11
	NSAAQ-Scale 1	Pearson Correlation	,265	1
		Sig.	,431	-
		N	11	11
Chemistry	Argumentation	Pearson Correlation	1	,689**
		Sig.	-	,002
		N	18	18
	NSAAQ-Scale 1	Pearson Correlation	,689**	1
		Sig.	,002	-
		N	18	18

Table 3 shows the correlation of argumentation test and second subscale of NSAAQ that is related to the methods that can used to generate scientific knowledge. The correlation is significant for only elementary mathematics education students. There were 7 questions related to validity and reliability of scientific knowledge in the third subscale.

Table 3. *Correlation between Argumentation Test Scores and NSAAQ- Scale 2 Scores with respect to the major subject areas.*

Department			Argumentation	NSAAQ-Scale 2
Elementary Math.	Argumentation	Pearson Correlation	1	,586**
		Sig.	-	,000

		N	50	50
	NSAAQ-Scale 2	Pearson Correlation	,586**	1
		Sig.	,000	-
		N	50	50
CEIT	Argumentation	Pearson Correlation	1	,353
		Sig.	-	,038
		N	35	35
	NSAAQ-Scale 2	Pearson Correlation	,353	1
		Sig.	,038	-
		N	35	35
Physics	Argumentation	Pearson Correlation	1	,727
		Sig.	-	,011
		N	11	11
	NSAAQ-Scale 2	Pearson Correlation	,727	1
		Sig.	,011	-
		N	11	11
Chemistry	Argumentation	Pearson Correlation	1	,287
		Sig.	-	,248
		N	18	18
	NSAAQ-Scale 2	Pearson Correlation	,287	1
		Sig.	,248	-
		N	18	18

As illustrated in Table 4 that correlations between the third subscale of NSAAQ and argumentation test were found to be significant for elementary mathematics education and chemistry education students. The last sub dimension involved questions related to social and cultural embedded nature of scientific practice. Hovewer the correlation between this subscale and argumentation scores of students were not found significant for any of the subject areas.

Table 4. *Correlation between Argumentation Test Scores and NSAAQ- Scale 3 Scores with respect to the major subject areas.*

Department			**Argumentation**	**NSAAQ-Scale 3**
Elementary Math.	Argumentation	Pearson Correlation	1	,668**
		Sig.	-	,000
		N	50	50
	NSAAQ-Scale 3	Pearson Correlation	,668**	1
		Sig.	,000	-
		N	50	50
CEIT	Argumentation	Pearson Correlation	1	-,075
		Sig.	-	,667
		N	35	35
	NSAAQ-Scale 3	Pearson Correlation	-,075	1
		Sig.	,667	-
		N	35	35
Physics	Argumentation	Pearson Correlation	1	,380
		Sig.	-	,249
		N	11	11
	NSAAQ-Scale 3	Pearson Correlation	,380	1

		Sig.	,249	-
		N	11	11
Chemistry	Argumentation	Pearson Correlation	1	,744**
		Sig.	-	,000
		N	18	18
	NSAAQ-Scale 3	Pearson Correlation	,744**	1
		Sig.	,000	-
		N	18	18

Table 5. *Correlation between Argumentation Test Scores and NSAAQ- Scale 4 Scores with respect to the major subject areas.*

Department			**Argumentation**	**NSAAQ-Scale 4**
Elementary Math.	Argumentation	Pearson Correlation	1	,326
		Sig.	-	,633
		N	50	50
	NSAAQ-Scale 4	Pearson Correlation	,326	1
		Sig.	,633	-
		N	50	50
CEIT	Argumentation	Pearson Correlation	1	,133
		Sig.	-	,445
		N	35	35
	NSAAQ-Scale 4	Pearson Correlation	,133	1
		Sig.	,445	-
		N	35	35
Physics	Argumentation	Pearson Correlation	1	,509
		Sig.	-	,109
		N	11	11
	NSAAQ-Scale 4	Pearson Correlation	,509	1
		Sig.	,109	-
		N	11	11
Chemistry	Argumentation	Pearson Correlation	1	,472
		Sig.	-	,048
		N	18	18
	NSAAQ-Scale 4	Pearson Correlation	,472	1
		Sig.	,048	-
		N	18	18

CONCLUSIONS

The results indicate that there were domain-specific differences between understanding of argument and NOS. With respect to preservice chemistry teachers, the correlation between argument skills and understanding nature of science was significant. The findings are consistent with the premise that there might be domain-specific differences in reasoning patterns, for instance in argumentation.

The differences between cohorts were also supported by further analyses on correlations between argumentation skills and subscales of nature of science. For instance, the first subscale of nature of science test was related to nature of scientific knowledge. For this specific subscale the correlation was found significant for preservice chemistry and elementary mathematics teachers and not significant for preservice physics and instructional technologies students. Similarly, this difference can be noticed for the students' answers in the third subscale of the NSAAQ. This subscale involves questions about what counts as reliable and valid scientific knowledge. For preservice chemistry teachers the correlation between understanding of argument and nature of science specifically validity and reliabilty of scientific knowledge was significant. For this subscale the mean score of physics teachers ($\bar{X}$ =23.3) was noticeably higher than the mean score of for chemistry teachers ($\bar{X}$ =20.8). The preservice instructional technologies students got the lowest score ($\bar{X}$ =18.2) in this subscale. An interesting finding of the study was that the last subscale of the NSAAQ which included questions related to social and cultural embedded nature of scientific practice did not show significant correlations with any student-teachers' understanding of argumentation.

Matthews (1994) has argued that teacher education program should include aspects of the nature of science (NOS) in instruction because understanding of the NOS could facilitate the implementation of conceptual change models in their instructional approaches. In light of the results of this study, it can also be suggested that student-teachers' understanding of NOS is also related to understanding of argumentation. Improvement of argumentation skills would thus require an understanding of the various dimensions of NOS. More specifically the correlation between understanding of NOS and argumentation was found to be domain- specific, providing further support that disciplinary orientations are key considerations in the teaching and learning of NOS. In reference to misconceptions in science, McComas (1998) referred to "myths of science". According to McComas, the lack of philosophy of science content in teacher education programs, inefficacy of these programs in providing real science experiences for pre-service science teachers and textbooks are some of the main sources of these misconceptions. As discussed in this paper and others (Erduran, 2001; Scerri, 2000) not emphasizing the domain-specific aspects of science in NOS applications in science education may be considered a further possible source of these misconceptions.

Our intention for future studies is to elicit with qualitative data how the argumentation patterns relate to conceptions of NOS. The study highlights a research territoryfor synthesizing perspectives on particular aspects of NOS (ie. chemical knowledge) and processes of knowledge generation and reasoning (ie. argumentation), thereby providing a theoretical rationale for domain-specificity of scientific knowledge and its learning. Exposing science teachers to epistemological perspectives on science disciplines at the very early stages of their education are likely to empower them in understanding and teaching of their subject (Erduran et al., 2007).

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Appendix 1.

ARGUMENTATION TEST

Name:______________________________________

Gender:__Age: _____________Year in School:____Language Spoken at Home:____________

Part I: Making a Scientific Argument

Introduction: Once a scientist develops an explanation for why something happens, he or she must support their claim with some type of reason. The explanation and the supporting reason is called an argument. Scientists use arguments to convince others that their claim is indeed true. How do you think scientists create a convincing argument?

Directions: The first three questions are designed to determine what you think <u>counts</u> as a good *scientific* argument. In each question you will be given a claim. Following the claim are 6 different arguments. Your job is to rank the arguments in order using the following scale:

1 = This is the **most** convincing argument
2 = This is the **2nd most** convincing argument
3 = This is the **3rd most** convincing argument
4 = This is the **4th most** convincing argument
5 = This is the **5th most** convincing argument
6 = This is the **least** convincing argument

Your task is to rank the 6 different arguments in terms of how convincing <u>you think</u> they are. *Remember that you can only rank one argument as 1, one argument as 2, one argument as 3, and so on.*

Question #1. Objects sitting in the same room often feel like they are different temperatures. Suppose someone makes the following claim about the temperature of various objects sitting in the same room, which reason makes the most convincing argument?

Claim: Objects that are in the same room are the same temperature even though they feel different because…	**Your Ranking**
…when we measured the temperature of the table, it was 23.4^{O}C, the metal chair leg was 23.1^{O}C, and the computer keyboard was 23.6^{O}C.	________
…good conductors feel different than poor conductors even though they are the same temperature.	________
…objects that are in the same environment gain or lose heat energy until everything is the same temperature. Our data form the lab proves that point: the mouse pad and plastic desk were both 23^{O}C.	________
…objects will release and hold different amounts of heat energy depending on how good of an insulator or conductor it is.	________
…the textbook says that all objects in the same room will eventually reach the same temperature.	________
…we measured the temperature of the wooden table and the chair leg and they were both 23^{O}C even though the metal chair leg feels colder. If the metal chair leg was actually colder it would have been a lower temperature when we compared it to the temperature of the table.	________

Question #2. A pendulum is a string with a weight attached to one end of it. Suppose someone makes the following claim about pendulums, which reason makes the most convincing argument?

Claim: The length of the string determines how fast a pendulum swings back and forth regardless of the weight on the end of the string because…	**Your Ranking**
…the weight on the end of a long string has a longer distance to travel when compared to a weight on a short string. As a result, pendulums with shorter swings make more swings per second than pendulum with longer strings.	________
…pendulums with different string length have different swing rates. We measured the swing rate of a pendulum with a 10 cm string and a pendulum with a 20 cm string, The 10 cm pendulum had swing rate of 2 swings per second and the 20 cm pendulum has a swing rate of 1 swing per second.	________
…a pendulum with a 14 cm string had a swing rate of 1 swing per second and a pendulum with a 15 cm string had a swing rate of 1 swing per second.	________
…a pendulum with a 10 cm string had a swing rate of 2 swings per second and a pendulum with a 15 cm string had a swing rate of 1 swing per second.	________
…our textbook says that the weight on the end of the string has nothing to do with how fast a pendulum swings.	________
…we tested the swing rate of three pendulums, one with a 10 gram weight and 10 cm string, one with a 10 gram weight and 20 cm string, and one with 20 gram weight and a 20 cm string. The two pendulums with the 20 cm string had the same swing rate (1 swing per second) and were slower the pendulum with the shorter string (2 swings per second). If the weight on the end of the string mattered these two pendulums would have had different swing rates but they were the same.	________

Question #3. Scientists often use animals in their research. Suppose someone makes the following claim about the use of animals in scientific research, which reason makes the most convincing argument?

Claim: Scientists should be allowed to use animals for research because…	**Your Ranking**
…a computer or other non animal model can be used instead.	________
…animals are susceptible to many of the same bacteria and viruses as people, such as anthrax, smallpox, and malaria. Even though animals differ from people in many ways, they also are very similar to people in many ways. An animal is chosen for research only if it shares characteristics with people that are relevant to the research.	________
…public opinion polls have consistently shown that a majority of people approve of the use of animals in biomedical research that does not cause pain to the animal and leads to new treatments and cures.	________
…animal research was essential in developing many life-saving surgical procedures once thought impossible. For example the technique of sewing blood vessels together was developed through surgeries on dogs and cats by Alexis Carrel, for which he was awarded a Nobel Prize in 1912.	________
…infecting animals with certain microbes allows researchers to identify the germs that cause different types of diseases. Once discovered scientists can develop vaccines to test the effectiveness of these vaccines without harming any people in the process.	________
…humans have 65 infectious diseases in common with dogs, 50 with cattle, 46 with sheep and goats, 42 with pigs, 35 with horses, and 26 with fowl.	________

Part II. Challenging an Argument

Introduction: Once a scientist develops an explanation for why something happens, he or she must support the explanation with there reasons for why they think their explanation is correct. The explanation along with its supporting reasons is called an argument. Sometimes other scientists agree with the argument; sometimes they do not. When they disagree, they challenge the accuracy of the argument. How do you think scientists challenge the arguments of other scientists? The last three questions on this test are designed to determine what you think counts as a good challenge to a s*cientific* argument.

Directions: In each question you will be given an argument. Following the argument are 6 different challenges. Your job is to rank the challenges using the following scale:

1 = This comment is the **strongest** challenge to this argument
2 = This comment is the **2nd strongest** challenge to this argument
3 = This comment is the **3rd strongest** challenge to this argument
4 = This comment is the **4th strongest** challenge to this argument
5 = This comment is the **5th strongest** challenge to this argument
6 = This comment is the **weakest** challenge to this argument

Question #4—Jason, Angela, Sarah, and Tim are in physics class together. Their teacher asked them to design an experiment to determine if all objects in the same room are the same temperature even though they feel different. After they designed and carried out an experiment to answer this question on their own, they met in a small group to discuss what they have found out. Suppose Jason suggests that:

"I think that all objects in the same room are always different temperatures because they feel different and when we measured the temperature of the table, it was 23.4^{O}C, the metal chair leg was 23.1^{O}C, and the computer keyboard was 23.6^{O}C."

Angela disagrees with Jason. Your task is to rank the 6 different challenges given by Angela in terms of how strong you think they are.

Angela: I disagree…	**Your Ranking**
…because your evidence does not support your claim. All of the objects that you measured were within one degree of each other. That small of difference is just measurement error.	________
…I think that all objects in the same room are the same temperature even though they feel different	________
…if those objects were really different temperatures their temperature would have been much different. For example, when I measured the temperature of my arm it was 37^{O}C while the temperature of the table was 23^{O}C that is a difference of 14 degrees. Everything else was right around 23^{O}C.	________
…I think all objects become the same temperature even though they feel different because objects that are good conductors feel colder than objects that are poor conductors because heat transfers through good conductors faster.	________
…because I know you always rush through labs and never get the right answer.	________
…I think all objects become the same temperature because the temperatures of all those objects you measured were within 1 degree.	________

Question #5—Tiffany, Steven, and Yelena are in the same science class. Their teacher asked them to design an experiment to determine what makes some objects floats and some objects sink. After they designed and carried out an experiment to answer this question on their own, they met in a small group to discuss what they have found out. Suppose Steven suggests that:

"I think heavy objects sink and light objects float. This is true because when I put the 10 gram plastic block in the tub of water it floated while the 40 gram metal block sank."

Tiffany disagrees with Steven. Your task is to rank these 6 different challenges given by Tiffany in terms of how strong you think they are.

Tiffany: I disagree…	**Your Ranking**
…because Yelena is always right and she disagrees with you.	________
…because you did not test enough objects. How can you be sure that it is the weight of an object that makes it sink or float if you only tested two things?	________
…the metal block sank because it is very dense not because it is heavy and the plastic block floated because it has density that is less than water not because it is light.	________
…because light objects can sink too. A paper clip only weighs one gram and it sinks. According to you claim all light objects should float. How can a paper clip that is lighter	________

than a piece of plastic sink while the heavier piece of plastic floats? __________

…The plastic block may have been lighter than the metal block but that is not why it floated. The metal block has a density of 2.5 g/cm^3, which is more than water so it sinks. The plastic block has a volume 16 cm^3 which means its density is .6 g/cm^3 which is less than water so it floats. __________

…I think objects that have a density greater than water sink and objects that have a density less than water float. __________

Question #6—Elana, Shauna, and Sam are in a science class together. At the beginning of class, their teacher poses the following question: *"Should scientists be able to use animals in medical research?"* The teacher then asked Elana, Shauna, and Sam to discuss what they think about the issue in a small group. Suppose Shauna begins the conversation by saying:

> *"I think using animals in medical is a bad idea because people and animals suffer from different disease and the bodies of animals and humans are completely different. So how can scientists justify performing painful experiments on animals if they are so different?'*

Sam disagrees with Shauna. Your task is to rank these 6 different challenges given by Sam in terms of how strong you think they are.

Sam: I disagree… **Your Ranking**

…even though animal and human bodies are completely different like you say, I think using animals in medical research is a good idea because it would be impossible to prove that a specific germ is responsible for a disease without the use of laboratory animals. __________

…I think using animals in medical research is good idea and very useful. __________

…animals are not that different from humans. Animals and humans have similar organs and animals suffer from many of the same diseases that we do. __________

…because you don't know what you are talking about. You just care more about animals then you do about people. __________

…an animal is only chosen for research if it shares characteristics with people that are relevant to the research. For example; animals share many of the same organs as people so they can be used to develop new surgical techniques. Organ transplants, open heart surgery, and many other procedures that are common today were developed by experimenting with animals. __________

…how can using animals in research be a bad idea if it allows scientists to do research without having to conduct painful experiments on people? __________

Appendix 2.

THE NATURE OF SCIENCE AS ARGUMENT QUESTIONNAIRE (NSAAQ)

Directions: Read the following pairs of statements and then circle the number on the continuum that best describes your position on the issue described. The numbers on the continuum mean:
1 = I completely agree with viewpoint A and I completely disagree with viewpoint B
2 = I agree with both viewpoints, but I agree with viewpoint A more than I agree with viewpoint B
3 = I agree with both viewpoints equally

4 = I agree with both viewpoints, but I agree with viewpoint B more than I agree with viewpoint A
5 = I completely agree with viewpoint B and I completely disagree with viewpoint A

What is the nature of scientific knowledge?

When you think of the body of knowledge that has been generated by the work of scientists, how would you describe it? The statements below describe scientific knowledge from different viewpoints. Indicate which viewpoint you agree with the most using the scale below… Viewpoint A		A not B A > B A = B B> A B not A	Viewpoint B
1	Scientific knowledge describes what reality is really like and how it actually works.	1 2 3 4 5	Scientific knowledge represents only one possible explanation or description of reality.
2	Scientific knowledge should be considered tentative.	1 2 3 4 5	Scientific knowledge should be considered certain.
3	Scientific knowledge is subjective.	1 2 3 4 5	Scientific knowledge is objective.
4	Scientific knowledge does not change over time once it has been discovered.	1 2 3 4 5	Scientific knowledge usually changes over time as the result of new research and perspectives.
5	The concept of ‘species’ was invented by scientists as a way to describe life on earth.	1 2 3 4 5	The concept of ‘species’ is an inherent characteristic of life on earth; it is completely independent of how scientists think.
6	Scientific knowledge is best described as being a collection of facts about the world.	1 2 3 4 5	Scientific knowledge is best described as an attempt to describe and explain how the world works.

What counts as reliable and valid scientific knowledge?

A central claim of science is that it produces reliable and valid knowledge about the natural world. The statements below describe different viewpoints about what counts as reliable and valid scientific knowledge. Indicate which viewpoint you agree with the most using the scale below… Viewpoint A		A not B A > B A = B B> A B not A	Viewpoint B
13	Scientific knowledge can only be considered	1 2 3 4 5	Scientific knowledge can be considered trustworthy if it is well

	trustworthy if the methods, data, and interpretations of the study have been shared and critiqued.		supported by evidence.
14	The scientific method can provide absolute proof.	1 2 3 4 5	It is impossible to gather enough evidence to prove something true.
15	If data was gathered during an experiment it can be considered reliable and trustworthy.	1 2 3 4 5	The reliability and trustworthiness of data should always be questioned.
16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles.	1 2 3 4 5	Scientists know that atoms exist because they have seen them using high-tech instruments.
17	Biases and errors are unavoidable during a scientific investigation.	1 2 3 4 5	When a scientific investigation is done correctly errors and biases are eliminated.
18	A theory should be considered inaccurate if a single fact exists that contradicts that theory.	1 2 3 4 5	A theory can still be useful even if one or more facts contradict that theory.
19	Scientists can be sure that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	1 2 3 4 5	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never work that chemical.

How is scientific knowledge generated?

When you think of what scientists do in order to produce scientific knowledge, how would you describe this process? The statements below describe different viewpoints for how scientific knowledge is generated. Indicate which viewpoint you agree with the most using the scale below… Viewpoint A		A not B A > B A = B B> A B not A	Viewpoint B
7	Experiments are important in science because they can be	1 2 3 4 5	Experiments are important in science because they prove

	used to generate reliable evidence.		ideas right or wrong.
8	All science is based on a single scientific method	1 2 3 4 5	The methods used by scientists vary based on the purpose of the research and the discipline.
9	The methods used to generate scientific knowledge are based on a set of techniques rather than a set of values.	1 2 3 4 5	The methods used to generate scientific knowledge are based on a set of values rather than a set of techniques.

What role do scientists play in the generation of scientific knowledge?

The statements below describe different viewpoints for what scientists do and what they are like. Indicate which viewpoint you agree with the most using the scale below… Viewpoint A		A not B A > B A = B B> A B not A	Viewpoint B
20	In order to interpret the data they gather scientists rely on logic and their creativity and prior knowledge.	1 2 3 4 5	In order to interpret the data they have gather scientists rely on logic only and avoid using any creativity or prior knowledge.
21	Scientists are influenced by social factors, their personal beliefs, and past research.	1 2 3 4 5	Scientists are objective, social factors and their personal beliefs do not influence their work.
22	Successful scientists are able to use the scientific method better than unsuccessful scientists.	1 2 3 4 5	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists.
23	Two scientists (with the same expertise) reviewing the same data will reach the same conclusions.	1 2 3 4 5	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions.
24	A scientist's personal beliefs and training influences what they believe counts as evidence.	1 2 3 4 5	What counts as evidence is the same for all scientists.
25	The observations made by two different scientists about the same phenomenon will be the same.	1 2 3 4 5	The observations made by two different scientists about the same phenomenon can be different.

26	It is safe to assume that a scientist's conclusions are accurate because they are an expert in their field.	1 2 3 4 5	A scientist's conclusions can be wrong even though scientists are experts in their field.